MILITARY SURGERY

DUNLAP PEARCE PENHALLOW

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WITH INTRODUCTION BY

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ORIGINAL DRAWINGS BY

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PREFACE

War Surgery differs widely from that which is seen in civil practice even in large hospitals where occasional gun-shot injuries are encountered, as the wounds thus seen are usually comparatively simple and are treated early before complications have arisen. Wounds in warfare, on the other hand, are much more severe, and, furthermore, owing to the delay in collecting the wounded from the battle-field and also the difficulties of transportation, complications have usually arisen before adequate surgical aid can be given. Furthermore, many of the cases present complex problems in treatment owing to the multiplicity of the wounds and their type—and this is especially true of the bones. Therefore, many new problems, both as regards treatment and the types of apparatus to be used, are constantly being brought to the notice of the military surgeon.

In this book an attempt has been made to describe briefly the different forms of projectiles and the nature of the wounds which they cause, and the various complications which result from the different types of wounds. An attempt has also been made to show in a brief manner the principles of treatment which have been found to be most efficacious under the various conditions. While much of the work has been compiled from observations made at the American Women's War Hospital, current literature has been freely referred to in order to show the latest observations which various writers have made on this subject, and it is hoped that this work may prove of value to those who may at some time be called upon to perform surgery of a similar nature.

I wish to express my thanks to Sir Alfred Keogh for his kindness in writing the introduction and also for furnishing me with illustrations of shrapnel and high-explosive shells; to Dr. Fred A. Coller for many timely suggestions and for his assistance in arranging and having photographed the various forms of apparatus; to Dr. James E. Daniel and Mr. Stewart Black for their help as regards the X-rays and the photographs; and to the others who assisted me in various ways.

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August 17th, 1916.

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INTRODUCTION

A work on Military Surgery written by an American surgeon whose experience has been gained in a military hospital in England must have a special interest for us. The American Women's War Hospital at Paignton was established in 1914 as a Primary Hospital, and here the author of this work has obtained his most recent surgical experience.

Approaching his problems with the vigour which we are accustomed to expect from an American, Dr. Penhallow has reached conclusions on some points which many British surgeons have considered debatable. Nevertheless the work is singularly free from that dogmatism which during this war has so often embarrassed the less-experienced surgeon when called upon to choose an alternative among conflicting opinions. If much that the author says indicates the necessity for a readjustment of our ideas on fundamental principles, we are afforded opportunities for examining the grounds of his contention; for the book is severely practical, and illustrative cases of a common type are frequently given.

It is a distinct disadvantage that in war surgery there can be little continuity of treatment; the subsequent effects of early surgical procedure can rarely be gauged by the surgeon. The course and progress of injured limbs, for example, must often modify or completely change the earlier practice were it possible to obtain the subsequent history of cases. To those who are called upon to treat wounds in the earlier stages, Dr. Penhallow's views will therefore be of interest.

Surgeons will be particularly interested in the views which the author holds as to the propriety of bone-plating. British surgeons are, as a rule, opposed to this method of securing alignment in fractures with sepsis; but Dr. Penhallow holds, and appears to make good, the view that the procedure has been too sweepingly condemned, and that under certain conditions it is eminently justifiable. Familiarity with the technique of the operation is, of course, essential.

The work will be read with interest as a contribution to the solution of many other problems which occupy us at the present time.

(Signed) ALFRED KEOGH.

MILITARY SURGERY

CHAPTER I

GENERAL CONSIDERATION OF PROJECTILES—DEFINITION OF PROJECTILES—TYPES USED IN PRESENT WAR

Three General Classes :

I. Projectiles from Hand Weapons : Rifle, Revolver.
  - Description of Bullets, Weight, Size, Shape.
  - Motions imparted to Bullets : (1) Translation ; (2) Rotation ; (3) Oscillation.
  - Trajectory, Range, Striking Force on Tissues.
  - Effects of Bullets : Undeformed, Ricochet, Disintegration of.
  - Revolver Bullets : Shape, Weight, Size, etc.

II. Projectiles from Artillery :
  - (1) Shell : Description—Effects.
  - (2) Shrapnel : Description—Effects, with tables.

III. Grenades, Bombs, Mines :
  - Types of Grenade : Hand, Rifle, etc.
  - General Description and Uses.
  - Types of Bomb : From Trench Mortars, etc. Description and Uses.
  - Mines : Marine and Terrestrial. How the latter are Constructed and Fired—Rocks, Earth, etc., forming the Projectiles.

In the present war, owing to the fact that the opposing Armies are sheltered in trenches and that there is relatively little hand-to-hand fighting as compared with previous wars, the wounds are principally those caused by the use of projectiles, while bayonet wounds are seen in comparatively small numbers, and these latter will not therefore be considered.

By projectile we mean, in a large sense, any missile which is set in motion by the explosion of a charge of powder, and under this heading we include not only rifle bullets, but also the missiles which are projected by the bursting of shrapnel, high explosive shells, grenades, bombs, and mines.

There are three general classes into which we may divide projectiles :

I. Projectiles from Hand Weapons.
II. Projectiles from Artillery.
III. Projectiles from Grenades, Bombs, and Mines.

I. Projectiles from Hand Weapons

Under this heading we include rifles, revolvers, and also machine guns, the latter using the same type of ammunition as do the rifles. The construction of most of the bullets is uniform, and consists essentially of a central core of hardened lead surrounded by a casing of nickel, cupro-nickel, steel, copper, or German silver. In some instances the jacket completely surrounds the lead core, and in others the base of the lead is not covered. Some bullets, such as the French bullet D, are made entirely of copper composition.

Shape.—The shape of the majority of the bullets now used is cylindro-ogival rather than cylindro-conical as in the older types. The ogival-shaped bullet possesses a greater initial velocity and offers less wind resistance and, consequently, has a greater range.

It may, however, be of interest to describe briefly the types of bullet used by the belligerent Powers, and also the U.S. Army bullet.

The German Bullet S.—The bullet S of the German Mauser (Fig. 1, A) is a cylindro-ogival projectile of hardened lead in a soft steel envelope covered with German silver; the cylindrical part is scarcely more than one-quarter of the total length, the ogival part (19 mm. or $\frac{3}{4}$ inch) being very pointed and terminating in an insignificant flattened piece of about 1 mm. This bullet, with a calibre of 7 millimeters (0·28 inch), and a length of 28 millimeters (1·10 inches), only weighs 10 grams (154 grains).

The Austrian Bullet.—The Austrian Mannlicher bullet (Fig. 1, B) consists of a core of hard lead compressed into an envelope, with an outer casing of steel; it weighs 244 grains, is $1\frac{1}{4}$ inches long, and has a diameter of 0·31

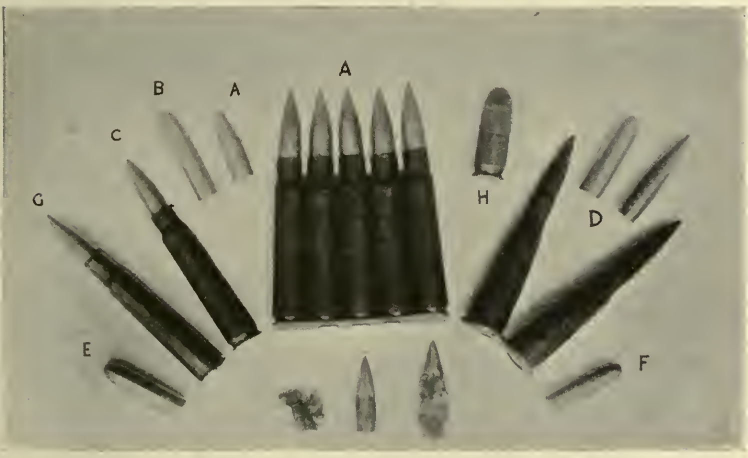

FIG. 1. Various Types of Bullets used; *A*. German S. bullet. *B*. Austrian Mannlicher bullet. *C*. Turkish bullet. *D*. French bullet, type D. *E*. Russian bullet. *F*. Belgian bullet. *G*. English bullet. *H*. Revolver bullet.

inch, and is of cylindro-conical truncated form, rounded and not pointed.

The Turkish Bullet.—The Turkish bullet (Fig. 1, C) is essentially the same as the German bullet S.

The French Bullet.—The French bullet—Bullet D (Fig. 1, D)—consists of solid copper composition without casing; it is bi-ogival, very sharp in front and truncated at the base. Its calibre is 0·31 inch, length 1·53 inches, weight 197 grains.

The Russian Bullet.—The Russian bullet (Fig. 1, E) is ogival-shaped with a blunt end, and has a casing of German silver over a core of hard lead. Calibre 0·30 inch, length 1·2 inches and weight 211 grains.

The Belgian Bullet.—The Belgian bullet (Fig. 1, F) is ogival with a blunt end, the central core being of hard lead, covered with German silver. Calibre 0·30 inch, length 1·18 inches, weight 213 grains.

The English Bullet.—The English bullet (Fig. 1, G) is of cylindro-ogival shape with a central core of hard lead covered with German silver casing. Calibre 0·30 inch, length 1·2 inches, weight 215 grains. (Delorme.)

U.S. Army Bullet.—This bullet which has recently been adopted has a pointed rather than an ogival head. It is 1·08 inches in length, ·3083 inch in diameter, weight 150 grains, and is composed of a lead core surrounded by a jacket of cupro-nickel steel. The velocity of translation is 900 yards at the muzzle, and the velocity of rotation is 3,270 turns per second as it issues from the rifle. The point-blank range, firing standing, is 718·6 yards. The centre of gravity of this bullet is disposed well towards its base. (Lagarde.)

In order to understand thoroughly the effects which bullets have on the tissues, it is essential to understand in a general way a few facts on ballistics.

When a bullet leaves the rifle, three motions are imparted to it: viz. (1) Motion of Translation; (2) Motion of Rotation; (3) Motion of Oscillation.

1. **Motion of Translation or Projection.**—Bullets are driven from the rifle barrel with great force by the explosion of a charge of powder, and the motion so imparted to them is known as the motion of translation or projection. This motion is one of the principal elements of the force of a bullet—in other words of its power and of its effects.

The initial velocity is expressed in the number of yards it would travel during the first second after leaving the rifle, if not hindered by air resistance and by the pull downward of gravity; and this is also known as muzzle velocity.

The remaining velocity, which it is much more important to know, is the speed of the bullet at various distances. This velocity decreases with the distance, owing to the weight of the bullet and to the resistance of the air.

The initial velocity of present-day bullets is considerable. The German bullet S has the highest (940 yards), which is superior to that of the French bullet D by 165 yards; but the French bullet, being heavier, retains its remaining velocity better, and is more dangerous at greater distances than is bullet S.

The French bullet D has an initial velocity of 767 yards, Lebel's bullet of 712 yards, the Russian bullet of 703 yards, the Austrian of 684 yards, and the English of 628 yards.

The remaining speed is in inverse ratio to the square of the diameter of the bullet and in direct proportion to its length and weight.

At	437 yds.,	bullet S has	710 yds.	remaining velocity;	D, 580 yds.
,,	656 ,,	,, ,,	514 ,,	,, ,,	D, 514 ,,
,,	1,093 ,,	,, ,,	329 ,,	,, ,,	D, 399 ,,
,,	2,187 ,,	,, ,,	181 ,,	,, ,,	D, 229 ,,

(*Delorme.*)

2. **Motion of Rotation.**—In order to maintain the bullet in its course and to steady it during flight, it is given a rotatory motion by the rifling of the gun. The velocity of this rotation depends upon its linear velocity and upon the twist of the rifling; in the modern rifle this is usually one complete twist in 10 inches. Though the rotation prevents the bullet from tipping, it has another effect—namely, that of causing it to deviate from the vertical plane of fire. This deviation is known as drift, and is always in the direction of the rifling, a right-handed twist causing the bullet to drift to the right and *vice versa*.

3. **Motion of Oscillation.**—Some bullets are also subject to an oscillatory movement or movement of deflection,

placing themselves crosswise or turning base foremost on meeting a slight obstacle in their course, or on hitting the body. These inversions are much more frequent with bullets S and D—a point of which the Army surgeon must not lose sight, any more than of the frequency of the ricochets.

Trajectory. — The curve described by the centre of gravity of a projectile during its passage through the air is called the trajectory. The curve of the trajectory is due primarily to the force of gravity, which exerts a downward pull on the projectile at the instant it leaves the rifle. The bullet having the greatest speed will have the flattest trajectory, and in order to obtain a flat trajectory it is necessary to have a high muzzle velocity plus a low air resistance. The flatter the trajectory, the greater is the extent of the danger zone. Up to 547 yards with the bullets now in use the trajectory is almost straight.

Range.—The considerable speed of present-day bullets allows them to attain a range of $1\frac{7}{8}$ miles or more (in the case of Bullet D, 4,155 yards or 2·36 miles).

Striking Force.—The power of bullets to inflict damage is the resultant between two forces—namely, the weight of the projectile and its velocity. This is expressed by the formula $P = \frac{WV^2}{2}$, W representing the weight and V the speed of the projectile, P being the power with which it strikes.

The following table from Delorme shows in kilogrammeters the initial and remaining damaging power of bullets S and Mannlicher, and of the French bullet D.

	Distance in Meters.											
—	0	100	200	300	400	500	600	700	800	900	1,000	2,000
Germany .	314	239	186	145	113	90	76	68	63	58	53	23
Austria .	310	223	167	139	119	104	92	81	73	67	61	31
France .	344	230	183	147	121	101	86	73	64	56	50	19

This table shows that the damaging power of these three bullets is practically equal; that it is enormous at 100 meters, considerable up to 500 meters, and that from that distance to 1,000 meters it decreases strikingly, and is very low from 1,000 meters to 2,000 meters.

When speaking of the effects of bullets, one should always be careful to consider these effects in connection with the range, and to speak of "very short distances" (up to 109 yards), or "short distances" (up to 547 yards), of "middle distances" (from 547 to 875 yards), and of "long distances" (up from 1,093 yards). The greater the striking force, the more extensive are the lesions.

The penetrative force of a bullet depends upon its power at the time of impact, and also upon the amount of resistance which it meets.

It follows from these facts that the sharp bullets S and D are more penetrative than the cylindro-ogival bullets with a flattened apex; that the longer bullet D penetrates farther than bullet S, which is shorter; that a ricochet striking sideways penetrates less than a bullet striking direct.

For bullets of the same speed, the resistance opposed by tissue to penetration is in inverse ratio to the square of the diameter.

Ricochets and Deformed Bullets (Fig. 2).—When a bullet enters the tissues it may either enter in the same shape (Fig. 2, A) as when it left the rifle, or, owing to a ricochet, it may become deformed before striking (Fig. 2, B); and again we find instances when, for some reason or other, the component parts may separate and the jacket remain in the wound (Fig. 2, C), while the lead core passes through, or where the jacket passes through, but the lead core becomes broken up and is seen in radiographic pictures as a fine spattering of metal.

Wounds caused by ricochet or deformed bullets are very frequent, being found in the proportion of about one-third of the cases. Furthermore, in order to lose its shape, a bullet must have a velocity of 820·6 yards per second.

Bullet S, made of hard lead and covered with a casing, loses shape, becomes flattened and divides up much more quickly on contact with the ground than bullet D, which is of copper composition.

Wounds caused by ricochet and deformed bullets are more serious than those made by bullets striking direct.

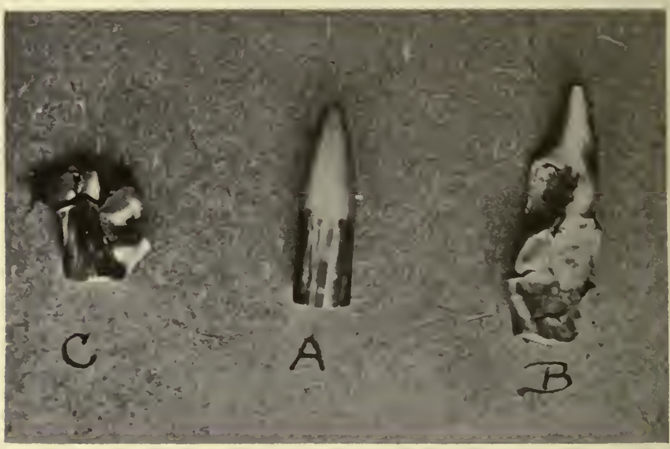

Fig. 2. *A* shows undeformed Turkish bullet. *B* shows deformed German bullet. *C* shows deformed casing from which lead core has become extruded. These bullets were removed from wounds.

Revolver Bullets.—These will not be considered in detail, but it will suffice to say that the same general principles which apply to rifle bullets hold good to a great extent in the case of revolver bullets. The extreme range is, of course, much shorter, and the bullet is effective only within ranges of 75 to 100 yards. The bullets are shorter and heavier and of a larger calibre, the latest type being a 45 calibre. At close ranges the projectiles exert a very marked stopping power. Fig. 1, H, shows bullet used in automatic pistols.

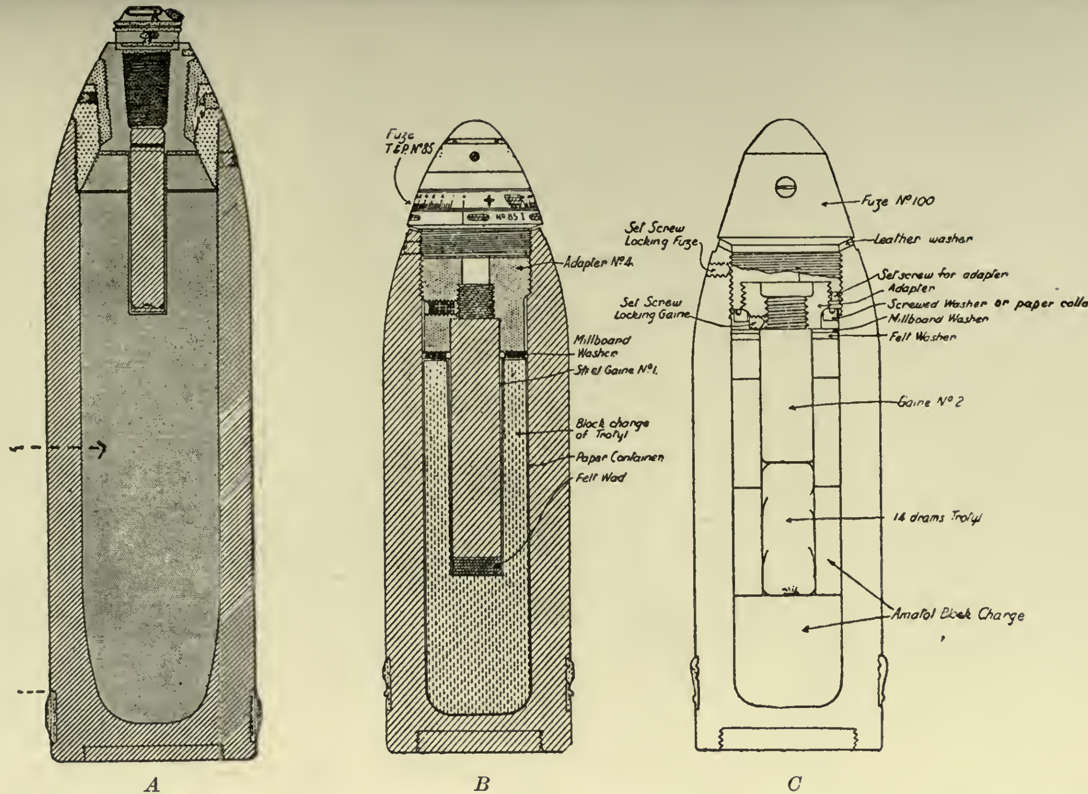

FIG. 3. Shows cross section of three types of high-explosive shell: (*A*) for 4·5 inch howitzer, case filled with trotyl, and (*B*) 13 and (*C*) 18-pounder high-explosive shells.

II. Projectiles from Artillery

These consist of (1) High Explosive Shells, and (2) Shrapnel.

1. **High Explosive Shells** (Fig. 3).—These are cylinders of iron and steel with a conical head. The projectile has

Fig. 4. Shows typical shell fragments as they are removed from tissues. In centre are two fuse rings, the upper one of which still has part of felt washer adherent to it. Just above ruler are some shrapnel bullets, the two in centre being undeformed, others deformed and flattened. Ruler shows comparative size of fragments.

thick walls, and the hollow core is filled with an explosive charge which is exploded by means of a time fuse. The casing is ruptured and fragmented, and each individual fragment becomes in itself a projectile capable of inflicting serious and lacerated wounds, owing to the shape of the individual pieces.

Uses.—Bowlby (3) describes a German high explosive shell and its effects as follows:

"High Explosive Shells (German) vary in weight from a few pounds to a ton, and they consist of a thick iron case containing in a central cavity a violent explosive charge of trinitro-toluene, of which as much as 200 lbs.

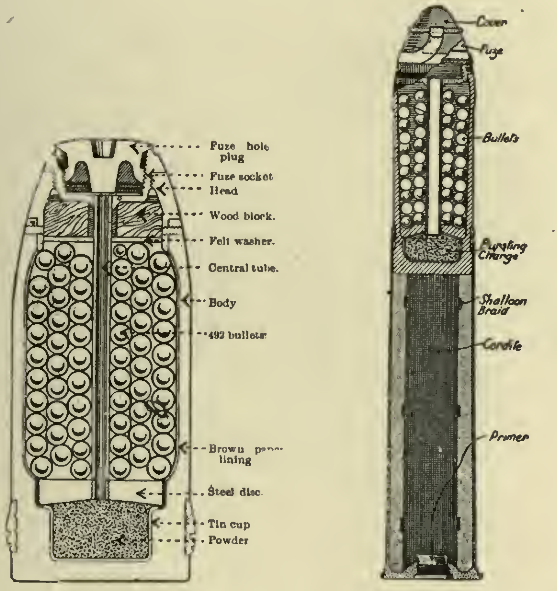

FIG. 5. Shows typical shrapnel shell in cross section with its integral parts; also shrapnel shell and brass case complete for use in gun.

may be present. Such shells usually burst on percussion by a detonator which acts by impact. . . . The fragments vary very much in size and shape (Fig. 4); the base, for instance, of a 17-inch shell may weigh 150 lbs., and if it struck a man would completely destroy him. Other fragments may weigh a few pounds, and may tear off a limb or crush it to pulp, while in the smaller shells there may be scores of fragments about the size of the end of a finger or much smaller."

He adds that it must be borne in mind that the mere explosion of a shell generates great power of destruction, the expansion of the gases alone being sufficient to kill, and reports an autopsy in which the only finding was multiple petechial hæmorrhages in the brain.

Fig. 6. Shell fuses. To right above ruler is a fuse cap similar to that seen on fuse above ruler to the left. In front is part of the fuse band which has become partially straightened. Comparative size will be seen by ruler.

2. **Shrapnel** (Fig. 5).—These shells consist of a cylinder of steel which contains a varying number of round lead bullets approximately 0·5 inch in diameter. The bursting charge is in the base, and is exploded by means of a time fuse in the head. Shrapnel has approximately an initial velocity of 1,700 F.S. At the time of bursting, the lead balls are driven out in the form of a cone at an additional velocity of 300 F.S. The case itself does not explode, but each individual bullet, as well as the time fuse (Fig. 6) and

the casing, becomes a separate projectile. Shrapnel is very effective when used against massed troops, but is of little effect when used against entrenchments.

The following tables taken from Lagarde on Gunshot Wounds may prove of interest as showing the area of dispersion of the fragments of shells and of shrapnel bullets. It also shows the approximate number of effective fragments which are formed by the bursting of a high-explosive shell.

Gun.	Extreme Range, Yards.	Shrapnel.			Shell.	
		Weight.	No. of Bullets.	Size and Weight of Bullets.	Weight.	Approximate No. of Effective Fragments.
3-in. Field-gun and Mountain Howitzer	Gun 6,500 Howitzer 5,600	15 lbs.	252	·5 in. 167 grains	15 lbs.	600
3·8-in. Gun and Howitzer	Gun 7,300 Howitzer 6,200	30 lbs.	340	·54 in. 230 grains	30 lbs.	800
4·7-in. Gun and Howitzer	Gun 8,000 Howitzer 6,640	60 lbs.	711	·54 in. 230 grains	60 lbs.	1,000
6-in. Howitzer	6,704	120 lbs.	1,074	·6-in., 306·4 grains	120 lbs.	1,500

Projectiles : Area of Dispersion

—	—	Shrapnel.		Shell.		—
		Length, Yards.	Width, Yards.	Length, Yards.	Width, Yards.	
At a range less than 3,000 yards	Field Gun Mountain Howitzer	400 300	150 100	300 200	100 75	Area of dispersion about 100 yards wide and 150 yards long (very effective within).
At a range over 3,000 yards	Field Gun Mountain Howitzer	300 200	125 75	250 150	75 75	A central zone of about 30 yards wide and 20 yards long.

III. Grenades, Bombs, Mines

It is interesting to note in this present war the extensive use of grenades, the grenade being one of the oldest forms of explosive weapon in use.

Sir Anthony Bowlby says: "Grenades are characterised by a shell case of iron or other metal containing a relatively large charge of high explosive. The bomb case

Fig. 7. Portions of exploded rifle grenade, the size of which can be seen by comparing with the scale.

varies immensely, being composed in some cases of iron about ½ inch thick, often partially cut up into segments about ½ inch square, and in other cases, chiefly German, of quite thin steel or other metal. When a bomb or grenade bursts, the case is commonly broken up into numerous fragments of every size, from a pin's head to a lump of metal weighing as much as an ounce (Fig. 7). Some of these may be quite pointed and with an edge like a knife; others are often quadrilateral. Some of the German bombs contain also irregular jagged pieces of loose metal, and others are loaded with rough iron bootnails about half an inch long and pyramidal in shape. All forms of shell and bombs also scatter stones, earth, or sand from the parapets, and these become projectiles, and are specially liable to injure the face, neck and shoulders of men standing on the trenches."

Grenades are all essentially the same, and differ only in the way in which they are projected. They may be divided into two classes: viz. (1) Hand Grenades, and (2) Rifle Grenades.

1. **Hand Grenades** (Fig. 8, B).—These are of various shapes, such as the "hair-brush" grenade, the ball grenade and various other forms. As the name implies, they are thrown by hand.

2. **Rifle Grenades** (Fig. 8, A).—These are essentially a small high-explosive shell, differing only from the other forms in that they have a long rod extending from the head of the grenade and fitting the barrel of the rifle. At the lower end is a small loose cap of copper, which revolves on the rod and fits the rifling of the barrel, acting as a gas check. These grenades are projected by means of a small charge of powder in the rifle. They have this advantage over the hand grenade, that the soldier does not necessarily have to expose himself in order to fire them, as is the case with the hand grenade.

Fig. 8. Shows three types of grenade. *A*. Rifle grenade showing corrugations to aid in fragmentation. The long rod fits the barrel of the rifle and at bottom is a small revolving cap of copper which engages in the rifling. *B* shows two types of hand grenades, one on the right showing a hook for hanging on the belt.

Bombs.—These are essentially larger grenades which are propelled from trench mortars, the German bombs being filled with trinitrotoluene. There is also in use a large bomb known as an aerial torpedo, which has wings to steady its flight.

Mines.—These may be either marine or terrestrial, but we shall consider only the latter, which consist of charges of high explosive buried in the ground and exploded by means of an electric spark, the earth and rocks thrown up by the explosion forming the projectiles.

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CHAPTER II

CONDITION OF THE WOUNDED

I. General Considerations.
II. Shock and Collapse.
  Causes: Hæmorrhage, Pain, Nature of Wounds, Exposure, Transportation, Sepsis.
III. Treatment of the Wounded as regards their general condition and the prevention of shock.
  Before admission to hospital:
    Control of Hæmorrhage, Pain and Fixation of Fractures, Dressings, Transportation.
  After admission to hospital:
    Rest, Food, Warmth; Hæmorrhage, Salines, etc.; Relief of Pain, Immobilisation of Fractures, Treatment before, during and after Operation.

I. General Considerations

In this war the condition of the men is far above the average, as they are all in the prime of life, are in excellent physical condition, well clothed and well fed, and have practically no exhausting marches to contend with. We may say of trench warfare at least that any exhaustion which occurs is due to causes other than that of muscular fatigue. The condition of the wounded man, therefore, depends largely upon the size of the wound or wounds. the regions involved, and the degree of exposure to which he has necessarily been subjected before adequate surgical care could be administered.

A large proportion of the gunshot wounds cause relatively little injury and do not give rise to any great amount of shock or collapse, unless the injury be extensive or unless viscera, vessels or bones are involved—in which case the soldier is apt to show signs of collapse depending to a great extent upon the severity of the injury. The principal thing which should be watched for in every seriously injured man, apart from infection, is shock or collapse. In every convoy of wounded we expect to find a certain proportion of men who, for one reason or other, are in a state of collapse or shock, and when a convoy of wounded arrives at the base hospital, many of the men present to a greater or lesser degree the characteristic signs of this state. The men reach the hospital twenty-four to thirty-six hours after they have been wounded, their clothes covered with mud from the trenches, and the bandages possibly blood-soaked or else hardened from dried blood and sticking to their wounds. Many of them are listless and apathetic, and show a marked degree of physical exhaustion. Their faces are both drawn and pinched, and their eyes sunken and lustreless; their skin is cold and their pulse weak and easily compressible. Their one idea is to be allowed to sleep. Before they are allowed to do this, however, they are given a warm bath and some hot soup, and all uncomfortable dressings are changed; in fracture cases proper fixation is applied. Twenty-four hours later, after they have had a long sleep and become rested, we notice a vast difference: the drawn and anxious look has disappeared from their faces, and in place of apathy we find them bright and alert; their colour is good and the pulse is of good quality; they feel rested and comfortable.

II. Causes of Shock and Collapse

The chief factors which we find causing shock and collapse are the following:

1. Hæmorrhage.
2. Pain.
3. Nature of Wounds.
4. Exposure or Exhaustion.
5. Transportation.
6. Sepsis.

The treatment of these various conditions will be considered more in detail shortly, but for the present it will suffice to say that any factor or group of factors which lower the resistance of the patient and which exhaust him mentally and physically are predisposing elements in the production of shock or collapse.

III. Treatment of the Wounded before and after Admission to Hospital as regards General Condition and the Prevention of Shock

The treatment of wounded soldiers resolves itself into two headings: (1) the treatment and care which are given to him in the firing line, and (2) the more careful surgical procedures which are instituted when he arrives in a more permanent hospital or at the base, where we are able to carry out more complete measures for the relief of the various symptoms.

The first-aid treatment of necessity is limited in its scope, and oftentimes men cannot be brought back to receive first-aid dressings for many hours after they have been wounded, and meanwhile are subjected to considerable exposure while lying on the wet and cold ground. A first-aid dressing, as the name implies, is simply the carrying out of emergency measures for the prevention of hæmorrhage, for the immobilisation of fractures, and for the control of pain. Hæmorrhage should be controlled either by a pressure bandage or by a tourniquet, or, if necessary, ligation of the vessel if it can be easily reached; but if a condition necessitating this exists, and a large vessel has been severed, the patient will usually bleed to death before the hæmorrhage can be adequately controlled. Hæmorrhage from small vessels and from bullet wounds and lacerated shell wounds can usually and easily be controlled by means of a tourniquet or by a firm bandage. It is important, however, that if a tourniquet is applied, a nurse or orderly should be detailed to watch the patient and to loosen the tourniquet occasionally. A tourniquet should not be left on longer than one hour, otherwise the circulation may become entirely cut off and gangrene of the limb result. The tourniquet should be loosened and the wound allowed to bleed slightly for a short time. It is inadvisable to attempt to control the hæmorrhage by packing the wound, as this may give rise to severe sepsis from contaminated matter which has been carried into the wound by the bullet. Fractures should be immobolised by means of any emergency splint in order to relieve any undue pain from the crepitation of the bones.

The nature of the wound also determines the degree of shock or collapse, for, as we have already stated, many bullet wounds cause relatively little shock unless they strike vessels or the viscera of chest or abdomen; whereas large and extensive lacerating shell wounds may cause a considerable degree of collapse.

Transportation also is an important factor in many wounds as regards shock, especially in cases of fracture where the limb is not properly immobilised, and also in abdominal wounds. Such cases are best allowed to remain quiet for several hours after they have been dressed before any attempt at transportation is made, otherwise the fatigue incident to a long uncomfortable ride in an ambulance or on a stretcher or even in a hospital train may prove too exhausting for the patient, and the chances of his recovery will be minimised. Furthermore, any patient developing serious symptoms during transportation may be dropped at any clearing station or hospital where he can obtain rest and more adequate care, be under more constant observation, and, if necessary, be operated upon.

Pain should be relieved by rest, by fixation of fractures, and by sufficient doses of morphia before admission to hospital.

We have already shown a typical picture of men as they are admitted into the hospital on being sent back from the front; and we are now able to institute more complete measures for the relief of the various symptoms, and also to overcome the existing shock and to prevent it from becoming more severe. It is essential that as soon as the men arrive in hospital they should be given, in all cases where it is not contra-indicated, a warm bath and some good substantial food, and that they should be immediately put to bed and allowed to rest. The condition of each and every man should be carefully watched; painful dressings should be changed; infected wounds which are under tension or show signs of any gaseous infection should be immediately incised and drained; hot wet dressings of saline or hypochlorous acid should be applied to the infected wounds; and all fracture cases should have proper fixation apparatus applied, unless the apparatus which is already on is comfortable and is immobilising the fractures sufficiently to prevent pain or abnormal mobility. Any hæmorrhage should be immediately controlled by ligation, and if there has been much loss of blood the deficiency must be supplied by increasing the fluid content, using if necessary saline infusion either intravenously or subcutaneously; and in the more severe forms of hæmorrhage, where the patient is markedly anæmic and the pulse is extremely weak, a blood transfusion should be given. Such patients should be given fluids to drink freely, the foot of the bed should be elevated and the body temperature maintained by means of blankets and heaters. In such cases rectal saline often proves efficacious, and to this should be added adrenalin in the proportion of one dram to the quart.

There will also be many men who will require operations for the readjustment of fractures and for the incision and drainage of infected wounds, and with such the chances of increased shock should be eliminated as much as possible before any operative procedures are instituted.

As many of the men on arriving at a base hospital will require immediate surgical procedures, it is essential that all precautions should be taken to prevent increasing the amount of shock in those who are already physically and mentally exhausted, and in whom, for the time being, the resistance is low. In all cases where an immediate operation is not indicated, we should institute measures which will improve the patient's general condition. He should be kept quiet in bed, receive plenty of nourishing food, and pain should be relieved by the application of comfortable dressings, by change of splints or whatever may be indicated.

When it is necessary to operate, the patient should be given, one half-hour before the operation, a hypodermic consisting of $\frac{1}{4}$ grain of morphia and $\frac{1}{100}$ grain of atropine.

During the operation his condition should be carefully watched; he should be kept well covered with blankets to prevent undue chilling of his body while he is under the anæsthetic, and the operation itself should not be prolonged any longer than is absolutely necessary.

In cases of amputation the main nerve trunks may be blocked by injecting a weak solution of cocaine or novocaine, in order to prevent afferent impulses being transmitted through and increasing the danger of shock. If at any time during the operation he begins to show signs of collapse, a saline-adrenalin injection may be given, as may also inhalations of oxygen.

Following operation the patient should be put into a warm bed and carefully watched; if there is any sign of collapse, the foot of the bed should be elevated about 8 inches, and a warm constant rectal saline given at the rate of about 10 drops per minute. The patient should also be well covered with blankets and surrounded by heaters to maintain his body temperature.

This in a general way is a brief outline showing the condition of the men as they arrive from the front, the factors which tend to produce shock, and the necessary treatment at the front, at the base, both before and after operation to overcome this condition when present, and to prevent it from becoming more severe.

CHAPTER III

INFECTION OF WOUNDS

I. General Considerations:
  Causes, etc.:
    (*a*) Amount of Trauma.
    (*b*) Prevalence of Micro-organisms.
    (*c*) Resistance, local and general.
II. Anaerobic Infection:
  Considerations:
    (1) *B. perfringens:* Prevalence, Symptoms.
    (2) Tetanus: Prevalence, Mortality, Symptoms, Treatment.
III. Pyogenic Organisms:
  Kinds, Prevalence.
IV. Latent Sepsis:
  Description.

I. General Considerations

Much has been written in the past concerning infection of gunshot wounds, and it was thought that with modern methods of antisepsis and first-aid dressings, combined with high-velocity projectiles, infection would be reduced to a minimum. Unfortunately this has proved not to be so, and the present war has taught the military surgeon many things regarding wound infection, and has also caused the reasoning man to readjust his ideas.

One, and possibly the most important factor, which has to be taken into consideration in the present war as regards wound infection is the fact that much of the fighting is being done over highly-cultivated land which has been extensively fertilised for many years. We know that the soil of such lands is the habitat of spore-producing organisms such as *B. tetani*, the *Bacillus aerogenes cap-*

sulatus, or *B. perfringens*, and also, owing to the nature of the fertiliser used, certain forms of streptococcus, such as the *Streptococcus fecalis*, are present. When we consider these facts, it cannot be thought strange that men who are fighting on such ground, and whose clothing and even skin are covered with earth which contains such bacteria, should become severely infected when wounded, especially as much of this contaminated clothing and earth is carried into the wound together with the projectile, which also may be infected by contact with the same bacteria-laden agent. Again, a man when wounded may be unable to move, and of necessity will have to remain lying on the ground, even without a dressing on the wound, for many hours before he can be brought back and a dressing applied, and during these hours the wound, if not already contaminated, will certainly become so from contact with the infected soil.

While it is true that many wounds, and especially simple bullet wounds, heal without giving rise to any clinical symptoms, nevertheless it is safe to say that all gunshot wounds are infected to a greater or lesser extent, and that the severity of the infection depends upon certain constant factors :

(*a*) The amount of trauma caused by the projectile.
(*b*) The prevalence of the micro-organisms contaminating the wounds.
(*c*) Resistance, both local and constitutional.

(*a*) **The amount of Trauma caused by the Projectile.**—The size of the projectile inflicting the wound determines not only the degree of infection, but also the amount of trauma, and the larger the projectile the greater the wound and also the severity of the infection. It may be truthfully said that the degree of infection in a wound is in direct proportion to the size of the projectile and to the amount of trauma inflicted. This is shown by the fact that wounds caused by shell fragments and by shrapnel bullets show a greater degree of infection than do the wounds caused by rifle bullets. A rifle bullet travelling at nearly full velocity and striking soft tissues may pass completely through without causing any great degree of trauma, unless it has previously become deformed from a ricochet or strikes large vessels, nerves, viscera or bone; and such a wound, which is relatively clean, heals up quickly without any clinical signs of infection. On the other hand, shrapnel bullets, which travel at a much lower velocity, cause a larger wound and are more apt to be retained in the tissues. The trauma is greater and, furthermore, infected earth and pieces of contaminated clothing will be carried in and retained with the bullet. Shell fragments, owing to their size and shape, inflict much larger and more lacerating wounds than do the rifle and shrapnel bullets, the consequent trauma is much greater, and a much larger amount of infected material is carried into the wound, where the bacteria find an ideal medium in the severely bruised and devitalised tissues in which there is extravasated blood on which to grow.

(*b*) **Prevalence of Micro-Organisms.**—In this war the bacteriology of wounds has been found to be considerably different from that met with in the ordinary civilian practice, and a large amount of work has been done to determine the various organisms which are most common. Fleming (1) shows that the streptococcus is the most prevalent of the pus-producing organisms infecting wounds, and the staphylococcus comes next in frequency, although, according to him, the staphylococcus infection is apparently due to an infection from the skin surrounding the wound rather than to a direct infection carried in by the projectile. He examined many samples of clothing taken from men who had been received back from the front, in order to determine if possible the relationship between wound infection and the bacteriological flora found on the clothing. In twelve samples of clothing examined he found that *B. perfringens* was the most prevalent, being found in ten samples; *B. tetani* was found in four samples, streptococci in five and staphylococci in only two, while other organisms, which, though not fully identified, were in all probability non-pathogenic, were found also in some of the samples.

Fleming's table (Table I) is given as showing an analysis of various wounds extending over varying periods of time after infection, and the prevalence of the different organisms found.

TABLE I.—ANALYSIS OF BACTERIOLOGICAL EXAMINATIONS OF A SERIES OF WOUNDS

Time after Infection.	Total number of Cases.	*B. aerogenes capsulatus.*	*B. tetani.*	Putrefactive bacilli.		Streptococci.	Coliform bacilli.	Staphylococci.	"Wisp" bacillus.	Diphtheroid bacilli.	Large gram + bacilli.
				Bac. X.	Bac. Y.						
Stage I: 1–7 days	127	103	22	14	5	102	37	40	9	—	2
Stage II: 8–20 days . .	56	19	5	4	1	51	18	16	17	4	4
Stage III: Over 20 days . .	27	5	—	—	—	24	19	19	16	—	6

(*c*) **Constitutional and Local Resistance.**—The constitutional resistance of the individual and the local resistance of the tissues determine to a marked degree the severity of the infection, and any factor or group of factors which tend to diminish this resistance also tend to render the infection more severe. While it has always been recognised that men who are enduring the rigours of an arduous campaign, and who have been under a severe nervous strain for a long time are more inclined to have a diminished general resistance than are men who are living under normal conditions, the same facts do not seem so wholly applicable at the present time. The men are well looked after, the food is good and of sufficient quantity, and the soldiers are kept as cheerful as may be under the circumstances; these factors, together with relatively short times in the trenches and longer intervals of rest at the rear, tend to keep the men in good constitutional condition and a high degree of resistance to infection, as is shown by the way in which the average wound clears up. In further support of this we find that the men who show the least resistance are those who could not be rescued for a long period of time, and who have consequently been chilled from lying on the ground, or who have lost much blood and have thus had their resistance diminished.

Again, the local resistance of a part is determined to a great degree by the amount of trauma inflicted upon the tissues by any given projectile, and this accounts for the fact that bullet wounds with a relatively small amount of trauma show a very slight degree of infection as compared with the large lacerated wounds in which the resistance of the tissues becomes reduced to a condition of very low vitality, in which there is considerable disturbance of the circulation and in which the tissues are filled with extravasated blood. According to Lagarde ([2]) microscopic examination of the soft tissues surrounding the wound shows laceration, hæmatoma and contusion—conditions favouring coagulation necrosis. He also states that extraneous matter is dispersed throughout the tissues, either partially or wholly devitalising them.

II. Anaerobic Infection

As has already been shown, the nature of the ground over which much of the fighting has been done is such, owing to its high degree of fertilisation, that it forms a natural habitat for spore-bearing organisms, and, as a consequence, anaerobic bacteria may be demonstrated in the majority of wounds. These organisms also attack the tissues much more rapidly and severely than do any other organisms. In a large proportion of wounds, however, even though the same anaerobes are present, they appear to do comparatively little harm, and their action seems to be merely a local one. This appears to be true to a greater extent in the open lacerated shell wounds, where the devitalised tissues are exposed to the air, than in the non-perforating wounds in which there may be an infected projectile together with contaminated earth and clothing. In such a wound as the latter, the organisms are removed from the action of the air, and can therefore proliferate under ideal anaerobic conditions, and it is in such wounds that we find the rapid and fulminating sepsis.

The two important and prevalent anaerobic organisms which we find so commonly in wounds of this present war are:

1. *B. perfringens*,
2. *B. tetanus*.

1. B. perfringens.—This is known also as the *B. aerogenes capsulatus* or Bacillus of Welch. Infections from these organisms are characterised by their rapidity, and also by their grave constitutional effects, especially in the more severely infected wounds. Wounds so infected have a characteristic fæcal-like odour, are dirty in appearance, have a dirty sero-purulent exudate, and contain pus. The constitutional symptoms are usually much greater than the local condition would seem to warrant, and it is therefore most important that such a condition should be recognised early.

Infection from this group may be divided into three classes:

(*a*) Wounds in which the infection may be recognised by the appearance, the characteristic odour, and by bacteriological examination.

In such a group as this the infection is purely local, and, if recognised and treated early, will remain local.

(*b*) Wounds in which there are swelling and inflammation of the adjacent soft parts and also crepitation or crackling of the skin as well as all the signs mentioned in Group (*a*). This is essentially a cellulitis.

(*c*) The most severe type is seen in those wounds where there has been some disturbance of circulation, such as the severing of an artery and a consequent devitalisation of the parts. It is in this class that we find the "gas gangrene," a most serious and grave condition as regards the life of the patient. Here we have also the same signs, but the constitutional symptoms are much more severe, and the patient presents all the appearances associated with shock or collapse; he rapidly becomes pulseless, the tongue is furred, hands and feet are cold, and death follows the onset in a few hours. There is also usually severe pain due to the increased swelling and tension, but as the tissues die the pain gradually diminishes.

Naturally we inquire why, with the same organisms, we should find such a variety of conditions, and also why some tissues appear to resist the infection better than others.

According to Bowlby (3) the explanation seems to lie in the fact that anaerobes develop most characteristically in dead or dying tissues, and that disturbance of circulation and the consequent lowering of the vitality of the tissues is a most important factor in anaerobic development.

This is shown by the fact that simple flesh wounds are rarely severely infected, while in the more extensive wounds of legs, shoulders and pelvic regions, where amputation cannot be performed readily, gangrene nearly always supervenes.

He also states that it is a well-known pathological fact that the action of gas-producing organisms is greatly assisted by the presence of staphylococci or other bacteria. In support of the rapidity with which the gas organisms attack the tissues he cites cases in which he has seen the formation of gas within five hours after the wound was inflicted, a whole limb gangrenous in ten hours, and a patient dead from hæmic infection in sixteen hours. In further support of the idea that anaerobic bacteria attack best dead or dying tissue, he quotes an instance in which he saw a wound which was only slightly infected before death, but three to four hours after death had occurred the whole leg had become a putrefying mass from the rapid spread of the organisms.

In considering the infection of wounds by *B. perfringens*, it is important to bear in mind several salient points—namely, the rapidity of the infection, the fact that the most severe infections take place in dead or dying tissue, and that the greater the injury and the more the tissues are devitalised, the more severe is likely to be the infection.

The treatment of this class of cases will be considered in the chapter on Wounds of the Soft Parts.

2. **Tetanus.**—Another important group of cases which are infected by anaerobic organisms, and which are of paramount importance owing to the severity of the infection, are those in which we find *B. tetani* and in which later tetanus develops.

Fortunately the incidence of tetanus is relatively low, owing to the extensive use of prophylactic doses of antitetanic serum. Nevertheless each wound presents potential factors as regards tetanus, owing to the same conditions of terrain as in the case of *B. perfringens*, and for this reason the possibilities of infection by this organism should be constantly borne in mind. Mackenzie-Forbes ([4]) states that it is wiser to assume that all wounded have been infected by tetanus and that all have not been treated with a prophylactic dose of serum at the front, and for this reason should be given a dose after admission to the hospital.

Sir David Bruce ([5]) shows some interesting observations regarding tetanus on 231 cases extending over a period of one year. The following table shows the conclusions at which he arrived :

(*a*) In the 231 cases under review the mortality was 57·7 per cent.

(*b*) Cases with a short incubation are more fatal than those of a longer incubation.

(*c*) The majority of cases occur on the tenth day after the infliction of the wound.

Other observers give figures showing a higher rate of mortality. During the past six months there have only been 36 cases of tetanus among those wounded who received a prophylactic dose of serum within 24 hours, and of this number 28 died—a mortality of 77·7 per cent. Other figures (6) show that in a group of 34 cases of severe tetanus in men who, for one reason or another, had not received the prophylactic serum within 24 hours, 32 died —a mortality of 94·1 per cent.

Tetanus may occur in all degrees of severity, from slight localised trismus to severe general convulsions, and it is important that an early diagnosis should be made in order that drastic measures of treatment may be instituted. That tetanus may develop at a period remote from the time of being wounded, and usually after some manipulation, has been shown in several instances.

Treatment.—The treatment of tetanus is most important, and divides itself into two classes :

(*a*) Prophylactic.
(*b*) Treatment when the disease manifests itself.

(*a*) *Prophylactic.*—In every instance a preventive dose of at least 500 units should be given subcutaneously at the earliest possible moment, and the fact that the serum has been given should be recorded, as well as the number of units used. In severe wounds 1,500 units may be given, but there is no evidence to prove that the smaller number is not sufficient.

(*b*) *Treatment when the Disease manifests itself.*—When once the disease manifests itself, the treatment of necessity becomes palliative, and may be described as:

(*a*) Local Treatment.
(*b*) General Treatment.
(*c*) Specific Treatment.
(*d*) Combined Treatment.

(*a*) **Local Treatment.**—Any wound in which the *B. tetanus* can be demonstrated bacteriologically should immediately be cleansed, under ether if necessary, and all devitalised and loose tissue removed and the wound swabbed out with carbolic acid, followed by alcohol. Wet dressings of some antiseptic solution, preferably hypochlorous acid, should be frequently applied.

(*b*) **General Treatment** by means of inhalation of chloroform or ether to control the spasms. Morphia, chloral, bromides and *cannabis Indica* may also be used for the same purpose, and all have a certain value, especially the first mentioned.

(*c*) **Specific Treatment.**—This is most important, and consists of several methods when once the disease has established itself, and when drastic measures are necessary in order to save the life of the patient. It consists in giving repeated doses of anti-tetanic serum, 500 to 3,000 units, each day either intravenously, subcutaneously, or even into the spinal canal in the more advanced cases. Other methods of treatment are also advocated. Stewart and Laing ([7]) recommend the use of carbolic acid injections into the tissues once the disease has manifested itself. They inject 2 c.c. of a 5 per cent. solution every two hours, and gradually increase the interval between injections as the spasms diminish. They cite cases also in support of this treatment.

Another method which has been advocated is that described by Meltzer ([8]) of the Rockefeller Institute, and consists in the use of a solution of magnesium sulphate There are four methods of administering this:

(i) *By Subcutaneous Injection.*—Not more than 2 c.c. and not less than 1·2 c.c. of the solution (25 per cent.) per kilogramme of body weight should be injected subcutaneously at least four times in twenty-four hours. As there may be considerable pain, a light inhalation of ether may be given. No massage should be given to hasten the absorption.

(ii) *By Intramuscular Injections* combined with inhalations of ether. This method is based upon certain findings that a moderate inhalation of ether increases considerably the efficiency of the magnesium sulphate. The patient should be fairly well etherised, and 2 c.c. of a 25 per cent. solution of magnesium sulphate injected into the muscles of the thigh. At the end of the injection the thigh should be gently massaged and the anæsthesia continued lightly for about twenty minutes.

(iii) *By Intravenous Injection.*—The concentration should not be more than 3 per cent., and not more than 5 c.c. per minute should be allowed to flow into the vein.

(iv) *By Intraspinal Injections.*—This is done in the same way as for lumbar puncture, and 1 c.c. of a 25 per cent. solution for every ten kilogrammes of body-weight should be given.

(*d*) **Combined Treatment.**—This consists merely of combining the various methods described, and is applicable only in the most aggravated cases as a method of last resort.

III. Pyogenic Organisms

Infection of gunshot wounds by the pus-producing organisms comes next in importance, and of these organisms the streptococcus ranks first in order of prevalence, as the majority of wounds are so infected. The *Streptococcus fecalis* appears to be the most common, and this is not strange when we consider the nature of the ground on which the majority of these wounds are inflicted.

Other forms of streptococci are found, as are also the staphylococcus *B. pyocyaneus* and the colon bacillus.

It would, therefore, appear that much of what has been said concerning the anaerobic group also holds good to a great extent in the pyogenic group, especially as regards terrain and mode of infection. Wounds infected by the pyogenic organisms do not show the severe local and constitutional effects that are seen in wounds contaminated by the gas-producing organisms, and the virulence does not appear to be so severe as in the infections from the same organisms which are so commonly seen in civil practice. This may be due in part to the high state of resistance of the men, but it also seems probable that the pyogenic bacteria causing these infections, having remained in the earth or on the clothing for so long, are of a less virulent type, and have become more attenuated than some forms of streptococci and staphylococci which are met with in civil practice, and which may have attained a high degree of virulence by transmission from one human host to another. Fleming's table shows the relative proportion of the various pyogenic organisms in wounds of different duration.

The treatment of this type of infection will be taken up in detail in the chapter on Wounds of Soft Parts.

IV. Latent Sepsis

While it is true that many wounds heal without giving rise to any clinical signs of infection, nevertheless it is safe to assume that no wound is sterile from a bacteriological point of view, and, even after such a wound is healed, operative procedures involving the healed track may cause a lighting-up of a virulent sepsis. In other words the bacteria remain quiescent in the scar tissue and the tissues immediately surrounding the healed track, but by traumatising these tissues and lowering their vitality, the bacteria are liberated and immediately begin to grow. For this reason operative procedures not absolutely necessary should never be undertaken on any healed wounds, especially wounds involving nerves or about joints or blood-vessels and tendons, until at least three months have elapsed from the time of healing of the wound. Furthermore, due care should be exercised in commencing massage or passive motions, especially if the wound be in the neighbourhood of a joint.

That Latent Sepsis is not confined to any one organism is shown by the following three cases :

1. **Tetanus** (9).—The patient, aged twenty-five, Royal Field Artillery, was wounded on October 11th, 1915, by shell fire while in the trenches at Loos. At that time he received a prophylactic dose of anti-tetanie serum 750 units and his first-aid dressing. He was admitted to the American Women's War Hospital, Paignton, on October 16th. Examination showed multiple shell wounds of the face, neek, right arm and hand. These wounds were small, and some of them contained small pieees of shell. The right thigh presented on the anterior surface a large superficial granulating wound, 2 by 4 inches. The right lower leg, just above the external malleolus, showed two small infected wounds. There were marked displacement inwards of foot, abnormal mobility and erepitus. Fibula showed fracture 2 inches above external malleolus, and tibia presented an oblique comminuted fracture at the same level.

After admission various pieces of shell were removed, the large wounds of forearm and thigh sutured, and finally healed by primary union. Fracture redueed and held in position by plaster. Patient was apparently making an uneventful convaleseenee except for eondition of leg, whieh was badly infected and was requiring eonstant treatment.

On December 4th patient was given ether to overeome contracture of his forearm and to eorrect position of his leg. One week later he complained of some pain in the masseter muscles, but this was thought to be somewhat the result of the etherisation, as he had not been breathing particularly well at that time, and it had been found necessary to hold his jaw forward with considerable force. Five days later, on December 16th, the pain in the jaw had increased somewhat, and patient found he was unable to open his mouth to its full extent. The reflexes were exaggerated, and during the day he had more marked tonic spasm of masseter muscles. It was felt that he probably had tetanus, and he was given 1,500 units anti-tetanus serum subcutaneously. Temperature and pulse at this time were essentially normal. On December 18th he was much improved; there was less tonic spasm of the masseter muscles, but he had, and had had since the previous night, clonic spasms of the diaphragm, abdominal and back muscles. Reflexes still exaggerated. Blood count taken at this time showed a leucocytosis of 10,400; differential white count gave the following percentages: polymorphonuclear neutrophiles, 65; eosinophiles, 6; basophiles, 0; small lymphocytes, 18; large lymphocytes, 5; large mononuclear leucocytes, 3; and transitional leucocytes, 3. December 19th: 1,500 units anti-tetanus serum intravenously. December 20th and 21st: 1,500 units anti-tetanus serum on each day.

From that time to January 1st patient showed steady improvement. At that date the spasms had disappeared, reflexes were normal, there was no pain in the masseter muscles, and he was able to open and shut jaw without any discomfort. He was up and about the ward, walking with crutches. January 20th: leucocyte count, 10,200; differential count gave the following percentages: polymorphonuclear neutrophiles, 72; eosinophiles, 3; basophiles, 1; large lymphocytes, 4; small lymphocytes, 16; large mononuclears, 1; and transitionals, 3. White count made a month after last inoculation shows practically the same leucocyte count, but the eosinophiles are approaching normal.

It is interesting to note that both the eosinophile and leucocyte count are increased, but it is doubtful whether very much stress can be laid upon this, owing to the fact that the patient has a septic wound in his leg which is still discharging. According to Hill (10), in the *Archives of Internal Medicine* for December 1915, there is in cases of tetanus an increased leucocyte but a diminished eosinophilic count. It is also interesting to note that as soon as the anti-tetanic serum was given, the patient immediately began to show signs of improvement, and although a total of only 6,000 units was given, he made a complete recovery.

2. **B. perfringens** (11).—Private ——, aged twenty-nine, while making a charge at the Dardanelles on August 8th, 1915, was wounded through the left hip. He crawled into a shelter out of the line of fire, and had to remain there for ten hours before he could be brought back. He was then taken to the dressing station, where the wound was treated. The next day, while being transferred on a stretcher, he received another bullet in his right hip. He was put on a hospital ship and transferred to Alexandria, where one bullet was removed from just above the knee. He was admitted to the American Women's War Hospital, Paignton, on August 26th. Examination at that time as follows: Well-developed and nourished man, came in as an ambulatory case. General physical examination: Negative save as follows: 2 inches behind anterior superior spine on right side is a small healed wound. Just on outer side of right leg, 1½ inches above right knee, is a small incised wound, slightly infected, where bullet was removed. On left side, just over tuberosity of ischium, is a small healed wound. Palpation about ischium elicits considerable pain; patient unable to sit on left side, as left buttock is very tender, and he states that it feels as if something sharp were sticking into him. X-ray taken shows bullet lying in region of lesser trochanter and posterior to it. The wound just above the knee healed

uneventfully. There was considerable doubt as to whether it would be wiser to remove the bullet from the thigh or to allow it to remain. The patient, however, complained so much of pain on sitting down that it was thought advisable to make an attempt to remove it. The bullet was very carefully localised by means of the fluoroscope on several occasions, and showed very little change of position, but remained just on the level of, and posterior to, the lesser trochanter.

October 9th.—Operation. With the patient lying on his face a 3-inch incision was made on the posterior aspect of the thigh just below the gluteal fold, the upper limit of the wound being at the fold. The incision was carried down through the deep fascia and the muscles were separated, but it was found impossible to reach the bullet without enlarging the incision upwards, which was done. The bullet could be felt embedded in muscle, and lying against the lesser trochanter, but owing to its depth it was found to be very difficult to remove. A counter incision was therefore made in the buttock 2 inches above the upper limits of the first incision, and a finger inserted through this down to the bullet, which could then be manipulated by means of a finger above and a finger below, and by this method it was freed from the surrounding muscles and removed. No evidence of encapsulation and no pus found. The wounds were sutured in layers and closed without drainage. Good ether recovery.

October 10th.—Temperature elevated to 102° F., pulse 116. Wound examined; not reddened, but thigh somewhat swollen and tender. Re-dressed.

October 11th.—Temperature in afternoon became elevated to 104°, and pulse 120. Wound again examined, and whole thigh found swollen, tense, reddened and indurated; some crepitation in skin. From the wound itself a brownish serum was exuding, and when the sutures were removed, some bubbles of gas escaped. There was also the characteristic odour of gas bacillus infection.

The patient was immediately taken again to the operating-room, etherised, and multiple incisions were made on the thigh. Infection was found to be deep down throughout the muscles and fascia. The wound was dressed with hypochlorous acid solution. Culture taken. Bacteriological examination showed abundant *B. aerogenes capsulatus.*

October 15*th.*—Condition improved. Temperature became less elevated. Wounds slowly healing up.

October 20*th.*—Temperature and pulse practically normal. Condition of wounds satisfactory. The wound on buttock made for insertion of finger healed by first intention.

October 25*th.*—Temperature and pulse normal. Wounds clean and granulating.

October 30*th.*—Wounds closing and granulating in rapidly. Temperature and pulse normal.

November 12*th.*—Since last note the patient had an uneventful convalescence, except for a slight elevation of temperature following operation for the closing of the wound in the upper part of the thigh in order to prevent a large painful scar. A few stitches were at this time removed and the wound drained, packed with iodoform gauze, and treated with hypochlorous acid. Culture at this time showed staphylococcus, but wound healed very rapidly in spite of it.

January 12*th.*—Wounds entirely healed. The patient up and around ward, and is now ready to be invalided.

It is interesting to note that the wound of entrance in the buttock was entirely healed at the time of admittance to this hospital, and it was not until the tissues had been traumatised by operative interference that any signs of infection manifested themselves. Also, that at the time of operation no evidence of infection, such as encapsulation of bullet or pus, was found.

3. **Pyogenic Infection.** — R. K., age twenty, Royal Engineers, was injured on December 12th, 1915, by being kicked in the leg, causing compound fracture of his tibia

He was dressed three hours later at a field hospital, and was admitted to the American Women's War Hospital on December 20th. At the time of entrance his left leg presented a small, clean granulating wound $\frac{1}{4}$ inch in diameter at junction of lower and middle thirds of tibia on inner side. Leg slightly swollen, some fading ecchymosis, considerable abnormal mobility, and some displacement forward and upward of lower fragment of tibia. The upper border of the lower fragment could be felt subcutaneously about 2 inches above level of external wound. No disturbance of circulation or sensation in foot. X-ray showed oblique fracture of tibia and transverse fracture of fibula, with displacement upward and forward of lower fragment of tibia.

December 28*th*.—Wound healed, patient etherised, plaster applied under traction from toes to mid thigh to correct deformity.

December 30*th*.—X-ray showed no change in position. It was therefore decided, as the wound in the skin was entirely healed, to perform an open reduction and to hold fracture in position by means of a Shermann's plate; especially as the wound had been caused under advantageous conditions, or rather, not by a gunshot wound, the dangers of infection were thought to be very slight.

January 3*rd*.—Ether; operation; incision over site of fracture on inner side of tibia; fracture exposed. Considerable over-riding and separation of fragments found with some fascial elements between the ends. On outer side was a small triangular-shaped piece of cortical bone. Fascia removed from between the fragments and wound washed thoroughly with saline; fracture reduced and held in good position by bone plate. Triangular piece of bone held in position also; Fascia closed with cat-gut and skin closed with silkworm gut; alcohol dressing; posterior wire splint.

January 15*th*.—Wound of operation healed by primary union; all sutures out. Five days ago original wound became swollen and reddened, and began to discharge a considerable amount of pus. This was incised and drained. Culture shows staphylococci and some streptococci.

January 24th.—Wound still discharging; small pocket of pus under skin opened under gas anæsthesia.

January 30th.—Wound clean and granulating. X-ray shows good alignment and position, and good callus formation. Since that time plate has been removed and patient has gradually made an uneventful recovery.

These three cases illustrate well the fact, which has already been mentioned, that even though wounds may be healed, and there is no evidence of infection, yet bacteria are still present in the scar tissue, and, owing to the traumatising of the tissues by operative procedures, they become liberated and an extensive suppurative process results.

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CHAPTER IV

GUNSHOT WOUNDS OF SOFT PARTS

I. Wounds caused by Projectiles:
  (1) From Hand Weapons.
  (2) From Artillery—
    (a) High Explosive Shells.
    (b) Shrapnel.
  (3) From Grenades, Bombs and Mines.
II. Types of Wounds:
  (1) Perforating or Seton.
  (2) Non-perforating or Penetrating.
  (3) Lacerated and Contused Wounds.
  (4) Gutter Wounds.
III. Aseptic and Infected Wounds.
IV. Hæmorrhage: Primary and Secondary.

I. Wounds caused by Projectiles

Gunshot wounds of soft parts form an interesting and instructive study of the action of various projectiles on human tissues, and injuries of all degrees of severity are seen, caused not only by the so-called humanitarian bullet of the modern military firearms, but also by the various other projectiles now in use in modern warfare.

The nature of the wounds depends upon the projectile causing the injury, the tissues traversed by the missile, whether soft tissues alone or soft tissues and bone are involved, the velocity, shape and size of the missile, the way in which it strikes, and the amount of resistance which it meets. Wounds in general may be classified according to the nature of the projectile causing the injury, as follows :

(*a*) Wounds from Hand Weapons—Rifles, revolvers.
(*b*) Wounds from Artillery.
(*c*) Wounds from Grenades, Bombs and Mines.

(*a*) **Wounds caused by Rifle Bullets.**—Modern rifle bullets cause a large proportion of the mortality in warfare, and also inflict a high percentage of wounds of the soft parts—facts which it is important to bear in mind. According to our statistics at the A.W.W.H., wounds by bullets form 55 per cent. of the total number of wounds received by all forms of projectiles. According to Delorme (1), fatal injuries by bullet wounds are in the ratio of 25 per cent. of the total fatalities ; serious injuries 15 per cent. and slight injuries 60 per cent. of the total injuries.

We have already described the size and shape of the various bullets used by the belligerent Powers in the present War, the motions imparted to them, and also their instability on meeting with any obstacle, and will deal here with the nature of the wounds they cause.

Bullets fired from a proximal range, and striking point on, cause only a small puncture in the skin ; in passing through the integument they separate the tissues without causing a marked degree of trauma, and it is in such wounds as these that we find the most advantageous conditions for healing without evidence of infection. Furthermore, such bullets carry in with them very little foreign matter such as dirt or clothing, and cause the so-called aseptic or clean bullet wounds.

On the other hand, we are constantly seeing instances which prove that the bullets are unstable, or turn on their short axis, and these bullets will strike the tissues either obliquely or transversely, and even base on, causing wounds which are often of a relatively large size. Again, when a bullet becomes deflected or ricochets, the surface which strikes the body is much greater in area and is irregular in shape, and, consequently, the force with which it strikes the tissues is much greater, resulting in a higher degree of injury owing to the contusing and traumatising of the affected parts. We also find bullets which become disintegrated either just before striking the tissues or while passing through, and this deformity seems to be found more frequently in the case of bullets in which the lead base is not covered by a metallic casing than in the case of those which are of solid metal or have the base covered. In the former the core apparently becomes forced out, and we sometimes see instances where the lead core remains in the wound but the casing is passed through, or else the casing becomes very much broken up and distorted and remains in the wound while the lead core is not found. Bullets such as these, besides causing a greater amount of injury, also carry into the wound a much larger quantity of foreign matter, such as contaminated earth and clothing. The severity of the injury, as has already been mentioned, depends upon the velocity of the bullet, its shape, and the nature of the tissues which it strikes. The most severe injuries are seen generally from projectiles possessing high velocity, or in other words projectiles which inflict injuries at proximal ranges or distances up to 500 yards, these being the so-called explosive bullets—named thus on account of the effects they produce on the tissues, for while the bullet may cause only a small puncture at point of entrance, owing to its rapid propulsive and divulsive force in driving tissues before it, it causes a large gaping wound at the point of exit, which simulates the effect of an explosive bullet. These effects are not seen from pointed bullets which strike absolutely point on, but it is only when the projectile becomes slightly deviated while travelling at a high rate of velocity that this action is observed. According to Delorme, intense divulsive and propulsive effects are exercised with greater facility the more the tissues are capable of dissociation, the less they show elasticity, as in the case of muscles, and the freer the molecules, as in parenchymatous organs and the brain—the incompressibility and their frequent projection explaining the tremendous extension of the havoc that at times is wrought by bullets upon organic receptacles such as the bladder, intestines, stomach and gall-bladder. The most elastic tissues of the body, such as tendons and fascia, especially when they are movable as tendons are, can transmit over a greater distance the active force imparted to them by a bullet. Thus they will be apt to traumatise the less resistant tissues, such as muscles and skin. Fragments of bone detached by a bullet act as supplementary projectiles, as they are propelled outward and tend to intensify the action. Delorme also states that when the active force of the projectile is between 547 and 1,094 yards, the action of the bullet tends to become localised ; the injury is more in the nature of a punctured wound with a weak projection ; when the active force is weak, beyond 1,094 yards, the injury becomes still more circumscribed. The bullet acts by puncture and especially separates the fibres of the tissues.

The zones of action of bullets have been classified as follows :

1. Explosive Zone, up to 547 yards.
2. Perforation Zone, ranging from 547 to 2,188 yards.
3. Contusion Zone, beyond 2,188 yards.

(*b*) **Wounds from Artillery.**—These may be divided into (*a*) Shrapnel Wounds, and (*b*) High Explosive Shell Wounds.

(a) *Shrapnel Wounds.*—The principal projectiles from shrapnel are the bullets which have already been described in a previous chapter, and which have a relatively low velocity and a large diameter.. The fuse and the casing must also be considered as projectiles, as either of them is capable of inflicting considerable damage to the tissues, on account of their weight and the velocity imparted to them. The bullets themselves have not a great penetrative power, and the damage they cause is usually slight as compared with the damage inflicted by a rifle bullet. The nature of the wound caused by a shrapnel bullet depends largely upon the height from the ground at which the shrapnel bursts (bursting height); the closer the bursting height is to the ground, the more concentrated are the bullets, and the greater velocity they have—consequently the greater the damage inflicted. However, if the bursting height is far above the ground, the bullets become very much scattered, rapidly lose their velocity, and inflict comparatively little damage. It must not, however, be inferred that shrapnel is not dangerous, for when its bursting point is close to massed troops, or above the trenches, or above men in the open, it is a very deadly weapon; but its danger diminishes with the increase of the distance at which it bursts.

The wounds from shrapnel bullets are usually penetrative and occasionally perforating, but the amount of damage inflicted on the tissues is relatively small unless blood-vessels, nerves, viscera or bone be involved. Shrapnel bullets are usually retained in the tissues, and wounds caused by them are generally infected owing to the diameter of the bullet, which carries before it and implants deeply in the wound a large amount of contaminated matter such as clothing, and owing also to the fact that the trauma of the tissues in the immediate vicinity of the wound is greater from a shrapnel bullet than from a rifle bullet.

(b) *High Explosive Shells.*—Owing to the fragmentation of the shell-case and to the size and shape of the individual pieces, which, as has already been shown, vary from a fragment weighing many pounds to minute particles, the severity of the wound or wounds depends altogether upon the size of the projectile inflicting the injury; and we find wounds ranging through all grades, from the most severe type, where the tissues are lacerated beyond all recognition and where limbs are torn off, down to the small superficial wounds in which the shell fragments are embedded in the skin, and consist of small pieces which cannot be felt with the probe and are revealed only by examination by means of the X-ray.

Wounds from shell fragments may be simple or multiple, the number depending upon the proximity of the bursting shell. It is not uncommon to see men with a dozen or more wounds caused by shell fragments of varying size; and just recently I had in this hospital a patient who showed forty wounds scattered over his neck, back, arms, and buttock; he was leaning over in the trench at the time the shell exploded, and was literally peppered with a shower of small fragments; the largest wound he had was only about 2 inches long, and the others varied from this to the size of a pin's head, and all were relatively superficial. Owing to the irregular nature of the larger fragments, there is much tearing away of tissues, together with some extravasation of blood, and oftentimes large masses of extraneous matter are carried into the wound, where they find a fertile field in which to produce pus-forming organisms, practically all shell wounds of any degree of severity being therefore infected.

(*c*) **Grenades, Bombs and Mines.**—Wounds from grenades present to a large extent the same appearance as do wounds from smaller shell fragments, and we find here, as with shell wounds, varying degrees of severity depending upon the proximity at which the grenade exploded and the force with which the projectiles were driven into the tissues. Projectiles from grenades lose their velocity very rapidly, and it is only at close quarters that they inflict much serious damage. The wounds caused by this type of missile are practically all infected, and we often find large areas of tissue which are simply filled with fragments of the container and also of the contents.

In the case of terrestrial mines we also find wounds caused by the rocks and earth which are thrown up by the force of the explosion, and which in themselves become projectiles and may cause considerable injury to the tissues either by bruising or tearing.

II. Types of Wounds

Wounds are classified as:

1. Perforating or Seton Wounds.
2. Non-perforating or Penetrating Wounds.
3. Lacerated and Contused Wounds.
4. Gutter Wounds.

1. **Perforating Wounds** may be caused by bullets, shrapnel bullets, and shell or grenade fragments; and

Fig. 9. Perforating rifle-bullet wound. Shows inverted edges of wound of entrance on inner side of thigh and everted edges of wound of exit on outer side.

from the appearance of the wound one is usually able to determine the nature of the projectile inflicting it. A perforating bullet wound, if the bullet has struck point on, will present a small round wound of entrance, the edges of which are inverted and slightly congested, whereas the wound of exit, which may be of practically the same

Fig. 10. Bullet wound of back and arm showing abrasion and wound of entrance in mid line, larger wound of exit due to turning of bullet, and still larger lacerated wound on posterior surface of right upper arm extending down through portion of triceps.

size, will show edges slightly everted (Fig. 9). If, however, the bullet becomes slightly deflected, the wound of entrance varies considerably in size and shape, and the edge will be very ragged and more inverted, while the amount of contusion to the surrounding tissues will be greater. The wound of exit also in these cases presents an entirely different appearance, and instead of finding a small round wound, we find a large, ragged, lacerated

FIG. 11. Shows perforating shrapnel bullet wound.

wound in which may be seen the torn ends of muscles, tendons and fascia, and in such wounds there is usually a large loss of cutaneous and subcutaneous tissues (Fig. 10).

In perforating wounds caused by bullets we often see around the wound of exit a small cavity between the skin

FIG. 12. Shows perforating or Seton wound of side caused by shell.

and the aponeurotic fascia which may be filled with blood clot. This is known as Pirogoff's Pouch, and is caused by the bullet pushing away the skin and superficial fascia from the more resistant deep tissue.

Perforating wounds from shrapnel bullets show much the same characteristics as do those from rifle bullets, except that the wounds are larger, and there is more traumatising of the tissues adjacent to the wound (Fig. 11).

Shell and grenade fragments also may cause perforating

FIG. 13. Perforating shell wound of forearm. No bone involvement. Function unimpaired.

wounds, but such wounds are relatively superficial, and usually burrow under the skin and come out again within a short distance. The wound of entrance is irregular and ragged and does not always correspond to the size of the projectile causing the injury (Fig. 12). There is considerable traumatising of the tissues, and owing to the rough and jagged edges of the shell fragment tearing its way through the tissues, the wound of exit is also very much lacerated and torn muscle fibres and fascial elements will protrude (Fig. 13).

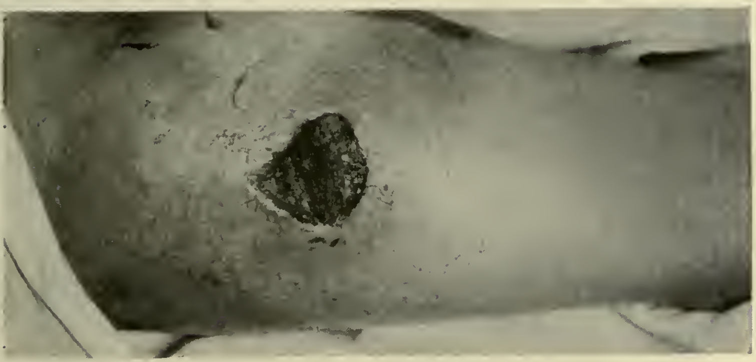

FIG. 14. Non-perforating shell wound of thigh.

FIG. 15. Multiple small non-perforating shell wounds.

2. **Non-perforating or Penetrating Wounds** of the soft parts may be caused by bullets fired at long range or by bullets which have had their velocity considerably reduced by contact with some obstruction which has either deformed or disintegrated them, or in some instances even caused them to enter the tissues base foremost. They are also caused by shrapnel bullets and by the smaller shell and grenade fragments. The nature of the wound

FIG. 16. Multiple small non-perforating grenade wounds.

depends upon the type of projectile causing it. In the case of rifle bullets, it may be a small puncture, or if the bullets are deformed or disintegrated the wound of entrance may present ragged and torn edges. Shrapnel bullets, by reason of their low velocity, usually cause this type of wound and are retained, and in such a wound we find a circular puncture in the skin slightly larger than that caused by an undeformed bullet. Shell fragments, on the other hand, owing to the variations in their size and

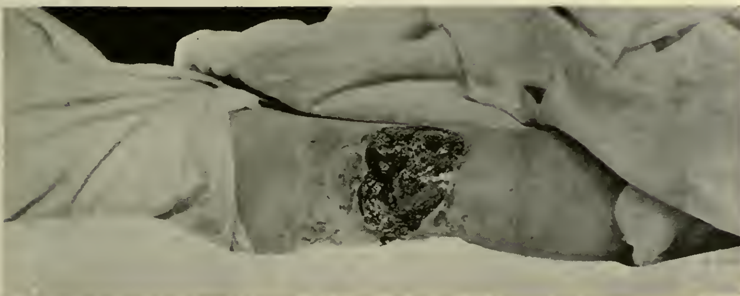

Fig. 17. Lacerated wound of thigh caused by shell fragment.

shape, may cause large excavated wounds where there is considerable loss of skin and of deeper tissues (Fig. 14), or if the fragments be small there may simply be small punctured wounds extending through the skin and fascia into the muscles, and often we find minute fragments embedded in the skin (Fig. 15).

Grenade fragments cause a large proportion of non-perforating wounds, as the velocity of these fragments is

Fig. 18. Lacerated wound of lower leg caused by cap of time fuse shown in Fig. 6.

very rapidly lost, and is low except at close range; and, as a result, we find grenade wounds varying from small punctures in the skin (Fig. 16) to deeper cul-de-sacs ex-

Fig. 19. Lacerated grenade wounds of both legs.

tending into the muscles and large gaping wounds where there is much destruction of tissue.

We may say, then, that a typical non-perforating or penetrating wound consists essentially of an aperture which may be of varying size in the skin, extending down through the aponeurotic fascia and muscles and forming a cul-de-sac at the bottom of which we find the projectile which has caused the injury, and also in the case of the larger projectiles a mass of contaminated clothing.

In the case of rifle bullets and minute shell fragments, the amount of trauma may be very slight, but with the larger fragments we often find that though the wound of entrance be small there is considerable destruction of

FIG. 20. Gutter wound of posterior surface of left upper arm caused by shell.

the deeper tissues together with a marked contusion of the tissues adjacent to the wound and considerable interstitial hæmorrhage.

3. **Lacerated and Contused Wounds** are usually caused by bullets which have deviated from their true axis, and by shell and grenade fragments. The edges of the wound are torn and lacerated, as are also the deeper structures such as the fascia and muscles, and there is usually considerable loss of tissue owing to the tearing and contusing action of the projectile causing the injury (Figs. 17, 18, 19).

4. **Gutter Wounds** may be divided into Superficial and Deep, according to whether the skin and superficial tissue alone are involved, or whether the wound reaches down through the deeper structures and involves the deep fascia and muscles. Gutter wounds are usually caused by shell fragments or shrapnel bullets, but may be caused by rifle bullets striking the tissues superficially, becoming somewhat deflected and ploughing deep furrows or eroding through the tissues. These wounds vary in size from a very small injury, which amounts practically to an abrasion,

Fig. 21. Gutter wound of left thigh caused by shell and extending down through vastus externus muscle, which is shown exposed.

to wounds extending through skin, fascia and muscles, and leaving a gap several inches in length and spreading to a considerable width (Figs. 20 and 21).

III. Aseptic and Infected Wounds

We have already shown the effects of the various projectiles on tissues, and the amount of trauma inflicted by each, and we will now consider briefly the two classes into which such wounds divide themselves as regards the process of healing, viz.:

1. Aseptic or Clean Wounds, and
2. Infected or Suppurating Wounds.

1. **Aseptic or Clean Wounds.**—Uncomplicated wounds of soft tissues by bullets which pierce the tissues point on or nearly so, and thus cause relatively little trauma, heal very quickly and give rise to no clinical evidence of infection. There may be at first a slight serous oozing from the wound, which, however, very soon dries and forms a crust under which healing takes place spontaneously. This applies almost always to those wounds which have a small aperture, and where there is no gap and also where the wound in the fascia is small. In such wounds the amount of trauma is slight; there is practically no contamination, or at worst it is so very slight that the local resistance of the tissues is usually able to counteract the infecting agent.

2. **Infected or Suppurating Wounds.**—Again we have larger wounds which are caused by deformed or ricochet bullets, and here the conditions are somewhat different. The wound of entrance is larger, the track is open well into the deeper tissues, there are considerable gaping of the wound of entrance and some trauma of the tissues, with consequent lower local resisting power. Furthermore the bullet which has become deformed or deflected by contact wth the earth is in itself an infecting agent, and will also carry before it into the wound a considerable amount of contaminated clothing. These larger wounds are also more apt to become infected by means of contact with the clothing before a dressing can be applied. If the wound be only a blind track at the bottom of which is an infected mass consisting of the bullet and shreds of clothing, the dangers of sepsis are greatly enhanced, and all wounds from ricochet or deformed bullets should be carefully watched. In such wounds we may get only a slight sero-purulent discharge which gradually disappears in the course of a few days; but, on the other hand, we may find the tissues becoming reddened, swollen and tender, showing every evidence of a suppurative process taking place. Such wounds are relatively septic, but

may clear up without any further evidence of extension of the infection. We may indeed say that uncomplicated wounds of the soft parts caused by bullets striking point on usually heal spontaneously without giving rise to any clinical signs of infection, while on the other hand wounds caused by ricochet or deformed bullets rarely heal without suppuration.

We have shown that deflected bullets cause wounds which usually suppurate, and this is also true of wounds caused by shrapnel bullets and by shell fragments. The wounds caused by these are larger, there is more trauma, and a greater amount of contaminated matter is carried into and spread about the wound; and if a large pocket be formed in traumatised tissues and the entrance be small or occluded, a very severe sepsis may result unless proper measures are promptly instituted. We must also seriously consider in such wounds not only the fact that the suppuration may be due solely to pyogenic organisms, but also that it is in such wounds that we find a severe and sometimes grave cellulitis resulting from the presence of *B. perfringens*, and furthermore the presence also of *B. tetani* must also be considered a possibility. Occasionally we see wounds from shrapnel bullets and small shell fragments and grenade fragments which may heal aseptically, but this is uncommon.

To reiterate briefly—we may say that small bullet wounds of soft tissues may be considered as clean or aseptic. Wounds from deflected bullets, however, while they may heal spontaneously, possess potential factors of suppuration which should not be neglected. Wounds caused by shrapnel bullets and by shell fragments, especially if the fragments be of small size, may sometimes heal spontaneously, but generally show signs of infection, and the larger the fragments and the greater the trauma, the more severe is the sepsis.

IV Hæmorrhage

Bleeding from bullet and shell wounds is usually not very severe in cases which are able to be sent to the rear, for if a main vessel be injured, the resulting hæmorrhage is usually rapidly fatal before it can be controlled. There are two classes of hæmorrhage which we must always bear in mind—viz., (i) Primary Hæmorrhage, and (ii) Secondary Hæmorrhage.

Primary Hæmorrhage is that occurring in freshly traumatised tissues and where vessels of varying size may be severed. It may be very severe and fatal, or moderate, or slight and easily controlled.

Secondary Hæmorrhage.—In all suppurating wounds, especially in deep wounds which are liable to form pockets, we must remember that at any time during the process of healing we may get a severe hæmorrhage due to the sloughing of the walls of blood-vessels which may have been traumatised by the original missile causing the wound or else by the eating away or eroding of the walls of the vessels by the tryptic ferments which are found in conjunction with the pyogenic organisms.

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CHAPTER V

TREATMENT OF WOUNDS EXCLUSIVE OF FRACTURES

I. Immediate Treatment.
II. Subsequent Treatment :
 (1) Clean Wounds.
 (2) Infected Wounds :
  Efficient Drainage : Dressings, Removal of *Foreign Bodies* and Contained Matter ; Antiseptic Solutions, Salines, etc. ; Possibilities and Control of Secondary Hæmorrhage ; The Immediate or Ultimate Closure of Certain Types of Wounds by Primary or Secondary Suture.
III. Infection by *B. perfringens* ; Gas Gangrene :
 Diagnosis and Treatment.

THE treatment of war wounds differs of necessity from the treatment accorded to wounds seen in civil life, and one should have some knowledge of the conditions governing such treatment in order to be able to appreciate the difficulties met with in attempting to do adequate dressings at the front. In the first place a man who is wounded severely may receive no dressing for hours or possibly even for days, except such as he may himself apply, as wounded men lying between the trenches cannot be rapidly collected and brought back except at night, there being no cessation of hostilities for the collection of dead and wounded. Men who are not severely wounded fare better, as they may be able to walk and thus get to a dressing station by themselves ; whilst the very severely wounded, who have to be transported by stretcher, fare the worst.

The field ambulances and clearing stations are crowded with wounded constantly pouring in, so it can readily be seen that it is only the most urgent cases which command the most extensive treatment. At best, however, at the ambulances only the simplest forms of dressing can be applied, and only operations of necessity such as amputations or ligations of vessels can be done here. From the ambulances the men are transported to the clearing stations, where adequate apparatus for the fixation of fractures may be applied, wounds cleaned and dressed, and operations of necessity performed. When we consider that after an important engagement the wounded treated at a clearing station number hundreds and sometimes even a thousand in one day, and that nearly 20 per cent. of these are fracture cases, the marvel is that the men come back to the base with apparatus as efficient as that we see, and that the wounds are dressed as well as they are.

Treatment of wounds may be divided for purposes of consideration into two stages, viz.—

(I) Immediate, or Treatment at the Front, and
(II) Subsequent, or Treatment at the Base.

I. Treatment at the Front

This consists essentially of treating the wounds antiseptically, applying protective dressings, and in giving a prophylactic injection of anti-tetanic serum. In the more simple wounds the skin adjacent to them is painted with iodine, and the wounds themselves are also painted with the same solution; or they may be treated with carbolic acid in the proportion of 1 to 20 or 1 to 40. With larger wounds the patients may be etherised, tissues removed and the wound swabbed with carbolic or with iodine, easily accessible foreign bodies removed, and, in the case of hæmorrhage, blood-vessels may be ligated. Over the wounds a dressing of gauze treated with bicyanide of mercury is applied. The immediate treatment of wounds, therefore, resolves itself into an antiseptic treatment with the idea of attempting to prevent the subsequent development of sepsis, and also the control of hæmorrhage.

II. Subsequent Treatment at the Base

Unfortunately, in spite of the vigorous measures adopted at the front, a large proportion of the wounded reach the base in a badly infected condition, while in others, chiefly those wounded by bullets and the smaller shell and grenade fragments, the wounds may remain clean and heal aseptically. Subsequent treatment therefore may be divided into two groups :

1. Treatment of Clean Wounds, and
2. Treatment of Infected Wounds.

1. Treatment of Clean Wounds.—This need not detain us for long. As has already been shown, simple bullet wounds and the smaller superficial wounds from shells and grenades heal aseptically, and only need to be painted with tincture of iodine and to have protective dressings to prevent them from becoming infected by contamination from without; and the amount of hæmorrhage, which is usually slight, from such wounds may be controlled by means of pressure bandages, by a tourniquet, or, if necessary, by means of a ligature.

Immobilisation of the muscles also will aid the aseptic healing process to take place more quickly.

2. Treatment of Infected Wounds.—Our choice of methods of treating infected wounds naturally depends to a great extent on the nature of the wound, and also upon the type of infection ; but the objects which we wish to accomplish are the same in all cases—viz. to remove the cause of the infection, to promote free drainage, to aid the tissues in their process of repair, and to attempt to increase the local resistance by drawing to the wounded part fresh healthy lymph, which has an action antagonistic to the micro-organisms.

The treatment of the larger and suppurating wounds is most important, and of necessity during the present war many new ideas have been formulated and many old ideas have had to be readjusted.

The important factor to be considered in the treatment of infected and suppurating wounds is the nature of the infection. As the majority of gunshot wounds are infected, as has been shown, not only by pyogenic organisms but also by anaerobic bacteria, it is most important that an early diagnosis of the type of infection be made. Where possible a bacteriological examination should be made of every infected case, even if it be only by means of a smear to determine the type of the organisms which are causing the infection. The diagnosis of the infecting agent is important, too, in that it determines to a great extent the course of treatment to be followed; for, as we have already shown, every gunshot wound presents potential factors as regards infection by *B. tetani* and *B. perfringens* as well as the pyogenic organisms which are commonly present. The treatment of these various conditions will be considered in general, except the infection by the *B. perfringens*, which has been described more specifically.

In all cases where possible, we wish to apply to the wound a dressing which will have a marked bactericidal effect upon the prevailing organisms, and one which will penetrate into all the recesses of the wound, and thus reach all the foci of infection. Furthermore, at the base it is not necessary to consider the question of transportation, and we are therefore able to institute measures which can be more or less permanent. Treatment of infected wounds, therefore, resolves itself into the following principles:

(*a*) Efficient Drainage, and

(*b*) Dressings, Antiseptics, Salines, Baths, Compresses, Foments, etc.

(a) *Drainage.*—The object of drainage is to prevent the accumulation of pus and necrotic tissues, for if these cannot rapidly escape and are allowed to accumulate, the process becomes more and more extensive owing to the tissues being burrowed into and eaten away by the tryptic ferments which are present in conjunction with the pyogenic organisms. All infected gunshot wounds, therefore, should be freely incised, all pockets and cul-de-sacs opened out and evacuated, all necrosed tissues, frayed ends of muscle and sloughing fascia should be removed, together with all blood clot, and any foreign matter, such as clothing, dirt, shell fragments or bone fragments, and the wound should then be swabbed out either with tincture of iodine or with carbolic acid followed by alcohol.

Next we must consider the type of drain to be used. In the first place, such a wound should not be packed tightly with gauze, for by so doing we obstruct the discharges from the wound rather than aid them to escape, and are artificially creating the condition which we are attempting to overcome—namely, the backing-up of infected material. Various substances may be employed and will make efficient drains if properly utilised. Perforated rubber tubing is good in certain instances for wounds in the soft parts, but should be used very guardedly in cases of Seton wounds, especially in the regions of blood-vessels, as a hard rubber drainage-tube pressing on a blood-vessel may cause more damage than would the sepsis itself, and the result of such pressure might be a severe and possibly fatal hæmorrhage due to the erosion of the blood-vessel. In the smaller wounds, rubber dam tissue may be used to advantage, or small strips of gauze packed loosely into the wound, so as not to obstruct it, or combinations of these may be used advantageously, depending on the conditions met with. In such wounds we wish to establish constant bathing of the deeper parts of the wounds, and to do this strips of gauze fastened to a small rubber tubing may be inserted into the deepest recesses of the wound, and the rubber tube itself connected with an irrigating apparatus containing the solution to be used. The solution is allowed to flow or rather to drip slowly into the wound, the gauze drains become saturated, and the overflow is removed by capillary attraction of the gauze, so that in this way we are able to bathe a deep wound constantly with an antiseptic solution.

In perforating wounds it may be necessary to enlarge both the wounds of entrance and exit, in order to establish free drainage and to establish drainage between the wounds of entrance and the wounds of exit. In certain types of perforating wounds, especially those lying superficially under the skin and which are filled with broken-down blood and detritus from the clothing, it may be sufficient to pass a strip of gauze from one wound to the other and then to curet the track vigorously with this gauze, thus removing all foreign matter and blood clot, and then to swab the track out with iodine. If this method does not suffice, it may be necessary to lay the whole track wide open in order to allow granulation to take place from the bottom.

(b) *Dressings.*—After we have established free drainage of a wound, it is important that we should apply to that wound a dressing which will be such that it will aid the wound in the process of eliminating the infecting elements, and for this purpose different forms of dressing are used, depending entirely upon the condition of the wound. Slightly infected wounds, or those which are superficial, heal rapidly by treatment with hot compresses or hot foments consisting of gauze wrung out in some antiseptic solution, which will produce a bactericidal effect upon the discharge from the wound.

Antiseptic Solutions.—In the treatment of wounds after free drainage has been established, the solutions which we use should, in order to be effective, have properties which will increase the physiological processes in the wound in addition to having the mechanical effect of washing away the bacteria. The results which we wish to attain consist not only in overcoming and inhibiting the bacterial growth, but in promoting a free flow of lymph and preventing crust formation or coagulation of the discharge, as this tends to retard the elimination of infected material and also causes the accumulation, under the crust, of many micro-organisms. While many and various antiseptic solutions have been advocated at different times, our choice of solutions in this present war has become narrowed down to those which produce the most marked antiseptic power, and those which are a helpful adjunct to the process of healing, and which at the same time will have no deleterious effects on the tissues. The solutions which are being advocated most generally at the present time and which we use almost exclusively at the American Women's War Hospital are the following:

(i) Hypochlorous Acid, and

(ii) The Isotonic or Hypertonic Saline Solutions of Wright.

(i) *Hypochlorous Acid.*—This is a modification of the old solution of chloride of lime—liquor sodii chlorinatæ, or Labarraque's solution—with which many of us are familiar, and which we have used to a great extent in infected wounds before this war. Hypochlorous acid is prepared in two forms—viz. Eusol (the liquid form), and Eupad (powder).

Eusol is prepared from chloride of lime mixed with boric acid powder, and forms one of the most efficient antiseptics known. It also has the advantage of being a deodoriser; it stimulates granulations, aids markedly in the separation of sloughing tissues, and when used in the proper strength has no injurious effects on the surrounding skin or on the tissues themselves.

Hypochlorous acid may be used also as a gas, and in this latter form it is believed to be more potent as a germicide, as it is more penetrating and is absorbed more readily by the tissues than is the solution. At this hospital we have had no experience with hypochlorous acid as a gas, so are unable to compare it from a clinical point of view with the solution, which we have found to be most efficacious.

Smith and Drennan (1) carried on a comprehensive investigation regarding the antiseptic qualities of hypochlorous acid, and I quote the conclusions at which they arrived :

1. Comparative tests confirm the conclusion already arrived at by various investigators, that hypochlorous acid is the most powerful antiseptic known.

2. Practical methods of using this antiseptic have been devised.

3. It can be used either as a gas or as a solution, the advantage of using the gas being that it will penetrate and will act at a distance.

4. Both the gas and the solution, while extremely potent against organisms and their spores, cause little or no harm to the tissues.

5. The effect of this antiseptic is purely local. The decomposition products are devoid of toxicity, and there is therefore no danger to be apprehended from absorption.

6. A flow of lymph is induced from the wound as part of the reaction of the tissues.

7. Fetor is rapidly eliminated.

8. If pain and irritation occur they can be easily controlled by reducing the concentration of the antiseptic.

9. The practical advantages of this antiseptic for field use are :

- (*a*) It can be used as a dry powder and therefore obviates the difficulty of procuring water.
- (*b*) It can be introduced into the gauze pad of the first field dressing.
- (*c*) Where water is available, the same powder can be made up as a lotion for general use.

Both Eusol and Eupad are easily prepared, and it may not seem out of place to give here the method of preparation :

Eupad is prepared by grinding in a mortar ordinary bleaching powder or chloride of lime and then mixing with this an equal weight of boric acid powder. The mixture should be kept in closely-stoppered bottles and not exposed to light more than necessary.

There are two ways of preparing Eusol :

(i) 25 grams of Eupad are shaken up with one litre of water, and the mixture allowed to stand for a few hours, after which it is filtered through cloth or filter paper.

(ii) To one litre of water add 12·5 grams of bleaching powder, shake vigorously, then add 12·5 grams of boric acid powder and shake again. Allow the mixture to stand for some hours, preferably for a night, then filter off, and the clear solution is ready for use.

This solution contains ·54 per cent. of hypochlorous acid, 1·28 per cent. calcium bi-borate, and ·17 per cent. calcium chloride, and this gives the best strength of concentration of hypochlorous acid, it having been found that, while stronger solutions may be prepared, they rapidly lose strength until they come down to ·5 per cent., after which they decompose very slowly.

Carrel ([2]) finds that ·5 per cent. of Eusol causes irritation of the skin and tissues. He also finds that the powerful antiseptic action is of short duration, and is lost when brought into contact with albuminous substances. He claims that the essentials of antiseptic treatment by Eusol are deep and continuous irrigation of the tissues, so that there may be a constant interchange of the solution, and by this means all solution which has lost its germicidal effect is being constantly replaced by new and fresh solution. Carrel's technique when he desires to obtain a continuous antiseptic effect is as follows :

The wound is washed out with 5 per cent. Eusol solution, care being taken that the solution is applied to every cavity of the wound. For this purpose perforated rubber tubes 6 millimeters in diameter covered with bath towelling are led to every pocket of the wound. In the case of compound fractures, the tubes are carried to the site of the fracture, and the ends lie among the fragments. The wound is then filled with gauze and covered with non-absorbent cotton through which the tubes project. Either continuous irrigation is employed or the Eusol solution is run into the tubes every hour. Carrel maintains that in the more successful cases treated by this method the wounds become aseptic and healthy in from three to five days, and that septic compound fractures treated in this way become clean and heal like aseptic fractures.

Another solution which has been advocated for the treatment of suppurating wounds, and one which promotes a freer flow of healthy lymph, is the *Isotonic* or *Hypertonic Saline Solution of Wright* (3).

(ii) *Hypertonic Salt* consists of 5 per cent. sodium chloride, to which is added 1 per cent. of sodium citrate, and acts on the principle of promoting a free flow of lymph, thus bringing to the wound a great supply of fresh lymph allied with anti-bodies.

Two strengths of saline solution are used, depending upon the condition of the wound.

Hypertonic Saline Solution.—This consists of a 5 per cent. solution of sodium chloride. As has been proved both experimentally and clinically by Wright, such a solution when brought into contact with wounded tissues has a marked lymphagogic action. In his older solutions he added ·5 to 1 per cent. of sodium citrate, which has the power of decalcifying the lymph and preventing it from coagulating; and while it is true that many still add the citrate, it has been proved that this is not absolutely essential, as hypertonic solution without the addition of the citrate will cause very little coagulation, and most observers have discarded the use of the citrate in the present war. Hypertonic saline solution, as has been said, aids in the resolution of inflammatory tissues, and, being an active lymphagogic, causes the wound to become bathed with healthy lymph which possesses marked powers of inhibiting the growth of certain bacteria, and therefore the amount of pus is lessened, sloughs become separated, and the granulations take on a bright and healthy appearance. Certain organisms such as streptococci and staphylococci may persist in lymph, however, so when the sloughs and necrosed tissues have become separated and the granulations take on a healthy appearance, we find it essential to change the solution.

To reiterate briefly, hypertonic salt solution used as a dressing for wounds aids in the resolution of the inflammatory process, inhibits the growth of bacteria, promotes an efferent flow of lymph which washes out the bacteria and detritus from necrotic and suppurating tissues, and also prevents the lymph from coagulating.

Isotonic Solution or Normal Salt.—This consists of ·85 per cent. sodium chloride solution, and its action differs in a marked degree from that of the hypertonic solution, for whereas the hypertonic solution produces osmosis and at the same time retards the escape of the leucocytes, the isotonic solution encourages diapedesis rather than osmosis, and consequently in wounds dressed with isotonic solution we find a marked emigration of leucocytes from the surface of the wound. These leucocytes, with their strong phagocytic action, form a protective layer which prevents the tissues from becoming further infected by the bacteria; in other words the local resistance of the wound is greatly enhanced. The surfaces of the wound now become covered with a film, and the bright red appearance of the healthy granulations is less. This film, however, is important, as it is in reality a protective layer of leucocytes. It therefore follows that, after the wound presents healthy granulations due to the use of the hypertonic solution, the strength of the solution should be reduced to that of the isotonic in order to build up a protective film against bacterial invasion, which may be prevented by the phagocytic action of the leucocytes.

Methods of Use.—In superficial wounds either the hypertonic or isotonic solutions may be used in the form of wet compresses or as fomentations, but in the deeper wounds, the depths of which cannot easily be reached by outside

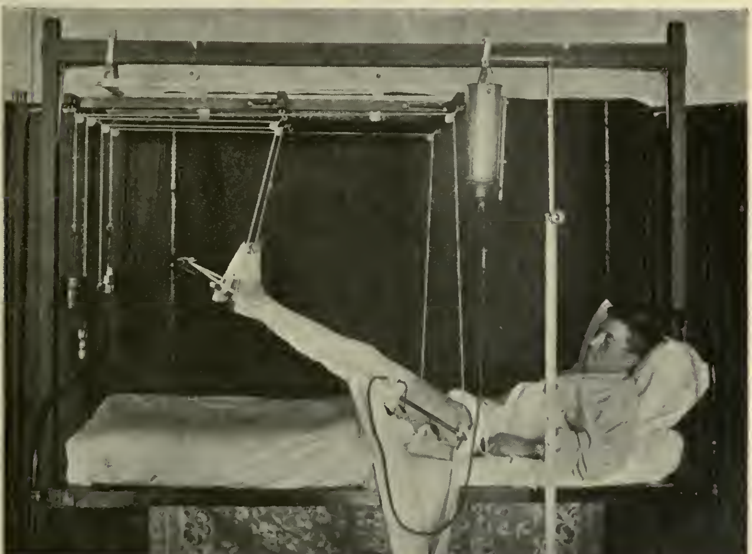


FIG. 22. Shows gunshot wound of thigh receiving constant saline irrigation. In foreground will be seen a Thermos bottle containing saline solution, small catheter inserted in lower wound and gauze drain in the larger wound near hip. Solution drains off by capillary attraction and is carried off by gutter made of rubber sheeting. Limb is held in a modified Thomas splint and suspended on a Parker modification of a Balkan splint.

dressings, constant irrigations of one solution or the other give the best results, and the wound is kept constantly bathed by an inflowing stream of saline and an outflowing stream of lymph and saline (Figs. 22 and 23).

Another method of treating wounds by salines is the method devised by Colonel Gray (4) for using sodium chloride in tablet or powder form, and which consists first of cleaning the wound thoroughly, then irrigating it with a 5 per cent. salt solution, after which the cavity is packed loosely with gauze saturated with 5 per cent. saline solution, and wrapped in the gauze are tablets of sodium chloride. It is important that the gauze should be in contact with all the walls of the cavity, otherwise the

FIG. 23. Shows more in detail the apparatus as used in Fig. 22. Wounds are left open except for insertion of gauze drain in larger wound. Saline is allowed to drip in constantly and is carried off by capillary attraction of gauze.

treatment will not be efficacious. A rubber-tube drain should also be placed in the wound to assist in removing the fluids. In this way we get, owing to the sodium chloride being able to absorb water, a constant hypertonic saline solution applied to the interior of the wound.

Another method which has also been described by

Hull (5) consists in making long narrow bags of gauze and filling them with salt. The sacks are sterilised and are inserted in the wound together with a small rubber drain, and the outer ends of the gauze bag, which should be left long, act as capillary drains for the removal of the fluids.

It will be seen that saline solutions promote either a free flow of lymph or an active emigration of leucocytes, and that they have a marked inhibitory power on bacterial growth and cause no coagulation of lymph.

As regards the relative values of hypochlorous acid and saline solutions, there is still considerable doubt as to which produces the best clinical results. From our own experience here we appear to get, as has been stated before, the best results with hypochlorous acid, especially in the treatment of gas infections; but in the treatment of other infections we are still undecided as to whether we get better results with hypochlorous acid or with saline solutions, though from comparative studies of the two methods we are beginning to be slightly more in favour of the saline solutions.

Secondary Hæmorrhage.—In every infected wound, and especially in those in the regions of the larger vessels and their branches, we must consider the question of secondary hæmorrhage. In every infected gunshot wound, therefore, even though the infection be slight, we must bear in mind the fact that a suppurating process is taking place deep down in the wound, possibly near a blood-vessel, and this vessel, which may already have been traumatised by the missile inflicting the injury, may become eroded by the action of the digestive ferments; its walls become weakened, and we may have a constant and severe hæmorrhage which, if not properly checked, may prove fatal. Furthermore, in perforating wounds, especially of the arm and thigh, we should be very guarded in the use of through-and-through rubber tubes for drainage, as such tubes may rest on a vessel, and by contact cause more damage than did the original missile inflicting the injury.

When secondary hæmorrhage occurs, there should be no temporising in the treatment; for, if the treatment be not sufficient, the hæmorrhage, although temporarily stopped, may recur again and again, and the condition of the patient becomes with each succeeding hæmorrhage progressively worse until we may get a hæmorrhage when the patient's condition is such that operative measures will be too late, and, owing to his inability to recuperate, the patient may die through collapse or shock. In large wounds, especially of the thigh or arm, if hæmorrhage occurs a tourniquet should be immediately applied, the patient etherised, the vessel cut down upon, and tied in its continuity unless the injury be so situated as to make this impracticable, in which case it may be ligated at the point of injury.

Infected wounds should not be packed for the control of hæmorrhage if other measures are available, for, as has already been shown, the packing of such a wound increases the possibilities of spreading the infection through a larger area, owing to the fact that a pack put in tight enough to control the hæmorrhage will absolutely prevent any septic discharges from draining out of the wound. Packs, therefore, for the control of hæmorrhage should be used very guardedly, and only in wounds where it is absolutely necessary, or owing to the difficulty of reaching the vessel to ligate it. The packs should be kept well saturated with saline solutions to drain off as much of the septic material as possible, and to draw a free flow of lymph from the walls of the wound.

The Immediate or Ultimate Closure of Certain Types of Wound by Primary or Secondary Suture.—There are certain types of wounds in which the infection may be slight, and which readily lend themselves to one of these two methods of promoting healing, which are more rapid than that of allowing them to granulate in.

Furthermore such treatment is important from an economic point of view as regards time of healing and the condition of the wound when healed. The wounds which best lend themselves to this method of treatment are the so-called gutter or furrow wounds, where the soft tissues are perforated and a considerable part of them carried away, and there is an extensive wound with widely gaping edges. Some of these wounds may involve only skin and superficial fascia, while others may be more extensive and will involve deep fascia and muscles. Such wounds if allowed to close in by granulation may cause considerable impairment of function of the parts involved, together with resultant painful and adherent scars which may be a source of considerable irritation, especially if they be so located that they can be traumatised by pressure or by the rubbing of clothing or equipment. Again, such wounds if allowed to close in by granulation may take many weeks in which to heal, whereas, if we are able to approximate the torn edges, the resulting scar is much smaller and the time of healing is much less. We also eliminate to a great extent the possibilities of contracture. We find gunshot wounds in war surgery which lend themselves to this form of treatment, and the results obtained seem to justify the procedure. Two methods of treatment have been advocated, viz.—

(i) Excision and Primary Suture, and
(ii) Secondary Suture.

(i) *Primary Suture.*—Certain types of furrow wounds lend themselves very readily to primary suture, and this is seen best in those wounds which have occurred within a relatively few hours, and where the inflammatory process has not extended into the adjacent tissues and consequently there is no inflammatory induration around the wound. Furthermore certain wounds, while having a large external gap, have relatively little loss of tissue, as the gaping is caused by the contracture of the separated muscles rather than by loss of tissue. Such wounds as these may be incised and sutured in layers, and, if the edges can be approximated without much tension, primary union may be secured in practically all cases. In certain cases where the wound is deep, approximation of the deeper layers may be difficult, in which case it will be necessary to introduce a drain for a short time.

The technique which we use at this hospital is that which has been described by Colonel Gray (6), who advocated this treatment in November 1914; and it may be as well if I quote what he has to say on the subject, as well as his technique:

"The mere length of a wound is no bar to operation. Some very long wounds have been excised. A missile may inflict what resembles an incised wound, but, by dividing the tissues at right angles to the line of their greatest tension, may, owing to the contractility of these tissues, cause a large gaping wound. In such cases there will be little tension when sutures are inserted and tied, if too great a mass has not to be excised. One can test roughly what the amount of such tension will be by attempting to push the surfaces of the wound together.

"It is not necessary to wait until the wound is surgically clean—in fact, in most cases the sooner the excision is made the better. The wound will probably be soundly healed in a shorter time than it will take to clean. During the 'cleaning' process the adjacent parts become so softened that sutures do not hold well. Only when a large 'bank' of inflamed tissue surrounds the wound is immediate excision inadvisable on account of the septic condition of the wound. In such cases it is probable that organisms have penetrated to a considerable depth, and will cause trouble when the tissues invaded by them are subjected to the pressure of sutures. By vigorous 'salting' (hypertonic treatment) such wounds are usually rendered suitable for excision in twenty-four to forty-eight hours.

"Other contra-indications are the presence of marked pocketing in the wound and the exposure of vascular or nerve trunks in the depth or of bone which it is inadvisable or impossible to remove.

"In any case excision of the soiled edges of skin and of the superficial connective tissue and muscle may be done with advantage. The healing process in the wound as a whole is thereby accelerated. Certain bony prominences—such as a vertebral spine or the edge of the acromion process—may be capable of removal with the other infected tissues.

"The presence of pocketing in a wound is very important. If part of such a pocket, or, indeed, if any septic focus be left, the operation will probably prove a failure. The technique is therefore very important. The operation can usually be done under infiltration anæsthesia of the neighbouring parts. It is well to add plenty of adrenalin to the anæsthetic solution, so that hæmorrhage during the operation is avoided. Accurate hæmostasis is important for success. The parts around are shaved and disinfected very thoroughly. The wound is wiped out, dried, and packed with gauze.

"For disinfecting purposes in these cases I favour the use of very strong iodine solution (5 to 10 per cent. in spirit or ether). This is painted thoroughly into every part of the wound and over the surrounding skin for a considerable area. It has the effect of drying the surface of the wound in a remarkable manner. The strong iodine is wiped off the skin with spirit or ether at the end of the operation.

"The skin close to each extremity of the wound is caught up by tissue forceps or a loop of thread, and slight traction is made in a direction away from the centre of the wound at an angle of about 45 degrees with the sound skin. The whole wound is then cut away *en masse* (skin, flesh, and, if necessary, bone) at a distance of about one-third to half an inch from the raw surface. Care must be taken that pockets or general surfaces of the wound are not cut into during this procedure. Bony prominences are removed along with the soft parts by dividing them with bone-pliers, gouge-forceps, or chisel.

"If the wound is deep, it is sometimes of advantage to insert the finger into the wound as a guide to where the tissues must be divided.

"A very sharp scalpel is invaluable. Cutting out the wound in pieces makes success precarious.

"The new wound surfaces should now be washed with saline solution and packed with gauze, and the surrounding skin wiped free of blood or discharge.

"Fresh towels, fresh instruments, and, if the wound has been handled, fresh gloves should now be used. The wound should be closed by wide sutures which underrun its floor, so that no dead spaces are left. It may be necessary to suture in layers. If so, the suture of each layer should include some of the tissue of the deeper layer. The skin should be accurately approximated by a few fine sutures. Further relaxation sutures are not often necessary

"The following dressing should then be applied. The line of sutures and the adjacent skin for several inches should be painted with a wound varnish, of which mastic, dissolved in some rapidly evaporating solvent, forms the important part (40 to 50 per cent.). When the varnish has become 'sticky' (after one and a half to two minutes), a covering of gauze, at least two layers thick, should be stretched tightly and smoothly over the sticky area, gently patted down, and cotton wool and bandages applied fairly firmly. If it is desired to inspect the wound at any time, after removing the bandage and wool, the top layer, or layers, of gauze should be peeled off by traction at right angles to the surface, the layer next the skin and wound being at the same time retained by the other hand. Perfectly satisfactory inspection can be made through the single layer of gauze. The loose edges of the gauze should be neatly trimmed.

"In many cases no further dressing is required until the stitches are to be removed. The final layer of gauze is then peeled off.

"If fine catgut sutures have been used for the skin, it is often found that the knots come away with the layer of gauze, the deeper parts having been digested. A fresh application of the mastic varnish and gauze should then be made and left until the wound is firmly healed.

"The varnish should on no account be painted over the gauze after it has been applied, otherwise the gauze cannot be peeled off as described.

"The varnish and gauze dressing is important for success. It is the best I know. It gives wide support, relieves tension, and prevents any dragging on the stitches. These factors are of great value in preventing stitch abscess."

The only difference between our technique and that which Colonel Gray uses is in the dressing, for whereas he applies a varnish, we use an alcohol dressing held in place by long strips of adhesive plaster, which act as supports to the tissues and also tend to relieve any tension about the wound.

(ii) *Secondary Sutures.*—Infected wounds and wounds where there is much sloughing of tissue, or where there is much inflammatory reaction about the edges, do not lend themselves readily to primary suture, and it is in such wounds as these that we get the best results with the so-called secondary sutures, or that suturing after the wound has become relatively free from infection. When such wounds are first seen it is essential that there should be a general cleaning up; the patient should be etherised, all sloughing and necrotic tissues removed, and the wound dressed with hot fomentations and irrigations of hypertonic solution to aid in overcoming the infection, and also to aid in the resolution of the inflammatory process of the induration about the wound. Later, when the tissues have become clean and the granulations are bright and healthy, a secondary suture may be done. Whether or not a wound is free enough from infection to suture is best determined by making smears from the exudate from the granulations, which can be done by applying a cover glass direct to the granulations and then staining the smear thus made in order to determine the relative proportion between the leucocytes and the bacteria present. When the wound becomes nearly free from bacteria and there is a large proportion of leucocytes present, secondary suture can be undertaken, and this is usually a few days after the extensive suppuration has subsided.

In certain wounds we find that the edges cannot be approximated very readily without undue tension, and in such cases as these a plastic operation is preferable, as is illustrated in Cases 2 and 3 given below.

The technique which we use at the American Women's War Hospital is as follows :

After the patient is etherised, the skin surrounding the wound is thoroughly cleaned with ether and iodine and the wound itself prepared in a similar manner ; the edges of the wound are then excised, exuberant granulations are curetted away, and the skin undermined far enough to allow of approximation of the edges ; ends of muscles and the edges of the fascia have all loose or frayed portions removed and are then approximated loosely with catgut. Skin edges are held together by means of several mattress tension sutures of heavy silk and short pieces of rubber tubing or gauze placed under the ends of sutures to relieve undue pressure on the skin. Tension sutures are placed as far back from the skin margin as possible, and the skin edges between the tension sutures sutured with horsehair or silkworm gut. Drainage is established either by means of a small drain of gauze or rubber dam from the lower border of the wound or by making a couple of stab wounds at the margin of the undermined skin flaps, and even though the wound be moderately infected, it heals very rapidly. Tension sutures are not left in any longer than

A *B*

Fig. 24. Shows shell wound of gutter type of left shoulder. *B* shows the result two weeks after being sutured. Small areas on either side of incision are due to pressure from tension sutures.

is absolutely necessary, on account of causing superficial sloughs in the skin, but as soon as the flaps have become adherent the sutures are removed and tension relieved by adhesive straps.

FIG. 25. This case is referred to in Fig. 10, and shows the result after the wound of right upper arm had been excised and a plastic operation performed. Photo taken four weeks after operation.

To reiterate, the following are important points to be borne in mind :

1. Secondary sutures of extensive wounds should be done in all cases where there is much loss of tissue.

2. Wounds should be thoroughly cleaned and healthy granulations allowed to appear before any operative procedures for closure are instituted.

FIG. 26. Shows grenade wound of left buttock. Tuberosity of ischium may be seen just below angle at right of picture. Operations were performed in gradual stages and the final result is shown in the lower photograph.

3. Stained smears should be made from the exudate every few days, to determine at what time the wound becomes ready for operation.

4. Small gauze or rubber dam drains should be inserted either at the lower angle of the wound or by counter incision on border of undermined skin flap.

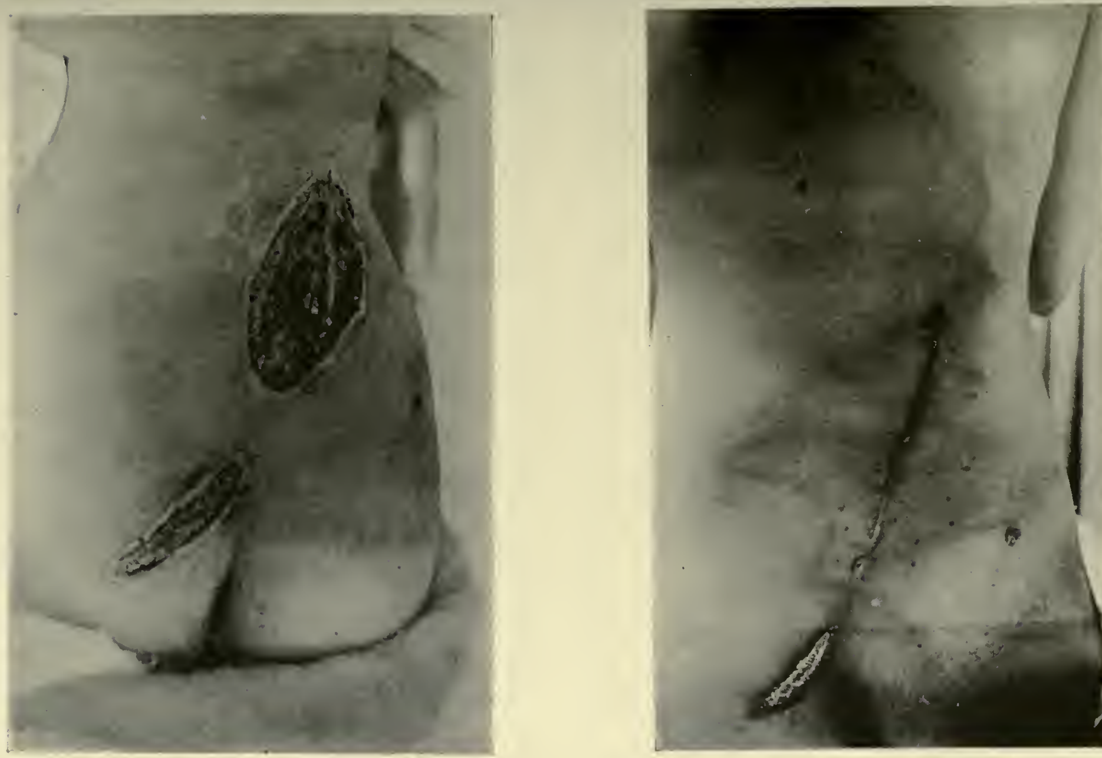
5. Tension sutures should be removed as soon as possible.

The following cases illustrate this procedure:

Case 1.—Fig. 24, A, shows a rather extensive shell wound of left shoulder, scapular region, extending down through fascia and muscles. Wound at time of entrance rather dirty, with considerable sloughing tissue, which was removed and wound was dressed with hot hypochlorous dressings every four hours. A week later wound was sutured and three large heavy tension sutures put in to approximate skin. This wound was entirely healed, as is shown in Fig. 24, B, ten days later, except for superficial sloughing areas where rubber tubing had been placed under the tension sutures. Patient sent to convalescent home and returned to duty a month later with wound healed, no impairment of function and no pain.

Case 2.—Fig. 25 shows a perforating bullet wound of back with a gutter wound on posterior surface of right upper arm, extending down to and severing some fibres of triceps (see Fig. 10). This wound was excised about two weeks after entrance, and the result one month after operation is shown in Fig. 25. No impairment of motion, no loss of flexion or extension.

Case 3.—Fig. 26 shows an extensive grenade wound of left buttock entering just posterior to great trochanter, destroying a large part of the gluteus maximus and also exposing the tuberosity of the ischium, which is seen just below the outer upper angle of wound in Fig. 26, A. This wound extended on to the perinæum, and carried away tissue for nearly half-way around the anus. Operation one week after admission — edges of wound trimmed



A B

FIG. 27. *A* shows gutter shell wound of back ; and *B* shows result three weeks after secondary suture.

and skin undermined, and edges approximated as far as possible. Three weeks later the patient was operated upon again, and skin edges still further approximated. One month later a third operation was done, when complete closure was made. Photograph of result (see Fig. 26, B) made one month after last operation shows only linear scars, except just at the border of the perinæum, where there is a small area of cicatricial tissue. Patient able to move round and sit down without discomfort, and was discharged to convalescent home six weeks after the last operation.

Case 4.—Fig. 27, A, shows a deep shell wound of the back, involving skin and deep fascia and muscles. Fig. 27, B, shows the result three weeks after operation.

III. Infection by B. Perfringens

As has already been shown, the *B. perfringens* is found in a considerable proportion of gunshot wounds, though it may not necessarily give rise to any clinical evidence other than that of ordinary sepsis; but this is uncommon, and wounds so infected usually show characteristic signs which it is important should be recognised early.

Diagnosis of B. Perfringens.—As every infected wound presents the possibilities of being contaminated by anaerobic organisms, a bacteriological examination should be made in every instance where possible; smears should be taken, stained, and examined, and the pus or discharge from the wound planted on culture media for the growth of the pyogenic and anaerobic organisms. The lack of a bacteriological examination, however, should not deter us from treating in a radical manner all wounds which we suspect may contain *B. perfringens*, even though the characteristic signs may be lacking; for it is far better to treat such wounds by radical measures in the beginning than to treat them conservatively on the assumption that the *B. perfringens* may not be present, and then later find the organisms in the wound, and that grave constitutional symptoms are developing.

The characteristic signs on which to base the diagnosis of gas bacillus infection are the following:

The wounds present a dirty and sloughing appearance; there is a dirty sero-purulent exudate; the wound has a peculiar fæcal-like odour; if the infection be not local there is crepitation in the skin, and also bubbles of gas may be expressed from the wound itself. The surrounding tissues are reddened, œdematous and tender, and show all the signs of a cellulitis. Again, the general condition of the patient is a good index of the severity of the toxæmia, and we may see cases in which the toxic symptoms are out of all proportion to the apparent severity of the wound. The temperature becomes constantly elevated, the pulse weak and rapid, the skin cold, pale and clammy. Delirium occurs, and in the most severe types death soon supervenes.

As we have already shown—and it is a point which should be re-emphasised—wounds infected by *B. perfringens* may be divided into three groups. The recognition of this is important, as it determines to a great extent the method of treatment to be followed. The groups are as follows:

(i) Those wounds in which the infection is purely local, and which may be recognised by bacteriological examination, by the dirty appearance of the wound, and by the characteristic odour.

(ii) Wounds which show evidence of a spreading cellulitis together with the other characteristics of the infection, and when toxic symptoms are present.

(iii) Wounds in which there has been some disturbance of circulation, such as the severing of an artery and the consequent devitalisation of the parts. We have here all the same signs, but greatly intensified, and the constitutional symptoms are severe. It is in such cases as these that we find the typical gas gangrene.

Treatment of Wounds infected by B. Perfringens.—In all cases where we suspect this organism, or which show signs of infection by the *B. perfringens*, we must realise that in order to prevent a rapid spreading of the infection we must adopt radical measures. The patient should be etherised, the skin surrounding the wound shaved and cleaned with ether and then painted with iodine. If the wound be large, open and sloughing, all traumatised and necrotic tissues should be cut away, the wound swabbed out with carbolic acid, followed by alcohol, or else with iodine, and hot wet dressings of hypochlorous acid solution or chlorinated soda applied. Where there is evidence of a cellulitis, all infected tissues should be freely incised and the original wound opened wide; all wounds should be left open and drained either by means of rubber tissue, rubber tubes or gauze, and the same dressings applied as before.

In extensive wounds of the legs or arms where there has been a disturbance of the circulation and a consequent devitalisation of the parts, a rapid amputation should be done immediately, preferably by the circular method, and the wound left wide open.

It is important that in all wounds infected by anaerobic organisms there should be free exposure in order that the tissues may become well oxygenated, thus destroying the organisms which are unable to live in aerobic conditions. Often peroxide of hydrogen may prove efficacious in treating these wounds, but it has been found that free incision and drainage followed by constant bathing with hypochlorous acid give excellent results as regards ultimate cure and the destruction of the infection.

Fraser and Bates (7) advocate in the acute toxœmia accompanying infection by *B. perfringens* the use of 0·5 per cent. hypochlorous acid injected intravenously. This method of treatment is used principally in the more severe forms, and as an adjunct after surgical procedures have been instituted and free drainage or amputation has been performed. They advocate the use of from 40 c.c. to 100 c.c. of 0·5 per cent. of hypochlorous acid, to which is added 8·5 grams sodium chloride per litre. The solution is carefully strained and sterilised before use, and is injected by means of a Record syringe into the median basilic vein. Fraser and Bates report a series of cases in which this method of treatment was followed out with an immediate improvement in the condition of the patient.

The comparative values of the use of the hypertonic saline solutions or of hypochlorous acid as dressings in the treatment of gas infection is still a much debated subject, some writers claiming better results with one solution and others with another. However, our own experience at the American Women's War Hospital with this type of infection has led us to believe that better results are obtained by constant irrigation with hypochlorous acid in the early stages, and later, when the wound has somewhat cleaned up and the infection has subsided, by using the saline solution. But the main point in these infections seems to be an early and free incision, which will allow of efficient drainage and exposure of the deeper tissues to the air.

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CHAPTER VI

FOREIGN BODIES—DIAGNOSIS, TREATMENT, LOCALISATION

Foreign Bodies :
  Projectiles.
  Clothing.
Diagnosis—Treatment.
Removal of Foreign Bodies—Localisation.

Foreign bodies which are found in wounds are of a variety of types. They may be bullets either whole or separated, as, for instance, the jacket or the lead core alone, or disintegrated fragments, or they may consist of shell fragments, shrapnel bullets, portions of clothing or equipment

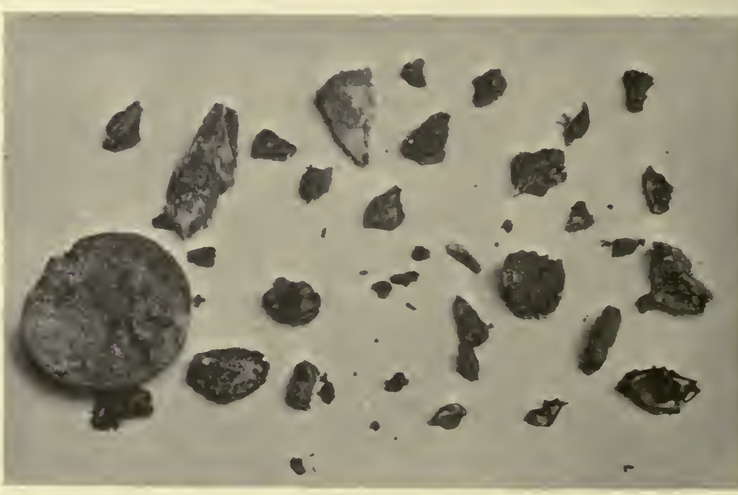

Fig. 28. Shows fragmentation of shell, and also casing from bullet. All these fragments were removed from one patient, who ultimately recovered.

such as leather or buttons, articles carried in the pockets and driven into the tissues by the projectiles, and frag-

FIG. 29. Shows large shell fragment lying in upper part of thigh. X-Ray also shows fracture of pubis.

ments of wood, stones, and earth from mine explosions or from a shell striking a building and detaching and projecting into the tissues portions of the wall.

Bullets, shell fragments, and shrapnel bullets, as well as portions of clothing, are the most common foreign bodies which we find in wounds, and they are usually found in the non-perforating or cul-de-sac type, although we occasionally find them, especially clothing, in perforating

Fig. 30. Shows shell fragment in thigh.

or Seton wounds. The variation in the forms and shapes of projectiles found in wounds is of extreme interest to the military surgeon.

Shell Fragments and fragments from bombs and grenades undergo no change after entering the tissues, but, owing to

FIG. 31. Shows shell fragment in calf of leg.

FIG. 32. Shows small shell fragment lying between radius and ulna, and also two small fragments over cuneiform.

their solidity, are found in the shapes which they assumed when the shell or grenade exploded, and such fragments may be found in the tissues as large irregular pieces of

Fig. 33. Shows fragments from a German hand grenade as revealed by the X-Ray of patient's leg.

metal (Figs. 28, 29, 30, 31, 32, 33), pieces of time fuse or even in some instances the complete fuse itself, or as minute particles which cannot be felt and which are only discernible, as a fine metallic spattering in the tissues, by means of a radiographic examination (Fig. 34).

Shrapnel Bullets.—These consist, as has already been shown, of hardened lead, and oftentimes they are made in

Fig. 34. Shows grenade wound of arm, the larger fragments being a part of the container. There is much destruction and comminution of the humerus. The drainage tubes may be seen in place. Considering the amount of destruction a considerable degree (50°) of motion was obtained.

two parts which are fused together. The changes therefore which they undergo are numerous, especially when they are arrested by bone. The bullets become flattened

(Fig. 35), deformed (Fig. 36), split (Fig. 37), and sometimes partially or completely disintegrated, and the various shapes they assume are well shown by the X-Rays, as well as the fine spattering of lead which separates off and which is left in the tissue adjacent to the track (Fig. 38).

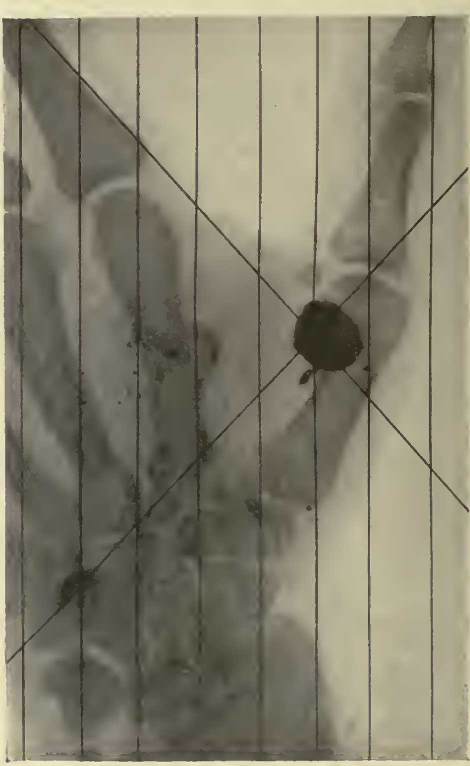

Fig. 35. Shows deformed shrapnel bullet in hand. Over metacarpal of index finger may be seen a few small fragments which have separated off.

Rifle Bullets.—These may be retained in the tissues in an undeformed state (Fig. 39, A), or, owing to the fact that they meet with some obstruction, either by striking from the ground or coming in contact with some solid substances

FIG. 36. Shows deformed shrapnel bullet with one small piece separated off at the middle of shaft at the ulna.

FIG. 37. Shows shrapnel bullet which has become segmented and partially disintegrated.

FIG. 38. Shows large shrapnel bullet with some small pieces of lead in the tissues.

such as bone, may become deformed in a variety of ways. They may become flattened or the point may be curved (Fig. 40), the lead core may be partially (Fig. 39, B) or wholly extruded and may remain in the wound (Fig. 41),

Fig. 39. *A* shows undeformed rifle bullet lying in the tissues. *B* shows rifle bullet which has become flattened, and at upper edge the lead core may be seen slightly protruding.

or may pass through and the case alone remain (Fig. 42), or the lead core may sometimes be found in wounds, while the casing may not be found. Bullets may also become separated and broken or fragmented (Fig. 43), and also completely (Figs. 44 and 45) or partially (Fig. 46) disintegrated by striking some solid substance (Fig. 47).

Clothing.—Clothing found in wounds may be made up of a mass of large pieces or of many smaller pieces or even

Fig. 40. Shows rifle bullet which has become deflected and the point bent and which is lying in the tissues in the reversed position.

filaments of cloth. Clothing is not found in cul-de-sac wounds which have been caused by sharp-pointed bullets striking point on, as the cloth does not appear to adhere to the smooth surface of the bullet, but is wiped off as the projectile passes through the external tissues. On the

Fig. 41. Shows deformed lead core of rifle bullet lying just under osalcis. Bullet removed.

Fig. 42. Shows casing of a bullet from which the core has been expelled, lying embedded in the muscles of the forearm.

other hand, bullets deformed from ricochets, or which strike the tissues obliquely or transversely, carry in with them portions of clothing. Shrapnel bullets, owing to their larger diameter, and also shell and the larger grenade

Fig. 43. Shows a rifle bullet which has become divided into two portions, and which has caused fracture of the head of the humerus. Case described in text under Joint Injuries.

fragments which are rough and irregular in size and shape carry considerable detritus in the shape of clothing before them into the wound.

Diagnosis.—The presence of foreign bodies must be suspected in every case where we find only one wound, even though that wound be healed. In certain instances, where the missile has not penetrated deeply into the tissues, it may be felt as a hard movable mass, not necessarily tender, and, in the case of aseptic wounds, there is very little induration of the adjacent tissues.

As has been shown, wounds caused by undeformed

Fig. 44. Shows effects from a completely disintegrated rifle bullet. Bullet passed through the phalanges of the 1st and 2nd fingers of right hand, struck the butt of the rifle, became completely disintegrated, and entered soft tissues of left hand. General fine spattering of lead is well shown.

bullets, and sometimes by shrapnel bullets and the smaller shell and grenade fragments, may give rise to no symptoms and heal aseptically, and the projectile may become encapsulated and remain as an inert foreign body. Again, we may have an indurated, tender, swollen, and sometimes reddened area about the wound, and in such wounds we always find a foreign body which is not being tolerated, and which is acting as an infecting agent. This may be either a deformed bullet, a shrapnel bullet, or shell or grenade fragment, together with portions of clothing.

Fig. 45. Shows complete destruction of rifle bullet on striking the femur, also marked destruction of femur.

Clothing alone is not usually found in a wound, but generally adheres closely to the missile causing the injury.

The presence of metallic foreign bodies can always be shown by fluoroscopic or radiographic examinations, and one or the other should always be made in every instance of suspected foreign body.

Treatment.—The question as to whether or not metallic foreign bodies should be removed is a much-discussed one, but certain general principles should govern the treatment:

Metallic bodies in the soft tissues, if not in the region of blood-vessels, joints, or nerves, may be tolerated in the case of aseptically healed wounds. One must also be

Fig. 46. Shows the core of a rifle bullet which has entered the foot and become partially disintegrated, and is embedded in the plantar muscles.

governed by the location of the missile and whether more trauma will be caused by operative interference than if the projectile were not disturbed. In infected wounds a metallic foreign body always acts as an irritant and is not tolerated, and therefore it should always be removed.

The principles which govern us in our treatment as regards foreign bodies may be summed up as follows:

(1) Missiles in infected wounds should always be removed.

(2) Projectiles in regions of nerves, vessels, or joints, or

FIG. 47. Shows rifle bullet which has passed through and fractured the humerus and has left the lead core along its track. The distorted casing may be seen lying over the ribs.

which cause impairment of function or pain should be removed.

(3) Missiles which are not tolerated and which give rise to mechanical irritation should be removed.

(4) Bullets which are tolerated, give rise to no pain, and

are so situated that trauma caused by operative procedures might cause more impairment of function than if the bullets were left in the tissues, need not be removed.

(5) Large shell fragments should always be removed, as these are always associated with contaminated matter in the wound, and apt to give rise to severe septic processes.

(6) The same principles which govern us in regard to rifle bullets may be applied to shrapnel bullets, bearing in mind, however, that shrapnel bullets are very apt to be associated with infected detritus such as clothing.

(7) Small shell fragments, if difficult to find and well tolerated, need not be removed.

(8) Foreign bodies just under the skin may be removed.

These, then, in a general way, are the principles on which we should base our treatment as regards the removal of foreign bodies, and furthermore one must always bear clearly in mind the fact that, although a bullet or other missile may be seen clearly in the radiographic picture, it is not necessarily easy to locate, and often the tissues will be unnecessarily traumatised by hunting for the projectile. It is safe to say that no operation for the removal of foreign bodies be undertaken on the data furnished by a single plate taken only in one plane; it is absolutely essential that at least two plates should be taken on planes at right angles to one another, and also that the missile should be carefully localised by means of a fluoroscopic examination before any operative procedures are instituted.

Localisation.—The localisation of foreign bodies is most important from a surgical standpoint, and most essential to the surgeon who undertakes the operation for their removal, for if the missile be not properly localised, the operation may be unnecessarily prolonged, and undue trauma inflicted on the tissues while searching for the foreign body.

It is not within my province here to describe in detail the various methods used in the localisation of foreign bodies, as these have been worked out by men more qualified to speak on the subject than I am, but it will suffice to say that the method which we use in this hospital is one which recommends itself by its simplicity, and is also one by means of which accurate localisation can be obtained. It is a method which was taught me by Dr. Walter Dodd of Boston, Mass., and requires no complicated apparatus, the only implement outside of the fluoroscopic screen and

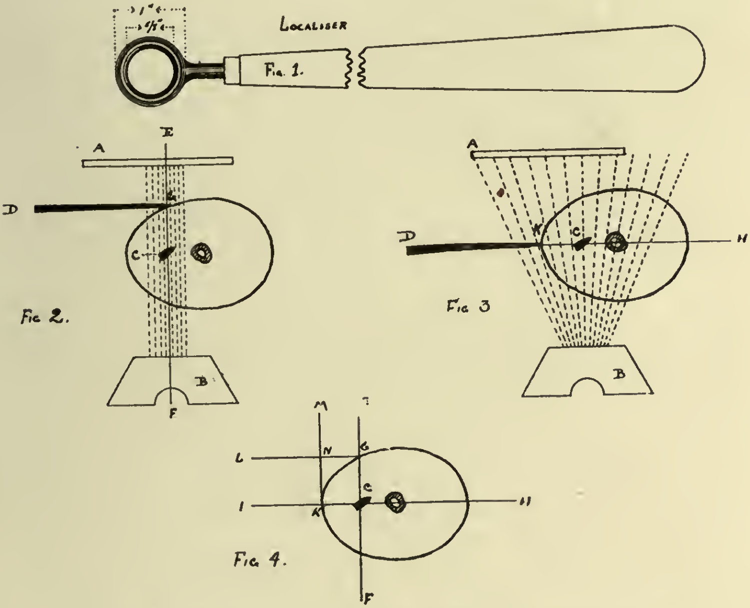

Fig. 48. Plate to illustrate the localisation of foreign bodies. Described in text.

the X-Ray outfit being a ring localiser (Fig. 48, I), which can be very easily made by means of a screw eye with an inside diameter of ½ inch, fastened to a wooden handle about 14 inches long. The patient is placed on the X-Ray table with the tube underneath, and by means of the fluoroscopic screen the region of the foreign body is located. The diaphragm in the tube box (Fig. 48, 2 B) is then closed down, so that we get an aperture only 1½ to 2 inches in diameter, and the tube carrier is moved so that the foreign body C will be in the exact centre of this illuminated space and the rays therefore, which pass through the tissues and illuminate the screen, will be essentially parallel. The ring of the localiser D is then placed exactly over this foreign body, the fluoroscopic screen A is removed and the point G marked on the skin with a pencil or by some other means. We then know that if we draw a perpendicular line EGF straight through the tissues at this point, the foreign body will lie somewhere along that line.

The next step is to locate the depth of the metallic body (Fig. 48, 3) and this is done by again using the screen A and also our ring localiser D; in this instance the diaphragm of the tube box B is opened up, so that we get more illumination. We next place the localiser so that the ring just touches the skin, and as we look through the screen we get two shadows, that of the foreign body (C) in the tissues, and that of the metallic ring of the localiser. We now move the tube along its traveller backwards and forwards, at the same time watching the shadows of the localiser and of the foreign body, and we shall see that, owing to the displacement of the tube, the two bodies move at rates which are not synchronous. Either the ring will move faster than the foreign body or vice versa. We therefore either by raising or lowering the ring move it until a point is reached at which, as the tube is moved, both shadows move synchronously. We now know that the ring of our localiser must be on the same plane as is the foreign body, and this point K should be marked on the skin.

(Fig. 48, 4.) We now have two points from which to calculate the position of the foreign body—our first line EGCF dropped perpendicularly, which passes through the foreign body, and our second line IKCH drawn at right angles from the point last localised, and the junction C of these two lines gives us the exact point at which the foreign body rests. When these two points have been obtained, therefore, it is easy to locate the exact position and depth of any foreign body.

If from point G a line LG be drawn at right angles to EF, it will be parallel to the line IH, and if we draw from point K a line MK parallel to EF it will be at right angles to LG and IH, and we have therefore constructed a rectangle by means of which we can obtain our measurements for ascertaining the depth at which the foreign body lies in the tissues. The line NK, which is the same as GC, will give us the antero-posterior depth of the foreign body; and the line GN, equal to the line CK, will give us the lateral distance.

This method we use entirely at the American Women's War Hospital, and have found to be very satisfactory and simple, and all the foreign bodies we remove are first localised in this way.

CHAPTER VII

WOUNDS OF JOINTS

Types of Wounds—Treatment.

GUNSHOT injuries of the joints form one of the most important types of injury seen in warfare, not so much on account of any fatality which may attend them, but principally on account of the associated disability which may follow from such an injury. In all the wars previous to the introduction of small-calibre and high-velocity projectiles, wounds of the larger joints were an extremely grave condition. In these times, owing to the less severe damaging power of the modern rifle bullet, and with our present-day knowledge of asepsis, such wounds present a smaller proportion of fatal results than was seen with the old type of armament.

This is perhaps best shown by the following tables taken from Borden (1):

PERCENTAGE MORTALITY FROM WOUNDS OF THE JOINTS IN FIVE WARS

Joint.	American Civil War.	Franco-Prussian.	Japan-China (Haga).	Spanish-American.	Anglo-Boer War.
Hip . . .	84·7	71·8	100·0	33·0	28·5
Knee . . .	53·7	48·9	25·0	5·5	4·2
Ankle . . .	26·9	24·0	0·0	0·0	0·0
Shoulder . .	31·1	35·5	0·0	0·0	3·7
Elbow . . .	9·4	21·2	0·0	0·0	2·0
Wrist . . .	12·9	12·6	0·0	0·0	0·0

Cases and Deaths in Each Class of Joint Wounds in Three Recent Wars

Joint.	Japan-China War (Haga).		Spanish-American War and Philippine Insurrection.		Anglo-Boer War.	
	Number.	Deaths.	Number.	Deaths.	Number.	Deaths.
Hip	1	1	3	1	7	2
Knee . . .	16	4	77	2	95	4
Ankle	4	0	26	2	40	0
Shoulder . . .	4	0	9	1	27	1
Elbow . . .	16	0	44	1	49	1
Wrist . . .	6	0	6	0	10	0
Total . . .	47	5	165	6	228	8
Mortality, per cent. .	—	10·6	—	3·6	—	3·4

It must not be inferred from this, however, that injuries to the joints, even in these days, are not associated with severe and frequently grave results, and this is especially so in those wounds which are caused by shell or grenade fragments, by shrapnel bullets, and by deformed and deflected rifle bullets. Such wounds, owing to the nature of the projectile, are especially prone to infection, and this, as well as the type of injury inflicted by such a projectile, gives rise to some of the most interesting problems not only as regards immediate treatment, but also as to the methods of obtaining the best functional results.

Wounds involving the regions about joints present the same general considerations as do wounds in other parts of the body, and we find, as with other wounds, that the severity of the injury depends upon the size and shape of the projectile and the force with which it strikes the tissues, and also upon the amount of contaminated matter which is carried into the periarticular tissues and into the joint cavities by the projectile causing the wound. Wounds of the joints may be caused by any type of projectile, which may simply penetrate the joint cavity or may perforate it. We also find fissures extending into the joints from fractures of the diaphysis ; also grooves and erosions of the articular surfaces as well as comminutions of the whole joint surface.

Injuries involving the joints may, therefore, be divided as follows:

1. Wounds involving the periarticular tissues without injury to the synovial membrane.

2. Injuries involving both the periarticular tissues and the synovia.

3. Perforating wounds:
   (*a*) without bone involvement,
   (*b*) with involvement of one or more of the bones forming the articulation.

4. Penetrating wounds associated with a lodged foreign body:
   (*a*) without bone involvement,
   (*b*) associated with a fracture of one of the bones forming the articulation.
   (*c*) with the projectile lodged in one of the articular surfaces.

5. Extensive comminution of the articulation.

Before considering these various types of wounds it may be as well to mention one other form of injury which is described much in detail by Makins (²) and to which he has given the term *vibration synovitis*. This condition is described by him as "The occurrence of considerable synovial effusion into the joints of limbs in which the articulation was primarily untouched. These effusions sometimes occurred even when the soft parts alone were perforated, especially when the wounds were situated above or below the knee joint. They were apparently the direct result of vibratory concussion of the entire limb dependent on the blow received from the bullet." Personally I have never seen such a condition at the American Women's War Hospital, as all the cases which have presented an effusion in the joint have also shown some bone injury, or else some involvement of the synovial membrane itself, or of the periarticular tissues.

We shall now consider the various types of injuries which we have already classified.

1. **Wounds involving the Periarticular Tissues without Injury to the Synovial Membrane.**—Such wounds consist essentially of injuries to the integument, and are usually due to erosions or furrows by bullets or by small shell or grenade fragments, to lacerations by larger shell fragments striking tangentially, and to small penetrations into the skin by small shell or grenade fragments.

Such wounds may be considered as wounds of the soft parts alone, when any injuries to the joint membrane or to the joint surfaces have been excluded by careful physical examination and by means of the radiographic picture.

2. **Injuries involving the Periarticular Tissues and the Synovia.**—In certain instances the projectile causing the injury may penetrate the skin, and also cause a small laceration or perforation in the synovial membrane. Such wounds may be caused by tangential or direct wounds from bullets travelling at a low velocity, by shell or grenade fragments, which lacerate both the superficial tissues and the tissues surrounding the joint.

Again, there may be instances where a small projectile penetrates through the skin, and causes a simple contusion of the synovial sac. In such injuries as these we find an effusion into the joint, sometimes containing a small amount of blood from the injury to the sac wall.

3. **Perforating Wounds:** (a) *Without Bone Involvement.*—Occasionally projectiles such as a rifle bullet may pass completely through a joint, especially the knee and shoulder joints, without causing any material injury other than to the synovial membrane. In the knee such wounds are caused by the bullet passing under the quadriceps extensor tendon or the patella and involving the upper part of the synovial sac, and in the shoulder, where there is a loose capsule, a space is left between the glenoid cavity and the head of the humerus through which the bullet passes.

(b) *With Involvement of One or More of the Bones forming* *the Articulation.*—Sueh wounds are usually eaused by bullets, and the injuries to the bones eonsist of eontusions or erosions of the eartilaginous surfaee ; or we may get more extensive injuries eonsisting of grooves or furrows on the artieular surfaees, as well as perforations through one or other of the epiphyses, with fraetures into the joint eavity. The wound of entranee is small, and the wound of exit may be small or may be slightly larger owing to the propulsion of the bone fragments through the tissues.

Sueh wounds may heal without giving rise to any signs of infection, but, on the other hand, and more espeeially in those wounds where there is a groove of the artieular surfaee there is mueh more danger of infeetion, as we often find that in sueh wounds the wound of injury is not a direet but a tangential one with a larger wound of entranee ; and, furthermore, there is usually assoeiated with this an extensive laeeration of the synovial sae. The more extensive skin injury and also the more extensive injury to the synovial sae invite the establishment of infeetion.

4. **Penetrating Wounds associated with a Lodged Foreign Body:** (a) *Without Bone Involvement.* — Oeeasionally we see injuries to joints where the projeetile enters the synovial sae and remains lodged in the joint eavity without eausing any gross lesion to the artieular surfaees. Sueh wounds may be eaused by rifle bullets with a low remaining veloeity, by shrapnel bullets, and by small shell and grenade fragments. In sueh eases the wound in the synovia may be a small perforation or it may be a laeeration—depending upon the size and shape of the projeetile eausing the lesion. In sueh wounds the dangers of infeetion depend upon the size of the external wound, the amount of injury to the synovial sae, and the size and shape of the projeetile eausing the injury, together with the amount of infeeted material whieh may be earried into the joint.

(b) *Associated with the Fracture of One of the Bones forming the Articulation.*—Sueh wounds may be eaused by rifle bullets, by shrapnel bullets, or by shell or grenade fragments, and consist of grooves or erosions of the articular surfaces, or of a varying degree of comminution of the bones entering into the formation of the joint. These wounds may also be caused by the projectile striking the epiphysis near the articular surface, and dislodging and projecting into the joint cavity fragments of bone.

(c) *Projectile lodged in the Articular Surfaces.*—Such injuries are occasionally seen as the result of the projectile, travelling at a low velocity, passing through the joint membrane, and becoming lodged in one or other of the articular surfaces of the joint. Such a type of injury is usually caused by a sharp-pointed rifle bullet.

5. Extensive Comminution of the Articulation. Shell fragments, grenade fragments, shrapnel bullets, and deformed and deflected rifle bullets may cause either extensive destruction or comminution of the bones entering into the formation of any joint. Rifle bullets at proximal ranges also have a marked destructive action on joint surfaces. Owing to the amount of fragmentation of the bones, and also to the amount of destruction not only to the soft tissues, but also to the osseous tissues, such wounds give rise to the greatest dangers from infection, on account of the marked devitalisation of the tissues about and in the joint. Furthermore, the projectiles which cause the majority of such injuries carry in with them a large amount of contaminated matter, which finds a ready field or which to grow in the destroyed and devitalised synovial sac. Further, such wounds offer less chance of a good functional result.

Complications.—We have now considered briefly the various types of injuries to joints which are caused by different projectiles, and we shall now proceed to discuss some of the more common complications which arise as a result of such injuries.

One of the first results to be considered, following an injury to a joint, is that of hæmorrhage. This is especially true of the larger joints of the body—such as the shoulder, the elbow, the hip joint, and the knee—in which regions we find not only the large main vessels, but also the large anastomotic branches, and associated with such injuries we may sometimes find, in addition to the injury to the bony structure, an injury to some of the adjacent blood-vessels. Such injuries may be caused either by the projectile causing the wound or by secondary projectiles, such as spicules of bone which have become detached and projected through the tissues and cause a lesion of the vessels. As a result we may get either a grave or fatal hæmorrhage or the formation of a hematoma and, as a result of the latter, pressure on vessels and nerves. In some cases, as for instance in wounds about the knee joint, we may get the formation of a hematoma in the popliteal space which will occlude the vessels in this region and, if not properly evacuated, may give rise to gangrene of the lower leg.

Injury to nerves is another important factor which must always be taken into consideration with wounds involving the joints; and this is especially true of the shoulder joint with its close association with the brachial plexus, and of the knee with the popliteal nerves lying in close proximity. Wounds of the hip joint, moreover, may be associated with injuries to the sciatic nerve.

Probably the most important immediate complication of any joint injury which we have to consider is that of infection. Infection, as has already been shown, depends upon the size and shape of the projectile inflicting the wound, and upon the amount of contaminated matter which is carried into the wound by that projectile. Furthermore, synovial cavities do not offer a good field for the resistance of bacterial invasion, and such wounds, if not efficiently treated, rapidly become infected—often with dire results to the patient.

Then, too, if the infection be not checked, it may extend and involve the blood-vessels which may already have been traumatised and, as a consequence, we may get a phlebitis or a severe secondary hæmorrhage.

Again, in injury to the bone, whether it be a perforation or a comminution, if infection be present we will find that the joint surfaces become eroded or destroyed from the infection and that cancellous bone itself becomes impregnated with pus and, as a consequence, we may have either complete destruction of the articular surfaces followed by a bony ankylosis, due to septic arthritis, or an osteomyelitis or a necrosis of the injured fragments of bone. The result of all these conditions is practically the same, and ankylosis is always to be expected in such instances.

Diagnosis.—The diagnosis of any injury involving the joint cavity is made on the appearance and location of the external wound, by the direction of the track made by the projectile, and the increased effusion of synovial fluid mixed with blood into the joint cavity.

In the larger lacerated wounds, if there is much injury to the synovial membrane, there will be no increased tension in the synovial sac, but there may be escape of the synovial fluid from the external wound.

In many cases there will be no difficulty whatsoever in making a diagnosis—it will be self-evident—but in many others it may be difficult to determine whether or not a missile has penetrated through the synovial sac. In such cases the diagnosis is easily confirmed by the X-Ray, and the location of the projectile, by means of radiographic pictures taken in two planes, will determine whether or not the joint cavity be involved.

Oftentimes, if the injury be situated away from the knee joint, it may be difficult to determine whether or not the joint is also involved, as sometimes happens owing to a long fissure extending from a distance into the joint. Occasionally these fissures may be determined by X-Ray; at other times the results are difficult to distinguish from a vibration synovitis as described by Makins. All such injuries as the latter are important, especially if the external wound be infected, for it is in such wounds that we get an extension from the external wound into the joint. Following the injury and the presence of the increased intra-articular effusion, there is usually a rise in temperature, which may be due either to the absorption of blood mixed with the synovial fluid, or it may be due to an infection. In the smaller wounds, where the diagnosis is not clear as to injury of the synovium, it is important to determine whether or not this effusion is due simply to the absorption of the blood or to an infection. In such cases a leucocyte count should be made, and the joint may be aspirated and cultures made from the withdrawn fluid. The diagnosis should always be determined as to whether or not the condition is a simple hemarthrosis or whether an infection be present—for the reason that the treatment is determined by the conditions which are found existing.

Prognosis.—In all wounds involving the articulations the prognosis should be carefully guarded, for whereas certain wounds, especially those caused by rifle bullets, may heal aseptically, wounds caused by deformed or deflected rifle bullets, by shrapnel bullets, by shell or grenade fragments, and which are associated with contaminated matter as well as with destruction of bony tissue, are prone to give rise to a severe and sometimes fatal infection.

Function.—In every injury to a joint, where there is much involvement or destruction of bony tissue, and whether or not in such cases infection be present, there is always a resultant loss of motion. This loss of motion may be only slight, or there may be complete ankylosis; and whether or not the loss of motion in a joint is partial or complete depends upon the nature of the injury and whether or not it is a slight fracture into the joint or a complete destruction of the articular ends of the bones forming the joint. It is, therefore, important that in all such injuries we should carefully estimate the extent of the lesion, in order to determine if possible the amount of impairment of function which will result. This is especially important, for if a complete ankylosis is inevitable we must immobilise the joint in such a position as to give the best functional result. The various positions in which joints should be allowed to ankylose will be considered more in detail under the specific headings of the various joints.

Treatment.—The treatment of all gunshot injuries involving joints is of prime importance, not only as regards the immediate effects upon the patient, but also as regards the ultimate functional result. The treatment divides itself into two main phases :

1. Treatment at the Front.
2. Treatment at the Base.

1. *Treatment at the Front.*—In these cases treatment at the front consists essentially of the disinfection of the wounds, control of hæmorrhage, immobilisation of the parts, and the injection of anti-tetanic serum.

Any extensive operations should be reserved for the base, unless there be evidence of a frank and virulent infection or unless there be so much destruction, not only of the bones but of the soft tissues, that there is complete obliteration of the circulation. In such cases the wounds must be adequately drained and contaminated matter removed, and in those cases in which the circulation has been completely cut off, and there is much destruction of tissue, immediate amputation should be done.

2. *Treatment at the Base.*—This is by far the most important treatment, as it determines to a great extent the future usefulness of the joint involved. Furthermore, the lines of treatment that should be followed at the base hospital depend upon the condition of the wound and the nature of the projectile causing the lesion, upon the degree of involvement of the articulations, and whether or not there be any associated contaminated matter and infection.

Treatment at the base, therefore, may be divided into:

(*a*) Conservative Treatment.
(*b*) Radical Treatment.

(*a*) *Conservative Treatment.*—With the present-day type of armament and with our knowledge of asepsis, we are able by means of conservative treatment to obtain results which would have been impossible with former methods and with older types of projectiles. In a large proportion of cases conservative treatment will suffice, and radical methods should not be adopted except as a measure of last resort. In wounds involving the periarticular tissues, excision of the wound, disinfection, and closure by secondary suture will often be sufficient to prevent any extension of the infected process into the joint.

Very small perforated wounds by bullets, even if there be some bone involvement, will often heal aseptically if the wound be thoroughly disinfected and an occlusive dressing be applied, as well as a splint to immobilise the parts.

In the larger lacerated wounds involving the joint capsule, and where there be any bone involvement as well as a retained foreign body, there should be no temporising, but the joint should be thoroughly opened and all contaminated matter and foreign bodies removed, as well as any loose fragments of bone. The joint cavity should then be thoroughly washed out with some antiseptic, the wound in the synovial sac closed, the external wound also closed and a drain inserted down, but not into the joint. Drainage into the articular surfaces means the ultimate destruction of these surfaces and the loss of function.

Excellent results have been obtained by washing the joint cavity out thoroughly with eusol, and then sewing up the capsule. Other antiseptics, however, may be used, such as 1/15,000 corrosive sublimate or even saline solution; but it is important that the irrigation should be carried out long enough to wash out all contaminated matter thoroughly, and also that the joint should be freely exposed so that the whole surface will receive the benefit of the irrigation and that no foci of infection be left behind. Even in cases where pus is present in the joint, good results may oftentimes be obtained by this procedure.

(*b*) *Radical Treatment.*—Radical measures should only be employed in those cases where there is a marked destruction of tissue associated with a profound sepsis. In such cases, where there is complete destruction of a joint and in which a bony ankylosis is bound to result, we have no articular surfaces to preserve, and in such instances an arthrotomy, with excision of the comminuted and necrosed fragments, will be necessary, and constant irrigation with saline or hypochlorous acid solution should be instituted. The part injured should be fixed in some form of immobilising apparatus, which at the same time will allow of free drainage and a ready access to the wound for dressings, and the limb should be arranged in such a position as to give the best ultimate result from the point of view of function.

In extreme cases, in the presence of a virulent infection together with much destruction of tissue, an amputation may be necessary in order to save the life of the patient.

If the infection be present and persistent in any joint, excision of the articular surfaces may be necessary in order to allow of the free escape of the purulent discharge.

In addition to the immobilisation by means of apparatus, extension is often an important adjunct, especially in cases of infections involving the shoulder or hip joints, as this allows of the separation of the articular surfaces and permits of freer drainage.

We have now discussed in a general way the various types of gunshot injuries involving joints, and have also given a general outline of the treatment to be followed. We shall now consider more in detail the various lesions of the different articulations and also the more specific treatment to be carried out in these various regions.

Upper Extremity

1. **Wounds of the Shoulder Joint.**—Injuries to this joint may be accompanied by lesions to other structures, and, owing to their anatomical relation with this joint, such wounds are often attended by injuries to the adjacent vessels and nerves as well as by injuries to the scapula, the clavicle, and the soft parts about the shoulder. Wounds of the shoulder joint may be caused by rifle bullets, by shrapnel bullets, by deformed or deflected bullets, and by shell and grenade fragments, and the amount of destruction to the joint depends upon the velocity of the projectile as well as upon its size and shape. Undeformed rifle bullets cause simple perforations without much destruction of tissue, or they may cause grooves or erosions. Bullets travelling at a high velocity cause extensive comminutions of the head of the humerus, as may also deformed or ricochet bullets and shell or grenade fragments. Bullets travelling at a low velocity may become lodged in the periarticular tissues without causing any involvement of the joint. Such an injury as this may also be caused by shrapnel bullets and by small shell and grenade fragments. Again, projectiles of a low velocity may penetrate and become lodged in the joint cavity.

Treatment.—The method of treatment of injuries of the shoulder joint is directly dependent upon the severity of the lesion in the soft tissues together with the amount of destruction of the osseous structures and also upon the amount of contaminated or infected material which is carried in with the projectile. The treatment, wherever possible, should be conservative, and careful radiographic examinations should be made to determine the amount of bony destruction which has occurred. The more superficial wounds, not involving the capsule, may be best treated by a thorough disinfection, excision of the whole track and suture. Simple perforations by jacketed bullets need only to be immobilised, to have the wounds thoroughly disinfected and to have an occlusive dressing applied. Such wounds heal aseptically. It is, however, important in such injuries, where there may be a partial loss of motion, that the arm should be held in a position of abduction (Fig. 49). This will be discussed more in

Fig. 49. Osgood apparatus for injuries about the shoulder joint. The apparatus may be adjusted to any angle desired, which is an important adjunct in the treatment of wounds about the shoulder joint, where one expects ankylosis.

detail later. In the more extensive injuries, where there is destruction not only of the joint but also of the soft tissues by deformed and deflected bullets and by shell or grenade fragments, and where infection is present, thorough drainage should be done, and all devitalised and necrosed tissues removed as well as any foreign bodies and loose spicules of bone which are present.

Radical Treatment.—In those injuries where there is extensive or complete comminution of the head of the humerus, as well as severe secondary complications such as hæmorrhage or infection, and also in those cases where conservative measures have not attained the desired result, more extensive methods of treatment may be required. In cases where there is a severe infection and where the head of the humerus is badly comminuted, a partial or complete excision of the head may be necessary in order to clear up the septic focus, and in this instance the joint should be freely exposed and all loose fragments of bone removed. In some instances, it may be only necessary to remove a part of the head of the humerus, but in other cases the degree of infection may be so severe and the amount of comminution so great that a complete excision will be justified. The wound should be thoroughly drained and irrigated with hypochlorous acid solution or with hypertonic salt, which treatment has been described under wounds of the soft parts. If the blood-vessels have been injured and obliterated and there is complete loss of the peripheral circulation, immediate amputation should be performed, and this is important in the more extensive wounds not only on account of the resulting gangrene, but also on account of the dangers from infection by *B. perfringens* which may supervene.

Position.—In the treatment of gunshot wounds of the shoulder, one of the most important factors to consider, apart from the active treatment of the existing condition, is the position in which the arm should be held when ankylosis is inevitable, in order to obtain the best possible functional result. If an arm be allowed to ankylose close to the body, the result from a functional point of view is poor, as the range of motion of such an arm will be very much limited. In order to obtain the best functional result the arm should be immobilised in a position of abduction at an angle of about 45° to 60°, and allowed to ankylose in this position. It should also be brought forward so that the elbow is on a line with the anterior axillary fold, and there should also be slight outward rotation. When ankylosis takes place in this position the result will be a functionally useful arm, and the abduction of the arm will be controlled by the elevation and lowering of the scapula, and the muscles which control this movement soon learn to accommodate themselves and also to increase their range of action. An arm ankylosed in this position will allow of the patient performing all his ordinary duties in an efficient and unobtrusive manner.

Some of these facts may be shown by the following cases.

Case 1. **Perforating Bullet Wound of Shoulder with Fracture of Greater Tuberosity.**—J. O'L., age forty-five, 2nd South Wales Borderers, was wounded while in barracks on April 9th, 1916, by a fellow-soldier who was cleaning his rifle in a room about 6 yards away, and who accidentally fired it. Bullet struck and went through patient's left shoulder.

Was admitted to the American Women's War Hospital on April 21st, 1716. Examination at that time was as follows: Left shoulder presents a small healed wound of entrance through the anterior portion of the deltoid on a level with the head of the humerus, and a smaller healed wound ¼ inch in diameter just on level with the spine of the scapula at posterior axillary line. Considerable ecchymosis of whole of upper arm. No disturbance of sensation. Passive motions free in all directions, but cause considerable pain over head of humerus. No crepitus. Active motions limited in abduction. X-Ray (Fig. 50) shows fracture through the greater tuberosity of humeral head.

April 30th.—Ecchymosis fading, still some pain on passive motion. Abduction on active motion slightly increased. To have massage.

May 23rd.—Since last note has been having vigorous massage, motions now free in all directions except in abduction, in which direction it is slightly limited. Patient is now able to use arm actively. Passed as suitable for duty.

A *B*

Fig. 50. *A* shows perforating bullet wound of the shoulder. Wound of entrance is on the anterior surface and wound of exit on back. The bullet passed through and caused a fracture of the greater tuberosity, as is shown in *B*. Wound was treated by fixation and occlusive dressings. Later massage was instituted and patient was discharged with a good functional result.

Case 2. **Bullet Wound non - perforating with Fracture through Neck of Humerus and with Fragmentation of the Head of Humerus.**—J. E. L., age twenty-two, 90th Winnipeg Rifles, was wounded on April 24th, 1915, at Ypres by a bullet which struck him in his left shoulder.

Was admitted to the American Women's War Hospital on May 2nd, 1915. Examination at that time was as follows: There is a healed bullet wound of entrance lateral to the head of the left humerus. Just under the skin two foreign bodies the size of the end of the little finger are palpable. Contour of upper third of arm resembles a dislocation, and passive motions elicit considerable pain and crepitus. Passive motion somewhat limited, especially in abduction. X-Ray (Fig. 43) shows a bullet broken into two portions lying just under the skin and against the head of the humerus. There is a fracture through the head of the humerus and the head is split in two portions. Bullet removed under local anæsthesia.

June 1st.—Operation: Under general anæsthesia an incision $3\frac{1}{2}$ inches long was made through middle of deltoid and head of humerus exposed. One loose fragment of bone lying free in joint was removed and a partial excision of the remainder of the head was done, and shoulder reduced. Adhesions in joint broken up and wound closed in layers; the arm immobilised on splint at an angle of 45°.

June 8th.—Wound healed by first intention.

July 1st.—For past two weeks patient has been having massage and passive motions. Shoulder joint partially ankylosed, but patient is now able to abduct arm voluntarily much better than at any time previous to the operation.

July 20th.—Movement of arm in abduction considerably increased. Patient can now elevate his arm so that he can feed himself. Abduction accomplished by elevation of the scapula. There is not complete ankylosis, as patient has some movement in rotation and is also able to extend arm anteriorly and posteriorly. Discharged, improved, for invaliding.

CASE 3. **Grenade Wound of the Shoulder with Destruction of the Head of Humerus.**—W. Q., age thirty, 4th Rifle Brigade, was wounded on March 15th, 1915, by a hand grenade. Was admitted to the American Women's War Hospital, March 30th, 1915.

The following history accompanied him from the hospital at which he had been treated in France: "Sergeant Q. admitted with grenade wound of left shoulder. The head of the humerus came away in pieces. He ran a septic temperature for about eight or ten days, then an abscess in the posterior aspect of axilla, an extension from the lower wound at the back of the humerus, was opened; since that time he has rapidly improved. The general swelling of arm and forearm has in great measure subsided."

Examination at time of entrance here was as follows: There is an open discharging wound 10 cms. long and 5 cms. wide on anterior lateral aspect of left upper arm. Posterior to and just below this wound there is a counter drainage area about 4 cms. in diameter. The wound is drained by through-and-through rubber tube. X-Ray (Fig. 51) shows complete destruction of the head of the upper part of the humerus, also many metallic fragments embedded in the tissues, and also many small bone fragments. Shaft of humerus about 1½ inches below the epiphyseal line presents an oblique fracture, the direction of which is from without inwards, and 1 inch below the inner margin of this fracture is another oblique fracture, the direction of which is from within outwards. Alignment of fragments good. Following admission the wound continued to discharge a considerable amount of pus and also necrotic fragments of bone. Operation deemed advisable for the removal of the septic foci.

April 6th.—Operation under general anæsthesia: Lateral wound was slightly enlarged and a large number of small necrosed fragments and bone removed, including a remnant of the head of the humerus. Arm put up in slight abduction. Oblique fracture of the shaft was found to be in good position with moderate union. Wounds closed with drainage.

June 15th.—Patient presented an uneventful convalescence. Wounds are now entirely healed. There is complete ankylosis of shoulder joint. Patient has fair movements and is able to use arm considerably. Motions are considerably impaired in all directions. Discharged July 22nd for invaliding.

FIG. 51. Grenade wound of shoulder showing extensive comminution of the head of the humerus, as well as an indirect fracture of the shaft at junction of middle and upper thirds. Numerous small grenade fragments seen scattered throughout the soft tissues. X-Ray also shows drainage tubes inserted into joint.

2. **Wounds of the Elbow Joint.**—Wounds of the elbow may be caused by any of the projectiles which have

already been described, and consist of perforations through the joint by bullets (Fig. 52), with destruction of all of the articular surfaces, of contact wounds by bullets with a low remaining velocity, by shrapnel bullets or by smaller shell or grenade fragments. With deformed or deflected bullets or with larger shell and grenade fragments, as well as with bullets travelling at a high rate of velocity, the destruction of the joint may be very extensive. Again, we find wounds involving only the periarticular tissues from bullets or shrapnel with low velocity and from the smaller shell and grenade fragments. With large shell fragments and grenades at close range the destruction of both the soft tissues and the bones may be very extensive. Injuries to the elbow joint, if at all extensive, are prone to involve not only the articulation, but also the nerves and blood-vessels which lie in close proximity to the joint and, as a result, we may have a complete or partial division of these structures with a resulting paralysis or gangrene due to the laceration of the blood-vessels.

Conservative Treatment.—Conservatism should be practised here, just as in other joints, and the treatment, which has already been described, for the removal of foreign bodies, the removal of necrosed or loose spicules of bone, and the prevention of sepsis should be carried out. In wounds involving the periarticular tissues, the foreign bodies should be removed, and the wounds treated as has already been described. Hæmorrhage should be controlled by ligation when necessary, and the treatment of any nerve injuries should be relegated to a later date, especially if infection be present.

Radical Treatment.—In cases where there is complete obliteration of the circulation or where a grave infection is present amputation should be done. In other cases, where there is extensive comminution of the bone together with sepsis, a partial or complete excision may be necessary, but this operation should be performed in those cases only where there is complete detachment of the bony fragments

A

B

Fig. 52. Shows perforation of elbow joint by bullet. *A* shows wound of entrance, edges of which are inverted. Bullet perforated joint (Fig. *B*), in the region of the coronoid process. X-Ray shows long oblique fracture of the humerus, splintering of the olecranon process and the shaft of the ulna, and destruction of the head of the radius. Bullet was removed subcutaneously from lower wound in Fig. *A*.

from their periosteal covering. Any fragments which show any attachment whatsoever should be left strictly

A *B*

C

Fig. 53. Shows amount of destruction caused by deflected bullet. Small fragments of metal core can be seen lying embedded in the tissues, and the amount of bony destruction is well shown (*C*). Figs. *A* and *B* show the external appearance of the elbow after the wounds had healed and also the amount of extension and flexion which was still possible following the amount of destruction which had taken place. In this case there was a complete section of the ulnar nerve, which was later freed from scar tissue and sutured. Case described in text under nerve injuries.

alone, as such fragments are still valuable and act as grafts in the formation of new bone tissue.

The amount of bony destruction which may occur and a good functional joint be still preserved is shown in the case of "A. W.," described under "Injuries to the Nerves" (Fig. 53).

Position.—The position in which the elbow should be

FIG. 54. Shows perforation by bullet, involving both the cuneiform and the unciform.

allowed to ankylose is important, and the one which gives the best functional results is that in which the forearm is fixed at an angle of about 90° to the upper arm. This will allow the patient to feed himself, to put his hand in his pocket, and also gives a better functional result and a less obtrusive appearance than if the arm were ankylosed in any other position. The forearm should be held in a position of semi-pronation. Furthermore, if there be any nerve involvement, the tone of the muscles should be

Fig. 55. Shows deformed shrapnel bullet lying in wrist joint. The bullet entered on medial side and the track made by the bullet may be easily seen by the detached fragments of metal. Bullet removed; good functional result.

maintained by electricity, and the hand should be supported so as to prevent undue relaxation in stretching of the muscles until such time as the function of the nerve may be restored by anastomosis.

A

B

FIG. 56. *A* shows lesion to the wrist caused by grenade. *B* shows metallic fragments scattered throughout the carpal joint with some destruction of the cuneiform and lower end of ulna. There is also a larger shell fragment at metatarso phalangeal joint of third finger. There was a resulting partial ankylosis due to infection.

3. **Wounds of the Carpus.**—The extent of severity in injuries of the carpus depends upon the type of projectile inflicting the wound. Bullets may perforate (Fig. 54) or may cause extensive comminution of the carpal bones. Bullets which simply perforate do not usually cause very much destruction of tissue, as the tendons are pushed aside. Shrapnel bullets (Fig. 55), deformed and deflected rifle bullets cause more extensive lacerations and destruction of tissue, whereas the more extensive destructions are caused by shell or grenade fragments (Fig. 56).

Treatment.—Conservative treatment usually suffices in these instances, as amputation or excision of the joint is rarely necessary unless there be an extensive and spreading infection which cannot be controlled by any other means or unless there be complete destruction of the blood-vessels. Conservatism should be practised in every instance, as a man with a stiff wrist or with ankylosed fingers is better off than a man with an artificial hand. Foreign bodies should be removed, as well as necrosed and loose fragments of bone, and all infected foci should be thoroughly drained. In the smaller perforating wounds involving one or other of the carpal bones, disinfection of the wound and an occlusive dressing, as well as fixation, will often suffice; only a small degree of ankylosis will result and this can be overcome to a great extent by the after treatment.

Position.—It is important in these cases to determine the probable amount of ankylosis which will result, as well as the degree of injury to the muscles and tendons. In those cases where ankylosis of the carpus takes place but in which there is still mobility of the fingers and hand, the best position is probably that of slight dorsiflexion, as this will allow of more complete flexion of the fingers.

In the more extensive wounds, where there has been complete destruction not only of the bones of the wrist but also of the flexor and extensor tendons, and where there is a resultant loss of use of the fingers, the best results are obtained by ankylosing the wrist without flexion and allowing the fingers to ankylose in a flexed position. This will allow of the patient using his hand as a hook by means of which he is enabled to carry various articles. In certain instances the patient is able to grasp and retain articles by opposing his thumb to one of the fingers.

FIG. 57. Shows perforation by bullet through metacarpo phalangeal joint. Radiating fissures may be seen on metacarpal and also on phalanx.

4. **Wounds of the Interphalangeal Joints.**—These consist of perforations by bullets with fissure fractures extending into the diaphyses of the phalanges (Fig. 57). They may also consist of complete destruction of the whole joint (Fig. 58). Again, we find grooves of the diaphyses near

A *B* *C*

FIG. 58. Shows a perforating bullet wound of interphalangeal joint of second finger.
A shows complete destruction of the joint in the antero-posterior direction.
B Lateral view showing destruction of joint.
C shows the external appearance at time of entrance. A part of the wound of exit may be seen as a slight elevation between the first and second fingers.
Finger was amputated on account of infection.

the epiphyseal line with fissures or comminutions into the joint (Fig. 59). Shell and grenade fragments cause more complete destruction of the joints and may entirely remove the finger (Fig. 60). Infection is usually associated with

FIG. 59. Shows grooving shell wound at base of index finger with fracture into the joint. Small pieces of shell fragment are shown in the X-Ray.

this class of wounds and, unless the injury to the joint be very slight, ankylosis is practically certain to supervene. Osteomyelitis and necrosis are the usual accompaniments.

Treatment.—In the less severe injuries the treatment should first of all be conservative, radical measures not being adopted until it has been proved that the function of the joint has been absolutely destroyed, or if chronic osteomyelitis be present, amputation affords the quickest and best possible cure, as otherwise the patient will be burdened with an ankylosed finger which would constantly be in his way.

Lower Extremity

1. **Wounds of the Hip Joint.**—Wounds of the hip joint form one of the most serious types of articular injury seen in modern warfare, not only on account of the anatomical relations of the sciatic nerve and of the large vessels, but also on account of the disability following such a wound. According to Delorme, articular lesions of the hip are 3·8 per cent. of joint injuries. Wounds in this region, as in other regions, are caused by various types of projectiles, and the amount of injury is here also dependent upon the velocity, size, and shape of the projectile.

The wounds of the soft parts about the hip and thigh will not be considered, as the general considerations of these wounds have already been taken up in other chapters. In passing, we simply mention hæmorrhage from the larger vessels, as it is an especially serious condition in this region. Antero-posterior wounds are particularly serious on account of the anatomical relations of the femoral artery and vein to the hip joint and, in the posterior regions, the large glutcal vessels. The treatment of hæmorrhage will not be considered, as it is fully described in another chapter. Undeformed rifle bullets may either penetrate the soft tissues and cause contusions or perforations of the synovial sac, or may penetrate into the joint cavity or may become embedded in the articular surface of the head of the femur. Shell fragments and grenade fragments give rise to lacerations of the synovial membrane, to comminutions of the neck of the femur or of the head, and in some instances may cause a separation of the neck

A

B

Fig. 60. *A* grenade wound of both hands showing loss of index finger on right hand and loss of third finger on left with fracture of the phalanges of fourth finger.

B shows X-Ray of condition described above. The proximal phalanx of index finger on right was totally carried away except at the base, which was split into the joint. The third finger of the left hand was destroyed except for a few small bone fragments of the joint.

of the femur from the shaft with a resultant traumatic coxavara. Smaller shell fragments may give rise to extensive lacerations of the joint capsule without causing any osseous injury. Associated with any of these injuries there may also be involvement of the acetabulum.

Diagnosis.—The diagnosis of injury to the hip is made by the location of the wound and the direction of the track made by the projectile, by localised tenderness on pressure, and by X-Ray examination. It is better that as little manipulation as possible should be made in such injuries, especially if the external wound be infected.

Prognosis.—Such wounds are particularly serious on account of the dangers from infection and from the severe hæmorrhage which often results. In the small wounds caused by rifle bullets the prognosis is much better than in large lacerated wounds with extensive destruction of the bony structures, associated with a large amount of contaminated matter. Formerly infection caused a large percentage of the mortality from such wounds, but in these days with our much improved methods of treatment the mortality from such cases is fortunately less. The decrease in mortality since the advent of the small-calibre projectiles is illustrated by the decrease since the American Civil War. Delorme gives the mortality in the Civil War as 84·7 per cent., in the Franco-German War as 79·7 per cent., in the Spanish-American War 33 per cent., and in the Boer War 28·6 per cent.

Treatment.—When once the diagnosis of an injury to the hip joint has been established the leg should be immobilised and the wounds, if extensive, thoroughly disinfected and foreign bodies and contaminated matter removed. In the smaller wounds caused by bullets, fixation, disinfection of the wound, and an occlusive dressing will often suffice. When infection is present, the wound should be thoroughly drained, all loose fragments of bone and foreign bodies removed, and the leg immobilised in some form of apparatus either by means of a Bradford frame and a Buck's extension apparatus or, preferably, by means of a bridged plaster spica which will allow of free access to the wounds.

In those cases where there is separation of the neck of the femur from the shaft and a consequent coxavara, an extension apparatus should be first applied to overcome the shortening, and, later, a plaster spica should be applied to keep the leg immobilised in the corrected position.

The more radical treatment which is employed when conservative measures prove inadequate consists in freely exposing the joint, removing all loose fragments of bone and the head of the femur if necessary. If extensive infection persists, it may be found necessary either partially or completely to excise the head of the femur, in order to furnish complete drainage of the acetabulum. Cases where there is a marked infection present an inevitable ankylosis, and one should not hesitate to excise if necessary the head of the femur, in order to overcome a persistent suppurative process. Another form of apparatus for the treatment of gunshot wounds of the hip is shown in Fig. 94, which consists of a frame upon which the patient may be suspended when the dressings are being done. Such an apparatus is of special advantage in that the patient or his apparatus need not be disturbed at such times. It facilitates dressings not only for the surgeon, but for the patient himself. Amputation should only be performed in those cases where the infection of the leg is so severe as to threaten the life of the patient, or where there is a gangrene as a result of the obliteration of the circulation. Such operations, however, are usually unsatisfactory, as the attendant mortality is so great, owing to the extensive shock caused not only by the operation itself, but as a result of the initial injury and the hæmorrhage which is associated with the more extensive wounds. That a severe septicemia may follow the more extensive injuries to the hip joint is shown by the following case.

Case 1.—A. G., age twenty, 7th Suffolks, was wounded on April 1st, 1916, while in the trenches, by a shell fragment which struck him in his left hip. Was operated upon the day following the injury, and shell fragment removed from his groin. Admitted to the American Women's War Hospital on April 7th, 1916.

Examination at that time was as follows: There is a lacerated penetrating wound 1½ inches in diameter and about 4 inches posterior to and on a level with the great trochanter. There is also a small incised wound about 1 inch long in left groin just below Poupart's ligament. This wound is superficial and does not connect with the posterior wound. Posterior wound is drained and the track extends in for a distance of about 6 inches. Patient in good physical condition, although somewhat mentally sluggish.

April 14th.—Condition of wound satisfactory. There is, however, a moderate purulent discharge. X-Ray negative. To-day patient suddenly complained of a sharp pain in his left knee. This gradually wore off, but some slight pain persisted. No local symptoms. No redness or tenderness in either knee or hip. Leucocyte count 20,000. In evening patient became slightly delirious. On the following day leucocyte count had increased slightly, and it was deemed advisable to explore the wound, as it was thought that probably a pus pocket had formed.

Operation: Incision was made through the skin and deep tissues following the track of the wound. This led directly to the hip joint, and the capsule of the joint was found to be very much lacerated, and the whole joint exposed. There was a small furrow in the neck of the femur, but no fracture. Wound was left open and through-and-through drainage established with the former wound in the groin.

April 17th.—Patient somewhat delirious during the night—temperature 104°. Patient put up in extension apparatus to immobilise leg.

April 18th.—Patient delirious, insensible to pain, and there is marked muscular tremor. Leucocyte count has dropped to 6,000. Lumbar puncture done and spinal fluid was found to be under considerable pressure. Fluid clear and bacteriological examination negative.

April 25th.—Since last note patient has run a persistent high temperature. At times has been mentally clear, and at others has shown a marked delirium. There is a persistent tremor which resembles the tremor of delirium tremens. For the past two days has been having occasional clonic convulsions, during which time his circulation is extremely poor and he becomes markedly cyanosed. Leucocyte count persistently low. Urine examination negative. Blood culture taken shows a non-motile bacillus.

April 30th.—During the past five days patient has grown progressively worse. Clonic convulsions come on at more frequent intervals. Circulation extremely poor, and there is now considerable edema of the lungs. White blood count still low. Wound is clean with very little drainage. Considerable abdominal distension for the past few days, which, however, is relieved by stupes. Patient looks extremely toxic and condition is very poor. Edema of lungs increasing. Pulse very rapid and thready. This condition continued all day until evening, when patient suddenly died.

Autopsy : Liver, spleen, kidneys, and lungs show state of chronic passive congestion. Heart shows vegetable growth 4 mms. in diameter on the aortic valves. Intestines normal as regards Peyer's patches. Culture taken from heart showed a mixed infection of B. Aerogenes Capsulatus, Streptococci and Staphylococci. Blood cultures taken four days before death showed a large slow-growing Streptococcus.

Case 2. **Wound of the Hip with Bullet embedded in the Head of Femur.**—J. B., aged nineteen, 1st Cheshires, was wounded on March 25th, 1915, by a bullet from about 800 yards which struck him in his left hip.

Admitted to the American Women's War Hospital on March 30th, 1915. Examination at that time showed a practically healed wound of entrance $\frac{1}{4}$ inch in diameter over great trochanter on his left femur. Passive motions of hip painful, especially in abduction. There was also considerable pain extending down leg to region of knee.

FIG. 61. Shows rifle bullet lying embedded in the head of the femur. Case described in text.

Patient able to walk, but this caused very sharp pain in hip joint. X-Ray showed a bullet lying embedded in the head of the femur (Fig. 61). Patient put up in extension apparatus with 10 lbs. weight to overcome muscular spasm and pain.

June 13th.—Since entrance patient has had periods in which there has been no pain, and at other times has had severe remissions. Up and about on crutches for the past month, but is still unable to bear weight on leg. Active

Fig. 62. Shows perforating bullet wound of knee. Wound of entrance at level of joint just internal to the patella, and wound of exit at same level on posterior surface. X-Ray shows large detached fragment of internal condyle of femur with some slight displacement. On entrance there was marked effusion in the joint, but wounds healed aseptically and effusion subsided. Fracture was reduced and uncomplicated convalescence resulted. Patient returned to duty.

movements of leg limited; passive motions are free in all directions except in abduction, but all movements elicit marked pain. Condition remained practically the same until June 22nd, when he was invalided with the following discharge note: "Condition practically the same. No muscular atrophy. Patient unable to walk except with crutches on account of severe pain in his hip joint. Pain still continues to radiate to the knee. Movements of leg practically the same as at last note. Discharged for invaliding."

2. **Wounds of the Knee Joint.**—Such injuries are frequently seen. Delorme gives the figures as 3 per cent. of all wounds, and also states that one-third of all joint wounds involve the knee. Wounds of the knee comprise the various types which have already been described and may be of the periarticular tissues alone or of the joint cavity. Rifle bullets, shrapnel bullets, small shell and grenade fragments cause contusions or perforations of the synovial sac. Such missiles also penetrate into the joint cavity with or without any involvement of the adjacent bones (Fig. 62). On the articular surfaces we find erosions or grooves, comminutions of the edge of the articular surfaces, projectiles lodged in the cartilaginous surface, and also fissures and comminutions into the joint from wounds of the epiphyses (Fig. 63). With the older types of armament the mortality was high, and of 868 gunshot fractures of the knee during the Civil War which were treated by the conservative method there was a mortality of 60·6 per cent. In the Spanish-American War and the Philippine Insurrection the mortality was 6·5 per cent. and in the Boer War 4·2 (Lagarde). In the Boer War the fatal cases were confined to those in which there was a severe infection following the trauma inflicted by shell fragments. Gunshot wounds of the knee vary from very slight injuries to severe traumatisms with extensive destruction of the bony tissues. In those cases where we find simple involvement of the periarticular tissues we may get as a result an effusion in the joint without any gross lesion of the capsule, whereas in the more extensive injuries we may find a great degree of comminution of the

articular surfaces together with a severe laceration of the external tissues. The dangers from such wounds consist of extensive hæmorrhage from the anastomosing branches about the knee or from the popliteal vessels, and such wounds may be further complicated by involvement of the popliteal nerves.

Treatment.—In such wounds immobilisation should be the first rule in all cases, together with a thorough dis-

Fig. 63. Shows shell wound of tibia involving knee joint. Some comminution of upper part of tibia. Shell fragments seen embedded in tibia. Partial ankylosis resulted in this case.

infection of the external wound. Small perforating or penetrating wounds usually heal aseptically, and disinfection of the wound and the application of an occlusive dressing should be sufficient. In such wounds the removal of the retained foreign bodies should be reserved until all acute symptoms have subsided unless signs of infection manifest themselves, in which case the foreign body should be immediately removed and the joint thoroughly irrigated. In the more extensive wounds the same procedures which have been outlined for wounds of the other joints should be carried out.

It is important that in all injuries to the knee joint an attempt should be made to preserve as much as possible of the articular surfaces, and great care should be exercised during the operation for the removal of foreign bodies not to traumatise the cartilaginous surfaces. The degree of injury to the joint should be recognised as soon as possible, and each line of treatment should be determined by the severity of the injury.

It is important as regards the ultimate function of the joint that we should discriminate between those cases in which we may expect to get little if any impairment of function and those cases in which the outlook, as far as movement is concerned, is hopeless from the beginning. In the first type of cases we include all those in which there is involvement of the periarticular tissues and the synovial membrane together with a retained foreign body, possibly some slight bony involvement and some infection. In the second type we include those cases in which there is extensive comminution of the joint surfaces together with a severe infection, and in such cases we realise that ankylosis is inevitable.

The treatment of the first class of wounds consists of disinfection of the skin wound and excision of all necrotic tissues. As little trauma as possible should be done to the synovial membrane other than the removal of the necrosed edges. The retained foreign body in the joint should be carefully removed and the joint cavity should then be thoroughly irrigated with some antiseptic solution or with saline, and it may be as well to mention here that excellent results have been obtained by thorough irrigation with corrosive sublimate or with Eusol. The synovial membrane is then tightly closed, and, if drainage is necessary, it should be carried down only to this point and not into the joint, as drainage into the joint cavity means the ultimate destruction of the joint surfaces and a poor functional result.

In those eases in which ankylosis is inevitable, the joint eavity should be left wide open, and all neerotie soft tissues and bone fragments removed. The eavity is then onee more thoroughly irrigated, the eapsule elosed if possible, and the wound drained as before.

In those cases where the effusion is slightly infected and shows a tendeney to reaeeumulate, good results may be obtained by aspiration and replaeement of the fluid with formalin-glyeerine solution or with plain ether. The formalin-glyeerine solution is made up as follows : 2 drams of 2-per-cent. formalin in glyeerine prepared in not less than twelve hours or more than one week previously should be used. Then aspiration and replaeement treatment should be kept up until baeteriologieal examination of the effusion shows no evidenee of the presence of mieroorganisms.

In the milder eases, where there is an effusion into the knee joint due to a eontusion or a small perforation, and if this effusion does not readily absorb, it may be treated by aspiration, and the withdrawn fluid should be examined baeteriologically, to determine the presenee or absence of any infcetion. If no infeetion be present and the fluid reeurs, it may again be aspirated, but if infeetion is present, the wound should be opened and treated as has already been deseribed.

In all instanees the knee should be fixed with some form of apparatus, either by means of a ham splint, a Cabot posterior wire splint, or, if the wound be at all extensive, a bridged plaster forms the most effieient fixation apparatus, as it also gives ready accessibility to the dressing of the wound. The leg should be kept immobilised for about three weeks after the aeute symptoms have subsided before any attempts at movements are made. Amputation should be performed only when infeetion is of sueh severity as to threaten the life of the patient or when gangrene as a result of trauma of the blood-vessels supervenes.

Captain Lockwood (4) gives some interesting figures from observations made in a base hospital in France. Out of fifty-six cases which he observed, he found that fracture of one or both bones existed in 53 per cent. of cases, a bloody effusion in 96 per cent., and pus perceptible to the naked eye in 56 per cent. The bacteriological reports on forty-two cases showed that organisms were present in 76 per cent. and, as regards the results of these cases, ankylosis occurred in three, limited movement in four, and free movement in forty-nine of the fifty-six cases observed.

Some of the common types of injury to the knee joint are shown by the following cases:

Case 1. **Bullet Wound of Knee with Bullet lying embedded in and perforating the Synovial Sac.**—W. R., age thirty-four, 2nd Suffolks, was wounded on February 24th, 1915, by a rifle bullet which struck him in his left knee. Admitted to the American Women's War Hospital on March 3rd, 1915.

Examination on entrance as follows: On external border of knee and 1 inch above patella is an infected sinus running downward and inward. Moderate effusion in the knee joint. No redness and no temperature. X-Ray (Fig. 64) shows rifle bullet lying just to inner side of patella.

March 11*th*.—Operation: Ether anæsthesia; sinus track disinfected and excised. Dissection carried down to synovial sac and rifle bullet was found embedded in this sac, and protruding through into the joint cavity. Bullet was removed and a moderate amount of non-infected synovial fluid escaped. Joint cavity thoroughly irrigated with 1 to 15,000 corrosive sublimate solution and wound in synovial membrane closed. External wound closed.

April 19*th*.—Following operation patient presented an uneventful convalescence. Wound healed by first intention and stitches were removed in eight days. Patient up and about for the past two weeks. Moderate effusion in joint following operation, which has now entirely disappeared. No pain or tenderness about knee joint and movements in flexion very slightly limited. Patient suitable for a convalescent home and then for duty.

Case 2. **Penetrating Shell Wound of Left Knee—Retained Foreign Body.**—T. W., aged twenty-six, R.F.A., was wounded on October 26th, 1914, by a shell fragment which struck him in his left knee and also by another fragment which wounded him in his right thigh.

Fig. 64. Shows rifle bullet lying embedded in synovial sac, and penetrating joint cavity. Bullet removed. Good functional result.

Was admitted to the American Women's War Hospital on October 31st, 1914. Examination on entrance as follows: On inner side of left knee is a small wound of entrance $\frac{1}{4}$ inch in diameter. There is no wound of exit. Wound clean and practically healed. There is also a small penetrating wound of right thigh and small healed wound of right shoulder and right elbow. X-Ray of knee (Fig. 65) shows small shell fragment lying in joint cavity beneath the patella tendon and between the articular surfaces of the femur and the tibia.

November 7th.—Operation: Incision $3\frac{1}{2}$ inches long made over external lateral aspect of knee and synovial sac exposed. This was opened and a small irregular piece of shell fragment was removed just underneath the patella tendon. There was a slight erosion of the articular sur-

FIG. 65. Shows small shell fragment lying between the articular surfaces of the femur and the tibia. Fragment removed. Good functional result.

faces of both the tibia and the femur. There was also an increased amount of joint effusion admixed with a slight amount of blood. No infection. Wound closed without drainage. Leg immobilised on ham splint.

December 17th.—Wound has healed by first intention. Patient up and about. Movements of knee nearly normal. No effusion. Patient discharged to convalescent home.

Case 3.—E. M., aged thirty-four, 8th Royal Dublin Fusiliers, was wounded on March 29th while in a dugout.

A shell burst close beside the dugout in which he was lying and he was struck in his right knee by a shell fragment. Was operated upon three days later and shell fragment removed. X-Ray (Fig. 66) taken at that time showed a small shell fragment lying against the outer border of his right patella. There was also a slight comminution of the outer border of the patella. Operation at that time was as follows: Wound in capsule disinfected

FIG. 66. Shows small shell fragment lying in joint cavity and also slight comminution of the outer border of patella. Shell fragment was removed as well as loose fragments of bone. Excellent functional result.

and excised. The external border of the patella shows some slight comminution and these fragments were removed. Small shell fragment was found under the lower border of the patella, and this was removed also. Joint was thoroughly irrigated with Eusol and wound in synovium was closed. Wound in skin closed except at one place where drainage was inserted down to the synovial membrane. For the first few days following operation there was a temperature of 101°, which fell gradually to normal. Leg immobilised in splint.

April 21st—i.e. nineteen days after operation—patient was admitted to the American Women's War Hospital, examination at that time being as follows: Right knee presents a curved incised wound 4 inches long on outer aspect of border of patella. Wound healed except for a small granulating area in the centre. There is no effusion in the joint. Patella freely movable. Temperature and pulse normal.

April 30th.—Wound entirely healed except at centre, where there is a small granulating area. There is no effusion in joint, no pain or tenderness. Splint removed. Flannel bandage applied.

May 14th.—Wound entirely healed. No effusion in joint. Has been having daily massage. Movements of knee good, and is now able to flex it to nearly 45°.

May 19th.—No subjective or objective symptoms. Is now able to flex knee to nearly normal. Suitable for discharge.

Position.—When ankylosis is inevitable following injuries to the knee joint, the knee should be held and allowed to ankylose in a slightly flexed position, as this will allow the patient to walk more easily than he could if the leg were completely extended.

3. **Wounds of the Tarsal Joints.**—These consist of perforations, erosions or grooves by rifle bullets, and of fissured fractures. Shell and grenade fragments and deformed and deflected bullets and shrapnel bullets cause fissured fractures and comminutions.

The treatment in these cases follows the same general principles as have been outlined for wounds of the carpal bones, and every effort should be made to preserve as much of the bony structure as possible. The foot should be immobilised at right angles. Conservatism should be the rule in such cases, unless an amputation is absolutely indicated, in which case it should be made at the point of election.

4. **Wounds of Interphalangeal Joints.**—The same general

principles hold for wounds in this region as have already been discussed under wounds of the interphalangeal joints of the fingers.

After Treatment.—In all joint injuries the after treatment is a most important factor, as it determines to a great extent the amount of restoration of function, and, as soon as acute symptoms have subsided, usually within two or three weeks following the injury, passive motions and massage should be started, and this, combined with dry heat, and galvanism or faradism, plays a most important part in all joint injuries.

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CHAPTER VIII

WOUNDS OF LONG BONES

Types of Wounds—Treatment—Bone Plating and Bone Grafting.

In war surgery there is probably no class of cases which shows such a marked difference from injuries seen in civil hospitals, both as regards the lesions caused by projectiles and also the method of treatment, as do gunshot wounds of the diaphyses. This type of injury forms one of the most important groups of wounds, both on account of the frequency of such lesions and also on account of the varying problems which each individual fracture gives rise to as regards the treatment. When we consider that in civil practice the proportion of fractures is not great as compared with other surgical conditions, that the majority of such fractures, moreover, are of the closed or simple type, and, further, that open or compound fractures are seldom complicated by extensive wounds to the surrounding tissues, it is easy to understand that fractures caused by projectiles and associated with extensive injuries to the bones as well as to the adjacent tissues, and further complicated by the presence of infection, give rise to many difficult problems which are seen under no other conditions. Furthermore, such injuries do not always occur singly and may be associated with numerous wounds elsewhere or with other fractures in the same bone. Again, gunshot fractures are usually infected and there may be also associated lesions of blood-vessels and nerves.

The following statistics have been compiled from the records of the American Women's War Hospital, and correspond very closely with the figures given by other observers. These figures were compiled from a series of 310 cases, and show that, of the total number of wounded, fractures occurred in about one-fifth of all the cases. Of this number some of the fractures were of the closed type and were caused not by trauma from projectiles, but by other factors incident to warfare, such as the caving in of a trench, by mine explosions, by the falling from a wagon or gun limber, and by kicks from horses or mules.

In compiling these figures, fractures of all bones were considered, and, if we exclude the fractures of the small bones of the hands and feet, there were ninety fractures of the lower extremity and eighty-five fractures of the upper extremity.

From the total number of fractures, including the small bones of the hands and feet, the following figures were obtained :

Infected Compound Fractures . . .	243
Fractures which healed aseptically . .	44
Total Number of Compound Fractures .	287
Simple Fractures	40
The Total Number of Fractures in 310 Cases	327

In this series secondary hæmorrhage occurred in three cases divided as follows :

Profunda Femoris	2
Brachial Artery	1

Nerve Lesions occurred in eight cases divided as follows :

Brachial Plexus	1
Musculospiral Nerve	4
Median Nerve	1
External Popliteal Nerve	2

In the 310 cases amputation was performed in 20 instances as follows:

Amputation before Admission	8
Amputation after Admission	12

The twelve cases in which amputation was required after admission were divided as follows:

Amputation of Fingers	8
Amputation of Thigh	2
Amputation of Leg	1
Amputation of Arm	1

Disposal.—The disposal of these 310 cases is of interest as showing the proportion of men who received compound fractures and who were able to return to duty, and also the proportion of those who were invalided out of the service, and of those who died.

In this series the total number of cases which died was 4—(Fractures of the Skull—3, Gunshot Wounds of the Spine—1).

Of the remainder the proportion was approximately as follows:

Returned to Duty	44 per cent.
To Convalescent Homes	24 per cent.
Invalided out of the Service	31 per cent.

Those men who were transferred to Convalescent Homes were those who would again be fit for duty after a short period of rest, so that in reality the proportion of men who had been admitted with fractures and who would ultimately be fit for duty was 68 per cent.

We shall now consider the various lesions of the diaphyses caused by projectiles (Fig. 67). These consist of:

(1) Contusions.
(2) Fissures.
(3) Contact Fractures.
(4) Perforations of One or Both Sides of the Diaphyses.
(5) Grooves or Gutters.
(6) Comminutions.
(7) Solution of Continuity of the Shaft.
(8) Fractures by Indirect Violence.

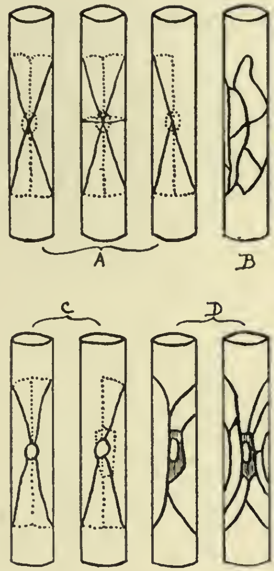


FIG. 67. Shows diagrammatic representation by Delorme of fractures occurring in shafts of bones.
A. Contact fractures with large fragments but no comminution.
B. Contact fracture with comminution.
C. Perforations—wounds of entrance.
D. Perforations—wounds of exit.

(1) **Contusions.**—This type of lesion is small and may often be imperceptible, and sometimes the only external lesion of the bone may be a laceration of the periosteum. Such wounds may be caused by any type of projectile which strikes the bone direct and has a very small remaining velocity, or they may be caused by smaller projectiles which strike tangentially and penetrate or perforate the soft tissues and injure the shaft of the bone very superficially.

(2) **Fissures.**—Fissures or cracks in the shaft of the bone are very frequent and usually occur in connection with other types of fracture, but, on the other hand, such injuries may be isolated, and we sometimes find long cracks or fissures. Such injuries are often difficult to diagnose, as they give rise to very few symptoms other than the initial

pain of the wound, and do not give rise to any disability or abnormal mobility. Sometimes the diagnosis is made at a time when the wound in the external tissues is being disinfected, and it may also be made by means of the X-Ray. Such wounds are caused by projectiles of a low velocity striking the bone either directly or tangentially.

(3) **Contact Fractures.**—These are caused by bullets, by shrapnel bullets, by shell and grenade fragments, and by deformed or deflected bullets which strike the shaft of the bone either directly or tangentially, and are arrested by the shaft. Such fractures may be either transverse or oblique, and may or may not be associated with large splinters of the bone, and may or may not give rise to longitudinal fissures.

These are the more common types of contact fractures without comminutions, and these large splinters may be either separated, in which cases there is little or no deformity in the continuity of the bone, or they may be held closely in position by the shape of the individual fragments or by intact periosteum and fascia.

There is another type of contact fracture caused by projectiles which have a higher velocity than those which cause the lesions already described, and such fractures are associated with comminutions of the splinters. In other words, these splinters, instead of being large intact fragments of bone, are broken up in one or more pieces. In these cases there is no loss of substance, and the comminuted fragments are usually held in place by the periosteum.

The diagnosis of such fractures is easily made by means of the X-Ray, and usually shows the projectile which caused the injury lying in close proximity to the lesions in the bone.

(4) **Perforations of One or Both Sides of the Diaphyses.**—Perforations may be through one side of the diaphyses alone or may perforate the whole diameter of the bone. The first type are usually caused by bullets which have a

low remaining velocity, and associated with this type of fracture we usually find, radiating from the point of perforation and due to the contact of the bullet, longitudinal cracks and fissures which simulate those already described. In addition, however, there is a small rounded or oval wound in the shaft of the bone from which these cracks and fissures radiate. Complete perforations are caused by bullets with a high velocity, and may be either simple in type or may show a varying degree of comminution. The wound of entrance in the bone is round or oval, and the track through the bone can usually be seen easily by means of the X-Ray. Where the bullet emerges in the bone there is usually some slight splintering and pushing outward of separated bone fragments. The wound of exit, however, is variable, and while there may be only a few detached splinters about the aperture of exit, we may, on the other hand, find a considerable degree of comminution of the cortical substance. The size and position or distance from the bone at which we find these detached fragments determines to a great extent the velocity of the bullet causing the injury. The greater the velocity the greater is the degree of comminution, and also the distance to which the detached fragments are driven.

Delorme states that "when the velocity is excessive free splinters are no longer carried along, but are violently thrown out in the form of a sheath. They no longer have any exact situation. They bury themselves in the soft parts at a more or less long distance from the track, and some of them break out of the limb through numerous separate orifices." He further states that "the dimensions of the splinters, like their number, are inversely in proportion to the velocity of the projectile—the less the velocity, the larger the adherent splinters and the less their number, and inversely."

(5) **Grooves and Gutters.**—Such injuries as these are caused usually by bullets which strike the diaphyses tangentially, and which cause a groove or gutter in the shaft

of the bone. From this groove we sometimes find radiating cracks and fissures.

(6) **Comminutions.**—Such injuries are caused by rifle bullets travelling at a high rate of velocity, by shrapnel bullets, and by shell and grenade fragments, and, as has already been said, the degree of comminution depends upon the size and the velocity of the projectile causing the injury. Comminutions of a varying degree have already been described under fractures by contact and perforations.

(7) **Solution of Continuity of the Shaft.**—This condition is described by itself, as cases are so frequently seen in which there is a complete loss of the bony substance, together with destruction of the periosteal covering. Such conditions may be caused by shell or grenade fragments and by rifle bullets which have become deflected and so have an explosive effect and which tear away a large amount of the soft tissues, and also cause a solution of continuity of the shaft (Fig. 84).

(8) **Fractures by Indirect Violence.**—Such fractures are essentially fractures by contact, and are associated with a lesion elsewhere on the same bone. It may happen that we see conditions in which the shaft of the bone has been wounded either by contact or by perforation or by grooving from a rifle bullet, a shrapnel bullet, or a shell or grenade fragment, in which there has been a lesion of the bony shaft by these projectiles, and, at a distance from the direct wound, we may find a simple oblique fracture caused by indirect violence to the shaft (Figs. 51, 71 and 82).

Complications.—We shall now consider the various complications associated with these injuries. The severity of the trauma not only of the soft tissues, but of the bone itself, depends upon the size, the shape, and the velocity of the projectile causing the injury, and here also, as with other wounds, the size of the projectile determines to a great extent the severity of the infection and the amount of contaminated matter which is carried into the wound. In the simple bone lesions caused by projectiles of a low velocity there may be no accompanying complications, and such wounds may heal aseptically, but, on the other hand, where the destruction of soft tissue and of bony tissue is much greater, various complications caused by injuries to other structures may accompany the wound in the bone.

The chief complications which we have to consider with this type of injury consist of hæmorrhage, either primary or secondary, of injuries to the nerves, of gangrene due either to injury or to occlusion of blood-vessels, of infection in its various forms and of necrosis of the bone fragments following the infection. The same general considerations as regards hæmorrhage, infection, and nerve lesions which we discussed in Chapter VII under "Wounds of Joints" hold good in the case of injuries to the diaphyses, and it will suffice merely to mention them in passing. The subject of necrosis, however, as well as that of non-union, will be considered more in detail later in this chapter.

Diagnosis.—The diagnosis of these various conditions which have already been described may be made by direct inspection of the bony injury at the time when the wound in the soft tissues is being cleaned up, and by the X-Ray. In those cases where there is a considerable degree of comminution, palpation of the injured part reveals a diffuse crepitation, but it is important in all gunshot fractures that no undue manipulation of the injured part should be made, as otherwise splinters which are still adherent to one another and which are attached by periosteum may become separated, and their attachments broken, and this is an important factor to remember, as it has a marked bearing on the treatment and the result. The size of the wounds of entrance and exit together with the direction of the track sometimes give us important information. The presence or absence of spicules of bone in the aperture of exit also determines the degree of comminution which has occurred, as may also the presence of fat globules, which are found present when there is much comminution of the long bones. In addition to this we find in the more extensive fractures deformity of the part injured, and in many instances the displaced edges of the bone may be felt subcutaneously. The diagnosis of the type of fracture is confirmed by radiographic examination. The various shapes which projectiles, such as rifle bullets and shrapnel bullets, assume on coming in contact with bony structures have been discussed in another chapter.

Prognosis.—In these days, with modern methods of asepsis, and a more complete knowledge of the repair of bone following injuries, together with more efficient methods of first aid and subsequent treatment, and with better methods of transportation, gunshot injuries of the bones give a much better prognosis than they did in the former wars with the older type of armament, and, while as yet very few statistics are available, from what information we can gather it seems fair to assume that the proportion of deaths from fractures will form a very small percentage of the total.

Treatment at the Front.—The preliminary treatment of such cases is important, as it determines to a great extent not only the comfort afforded by efficient apparatus during transportation, but has an important bearing upon the amount of infection which may result. Furthermore, preliminary treatment is of importance in the prevention of complications, such as injuries to blood-vessels, for if such fractures are not properly immobilised in the beginning the displacement of small fragments, due to transportation, may cause injuries to adjacent blood-vessels and, as a result, we may have a severe hæmorrhage.

Treatment at the front, therefore, should resolve itself into the disinfection of the skin wounds, the immobilisation of the fractured limb, and the application of protective dressings, the more extensive treatment of such fractures being reserved for the base hospitals.

Treatment at the Base.—This treatment is by far the most important, as it determines not only the rapidity with which these cases become again fit for duty or for discharge, but also determines the future usefulness of any limb involved.

Conservative Treatment.—Conservatism should be the rule, and no amputations should be performed unless conditions supervene which threaten the life of the patient, unless gangrene resulting from the occlusion of blood-vessels occurs, or unless it has been definitely proved that there is no regeneration of bone about the site of the injury or that a functionally good member cannot be obtained and that the patient will be far better off with an efficient artificial limb than he would be with a limb which would be a constant impediment to him. This is especially true in the case of the leg, a man with a modern, well-constructed artificial leg being able to do more and in a more efficient manner than he could with an improperly healed or deformed leg.

Perforated wounds by bullets as well as small comminutions and fissures associated only with a small wound in the external tissues heal readily if properly immobilised, and in such cases the external wounds usually heal aseptically, as there is practically no contaminated matter carried into such wounds by the bullet which causes the injury.

The larger lacerating wounds caused by deformed or deflected bullets, by bullets travelling at a high rate of velocity and having a divulsive and propulsive effect upon the bone fragments and, therefore, causing a large external wound of exit, as well as those wounds caused by shell and grenade fragments, require much more extensive treatment, not only as regards dressings and proper care, but also as regards the correct alignment and immobilisation by suitable apparatus. Such wounds are nearly always infected, and the degree of infection is here, as in other wounds, dependent upon the size and shape of the projectile inflicting the injury and the amount of contaminated matter which it carries in with it. In all wounds of the diaphyses associated with extensive lacerated wounds of the external tissues, as well as splintering or comminution of the shaft of the bone itself, conservative measures should still prevail. There is no doubt that if conservatism and patience are practised, many limbs can be saved and useful limbs be obtained in cases which at first seem hopeless.

If infection be present, the treatment in general of such wounds should consist of a free incision in order to obtain efficient drainage, the removal of foreign bodies, such as clothing or projectiles, and also the removal of bone fragments which are detached from all surrounding tissue.

It is an important point, and one which should be especially emphasised, that only those bone fragments which show no periosteal attachments or periosteal covering should be removed, and that all bone fragments, no matter how small, which are still attached to the periosteum should be left absolutely alone. These fragments which are still attached form an important point in the regeneration of such fractures, as so many of them still preserve their viability and will act as bone grafts and aid in the formation of new bone. This point has been illustrated time and again at this hospital, and we make it a rule here never to remove any such fragments until such time as it has been definitely proved that they are no longer viable or until spontaneous sequestration takes place. If we remove these fragments we retard the process of repair, and furthermore we may get as a result of such removal a condition of non-union or only partial union. It is far better to err on the side of leaving these fragments in place with the knowledge that they may have to be removed later than it is to remove them at the outset and then to feel that if they had been left in place they might possibly have been an important factor in the reunion of the bone.

The dressing of such wounds is important, as we must endeavour to remove as quickly as possible all infected foci and to establish clean and healthy granulations. In such cases the solutions which probably give the best results are the hypochlorous acid solution and the hypertonic salt

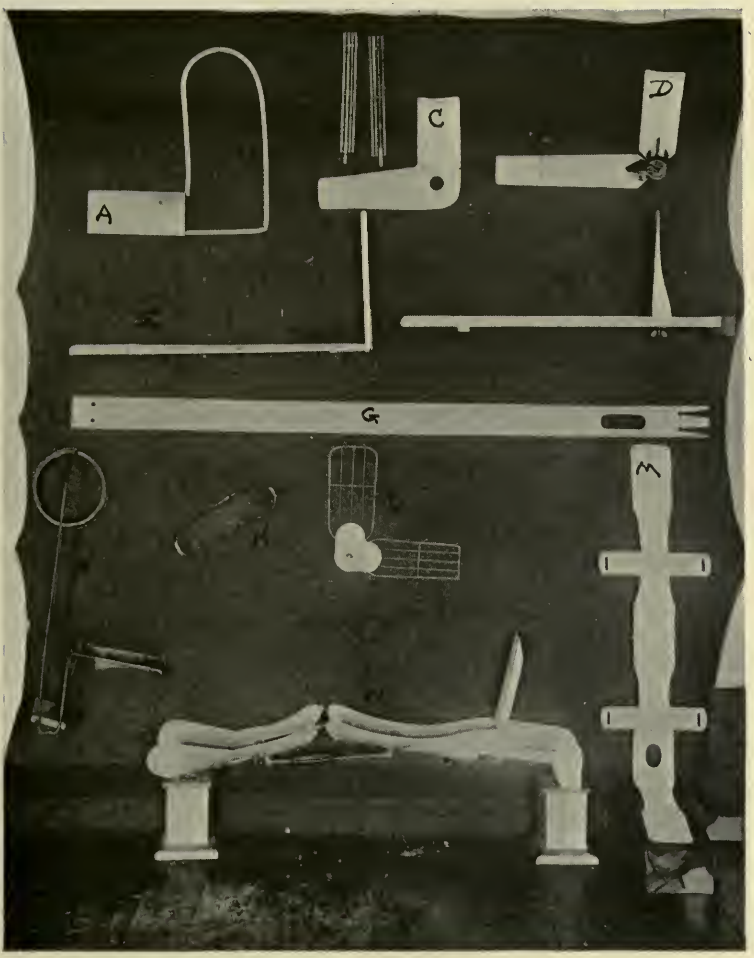


FIG. 68. Shows common types of English Army field splints. *A*. Splint for fractures of the arm. *B*. Emergency splint made of rattan. At the lower end of splint are seen two brass ferrules. This splint may be extended by slipping one of these ferrules over rattan at the other end. *C* is an arm splint. *D* is a jointed arm splint. *E* is an emergency splint for fractures of leg and is constructed of two pieces of wood held together by an iron brace. *F* is a Bach leg splint. *G*, Dupuytrens splint. *H* is a modified Thomas arm splint. *K*, a splint constructed of wire and wire gauze. *L*, an adjustable-angle wire arm splint. *M*, a Heyward's splint. *N* is a Liston thigh splint.

solution, and such wounds should be treated either by means of wet dressings frequently changed, and by irrigation at the time of changing the dressing, or by constant irrigation which will keep washing out of the wound the infected material.

One of the most important items in the treatment of such wounds, however, is the proper immobilisation of the injured bone, and this is important, not only in order to obtain correct position and alignment of the fragments, but also to prevent the fragments from moving, for if any abnormal mobility is allowed to persist, it will constantly constitute an added source of trauma and will preclude the possibilities of the infection subsiding as rapidly as it should.

For the permanent fixation of fractures at the base hospitals various types of apparatus may be used, and the type of apparatus utilised depends upon the nature of the injury and the position of the external wounds (Figs. 68 and 69). An apparatus to be efficient in open suppurating fractures should not only immobilise and hold in perfect alignment the fracture, but should also allow of easy access to the wound for constant and repeated dressings, and should at the same time be so arranged that it will be comfortable and will not become soiled by the discharge from the wound. The various types of apparatus and their methods of application will be discussed more in detail under their specific regions.

Radical Treatment.—This form of treatment consists essentially of amputation or of more extensive operative measures for the fixation of the bone fragments or where there is no union, and should be resorted to only when it has been definitely proved that conservative measures are of no avail or that the patient's life is threatened by a severe and spreading infection which can be controlled in no other way, or when there is extensive necrosis of the bone with no evidence of any regeneration.

Having discussed the various forms of fractures, we

FIG. 69. Shows the tin splints which are in common use in the A.W.W.H. *A* is a tin foot-drop splint. *B*, *E*, and *G* are different views of an internal angular splint. *C* and *H* are specially constructed splints to be used where there is a fracture of the forearm together with a solution of continuity of the extensor muscles. The splint has a tin gutter built to fit the arm with a piece at the bottom to keep the hand in a position of dorsal flexion. *D* shows a tin thumb splint. *F* is an Osgood-Penhallow humerus splint. *K* is an adjustable-angle ham splint. *L* is a splint for holding hand in position of dorsal flexion. *M* is a ham splint.

shall now consider the various bones involved and the treatment and the various forms of apparatus to be applied in each case.

Wounds of the Humerus.—Gunshot wounds of the diaphysis of the humerus consist of contact fractures by rifle bullets travelling at a low velocity, by shrapnel bullets, by shell (Fig. 70) and grenade fragments, of contusions, grooves (Fig. 71) and fissures (Fig. 72), by rifle bullets, shrapnel bullets, shell and grenade fragments, of comminutions (Fig. 73) caused by rifle bullets travelling at a high velocity and by shell and grenade fragments. They may also consist of indirect fractures which may be associated with any of the above-mentioned types of wounds.

Complications.—Associated with fractures of the shaft of the humerus we sometimes find injuries to the blood-vessels which lie in close relation to the diaphysis, or injuries to the brachial plexus or to the musculospiral nerve. Injuries to blood-vessels may give rise to an aneurism or to a total severance or occlusion of the artery, and, as a consequence of the latter condition, we may get a partial or total loss of circulation, with a resulting gangrene. Injuries, however, to the brachial artery are not so serious as regards the ultimate loss of the limb as are injuries to other arteries, as the collateral circulation readily re-establishes itself owing to the large number of anastomosing branches which are given off along the course of the artery especially in its upper part and about the elbow, and these branches readily accommodate themselves to the re-establishment of the circulation. Injuries to the brachial or musculospiral nerves occasionally occur and should be treated as will be described in a chapter on these special structures.

Infection is the principal complication with which we are concerned, as every gunshot wound of any size is infected, and we must always bear in mind the fact that such wounds may be contaminated not only by the pyogenic

Fig. 70. Oblique fissured fracture caused by shell fragment with some comminution caused by disintegrated bullet. Few small metallic fragments can be seen scattered throughout the tissues, as well as a few loose spicules of bone.

organisms, but also by the *B. tetani* and *B. perfringens*, and, furthermore, we must remember that the presence of

Fig. 71. Shows grooving fracture of humerus, just below head, also indirect fracture of shaft about 8 inches below this point. Fracture caused by bullet.

infection where there is much comminution of the bone may give rise to a severe and persistent necrosis which

FIG. 72. Shows fissured fracture of shaft of humerus caused by bullet. There are also considerable displacement and some comminution. Metal from fragmented bullet may be seen in tissues.

retards the regenerative powers of the periosteum in these bone fragments. Again, if such infection and necrosis be allowed to persist, non-union of the fragments may result.

Diagnosis.—As little manipulation as possible of the

Fig. 73. Shows comminution of shaft of humerus by rifle bullet, also indirect fracture 3 inches below.

arm should be done, as it can only establish the fact that abnormal mobility is present, and further confirmation of the type of injury should be made by means of the X-Ray after the arm has been immobilised. The appearance of the apertures of entrance and exit, as well as the direction of the track of the wound, gives one a considerable idea of the severity of the osseous lesion, and it is better to make the diagnosis by means of the X-Ray and by inspection rather than to cause a large amount of trauma by undue manipulation.

FIG. 74. Shows modified Thomas splint for fractures of the humerus.

Treatment—(*a*) *Conservative.*—After the diagnosis of the fracture has been confirmed and the position and condition of the fragments determined by means of the X-Ray, the type of apparatus to be used for immobilisation can be determined. In those cases in which the wounds in the external tissues are small, and if no infection be present and there be little or no fragmentation of the bone, a simple fixation apparatus will be sufficient. In such instances we may use an Osgood-Penhallow humerus splint (Fig. 69, *F*), which will correct any deformity from over-riding which may be present and which will also allow of the fragments being easily aligned. Furthermore,

Fig. 75. Shows Page aluminium splint applied for fractures of the humerus.

if only a small external wound be present, especially in the antero-posterior direction, this splint will allow of easy access for the dressing of the wound. Other types of apparatus consist of a modified Thomas splint (Fig. 74) or of a Page arm splint (Fig. 75), and either of these will allow of a certain degree of traction to correct the over-riding and will also give easy access to the dressing of the wounds (Fig. 76).

(*b*) *Radical Treatment.*—In those cases where there is a large extensive external wound associated with much comminution of the diaphysis and further complicated by

Fig. 76. Shows right-angle splint for fractures of the elbow or forearm. Splint constructed of aluminium.

the presence of extensive suppuration, operative measures should be immediately instituted and all necrotic and devitalised tissues removed, the wound thoroughly drained, and all bone fragments which are devitalised or which show no periosteal attachments should be removed. Such a wound will of necessity be immobilised in some apparatus which will allow of constant traction to preserve the alignment and to prevent shortening, and which at the same time will allow of ready access to the wounds either for constant irrigation or repeated changes of the dressing. Probably the best form of apparatus to use in this type of case is the Arm Extension apparatus, as shown in Fig. 77. This apparatus is fastened to the bed and is so arranged that it will allow of any degree of adduction or abduction of the arm, and the arm can thus be placed in the most advantageous position for the maintaining of the alignment. Furthermore, the arm support may be raised to such an angle as to aid the return flow of the venous blood and thus overcome any tendency to edema of the distal portions of the limb. Extension straps should be placed along the forearm and held in place either by means of adhesive plaster or by means of an adhesive varnish (Hausner's Glue), which is made as follows:

	Grammes
Resin	50
Alcohol	50
Benzine, Pure	25
Venice Turpentine	5

Powder the resin, then add half the alcohol, then the Venice turpentine, benzine, and wash out. Add remaining alcohol. Remove with benzine.

At the end of the extension straps is fastened a spreader, and the extension on the arm is obtained by means of sufficient weights to maintain the arm in good position and alignment without causing any undue amount of pull. With this apparatus the position can be maintained and dressings done without disturbing the position of the arm. Apparatus which is simple, which attains the desired result so far as maintaining the position and alignment is concerned, and which gives ready access to the wounds for dressings is preferable to the more complicated forms of apparatus which need constant readjustment. Later when the sepsis subsides and bony union begins to take place, some other form of apparatus, such as one of those which have been mentioned for the more simple types of fractures, may be applied. But it is most important in all these fractures, whether infection be present or absent, that the joints above and below the lesion should be immobilised and, further, that any tendency on the part of the muscles to cause deformity should be overcome.

FIG. 77. Shows extension apparatus for fractures of the humerus, as described in text. This apparatus was designed at the A.W.W.H. and is a modification of other forms which are in use elsewhere.

The later developments should be treated symptomatically, and as fragments of bone become necrotic or sequestrated they should be removed. Other forms of treatment for the immobilisation of fractures, where no other methods are available, will be discussed later, as will also the treatment of non-union.

The importance of conservative treatment and the leaving *in situ* of bone fragments is illustrated by the following case :

A. W., aged twenty-five, 3rd Grenadier Guards, was wounded on October 8th, 1915, during a counter-attack of the enemy at Hulluch. Patient received a bullet wound of the left upper arm. The bullet was fired from a short range. Received his first aid one hour later, and was transferred and admitted to the American Women's War Hospital on October 16th, 1915.

Examination on entrance as follows: Patient presents a gaping wound 4 inches long and 2 inches wide on the outer posterior aspect of upper third of left arm. There is a profuse purulent discharge from this wound. There is abnormal mobility of the humerus and comminuted fragments of bone may be seen in the wound of exit. X-Ray (Fig. 78 *A*) shows comminuted fracture of humerus at about junction of upper and middle thirds. Fragments vary in size from large to minute, and there is solution of continuity of the bone. Scattered throughout the soft tissues are many pieces of disintegrated bullet. On the day following admission the wound was thoroughly cleaned under ether anæsthesia and free fragments of bone were removed. Arm immobilised by means of an Osgood-Penhallow Splint. Wound dressed with hypochlorous acid.

November 16th.—Wound still discharging a considerable amount of pus. No evidence of union.

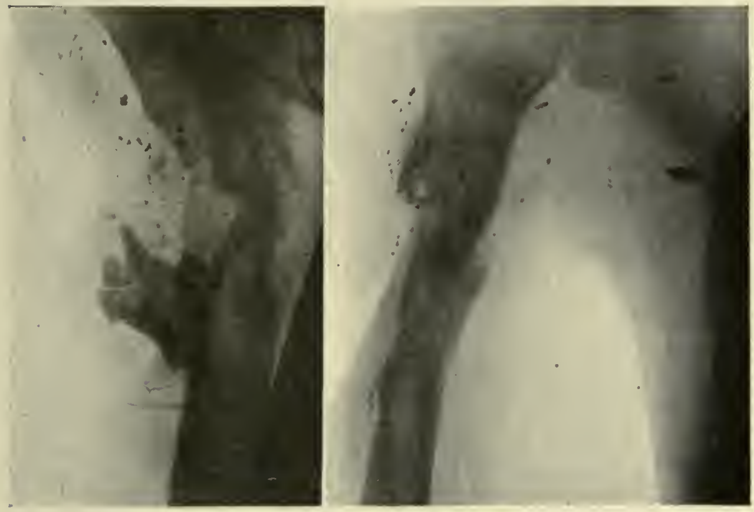
December 1st.—Patient running a moderately septic temperature for the past ten days, and wound discharges a few small pieces of necrotic bone.

December 3rd.—Ether; wound opened and several loose fragments of necrotic bone removed. One long spicule of bone found on posterior aspect of humerus, but as this still showed some attachment at its upper end it was left *in situ.*

January 1st.—Since last note wound has cleared up somewhat, but some necrotic bone may still be felt.

January 3rd.—Ether: wound explored and more necrotic fragments of bone removed. Wound left open and drained and dressed with constant hypochlorous acid. Patient in bed. Arm fixed on extension apparatus.

January 9th.—To-day there is some redness and induration in left axilla. Patient given gas in the ward and abscess cavity opened. Through-and-through drainage established.



A *B*

FIG. 78. *A* shows extensive comminution of upper part of humerus caused by bullet. Comminuted fragments vary in size from large to minute splinters of bone. Embedded in tissues may also be seen metallic fragments from disintegrated bullet, which fragmented on striking the humerus. *B* shows result 7 months after admission. There are good union and alignment, as has been described in text.

February 19th.—Since last operation temperature has become normal. Wound clean. Abscess in axilla entirely subsided. Wound in arm still discharging a small amount of pus. General condition good.

March 19th.—Patient up and about for the past week. Arm in splint. General condition good; patient has gained 13 lbs. during last month. Very little discharge from wound. X-Ray shows evidence of some callus formation, but clinically there is not much union.

April 19th.—Wounds closing in rapidly. Union much more firm.

May 15th.—Wound practically closed save for small sinus. X-Ray shows fragments in good position and alignment. Considerable callus formation has taken place along the bridge made by the long spicule of bone which had been left *in situ* (Fig. 78 *B*). Union good, alignment of arm good, patient having massage. Still in hospital at time of writing.

At one time it seemed doubtful whether the arm in this case could be saved, and as though it might be better, on account of the continued infection, to amputate. Through persistence and conservatism, however, there was a good functional result.

Prognosis.—In the more simple fractures where there is little or no comminution, and in the case of indirect fractures and in wounds caused by the smaller projectiles, such as bullets, aseptic healing may result or else healing with very little infection; but in the more extensive wounds where there is much laceration of the soft parts, together with more extensive infection and comminution, the prognosis may be much more serious and, furthermore, there may be associated with the infection and the destruction of the tissues severe injuries to nerves or blood-vessels which may result either in gangrene of the peripheral portion or a loss of function due to the nerve lesion.

Wounds of the Radius and Ulna.—In the forearm either the radius or the ulna alone may present typical bone lesions caused by projectiles, or both the radius and the ulna may be involved, depending upon the location of the wound and the nature of and course taken by the missile inflicting it. Injuries to either the radius or the ulna consist of fractures by contact from projectiles with a low remaining velocity, of fissures, grooves, and perforations

(Fig. 79). Deformed or deflected bullets give rise to more extensive injuries of one or both bones (Fig. 80), whereas bullets travelling at a high velocity, as well as shell (Fig. 81)

FIG. 79. Shows grooved and fissured fracture of radius caused by shell fragment.

FIG. 80. Shows perforated and fissured fracture of ulna from deformed and disintegrated bullet, fragments of which are seen in the tissues.

and grenade fragments, give rise to more extensive comminutions of one or both bones (Figs. 82 and 83). Occasionally cases are seen where there is a solution of continuity of the bony substance associated with an extensive lesion of tissue of the soft parts (Fig. 84). We may also find indirect fractures of one or other of the bones associated with a fracture at some little distance.

Complications of wounds of the bones of the forearm consist of hæmorrhage, either primary or secondary, of nerve injuries, and of infection.

FIG. 81. Shows comminution of radius and ulna caused by rifle bullet.

Hæmorrhage has already been considered in its different aspects.

Involvement of the nerves gives rise to typical lesions associated with such injuries, such as wrist drop or contractures of the fingers depending upon the nerve involved.

Infection is here as elsewhere one of the most important factors to be taken into consideration, for not only may we get a secondary hæmorrhage, but also an increased amount of necrosis of the bone fragments due to a persistent infection, and this, if allowed to continue, may give rise to non-

FIG. 82. Shows perforating rifle bullet wound of arm. Wound of entrance on flexor side and wound of exit shows large extensive wound on extensor surface. Bullet caused a groove in the radius with some splintering, and also an indirect oblique fracture about 1 inch from the groove. Range about 100 yards.

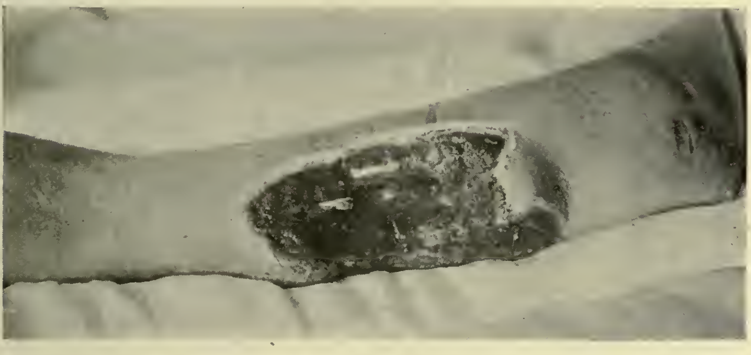
union in the shaft of the bone. Furthermore, if the tendons and tendon sheaths become involved by the infective process or have been injured by the original wound, we may get as a result a partial or complete loss of function due to the sloughing of these tendons. Again, if comminution of both bones be extensive, the motion of rotation and supination will be lost or partially lost, owing to bony union taking place between the radius and the ulna.

Diagnosis.—The diagnosis of fractures of the forearm depends upon the size and shape of the projectile, and upon the appearance of the wounds of entrance and exit

Fig. 83. Shows splintering of radius from shell fragment which is seen lying between the two bones.

and the direction of the track made by the projectile. Abnormal mobility and crepitation, especially if there be comminution, are present, but as little manipulation as possible should be made in order to verify the diagnosis. The appearance of the external wound will often indicate the degree of severity of the bone lesions, and the ends of the bone may be seen in this wound, or we may find small spicules of bone lying embedded and projecting from the tissues. The amount of damage, and the presence of associated foreign bodies, is best confirmed by means of the X-Ray.

Prognosis.—Simple wounds of one or both bones may heal aseptically and with very little deformity. Wounds where there is much comminution, caused by large shell



A

B

Fig. 84. *A* shows grenade wound of forearm with extensive destruction on ulna side. Ends of bones may be seen lying exposed in the wound. *B* shows the extensive destruction of the shaft with some comminution and splintering of the ends. Two small grenade fragments seen lying embedded in tissues.

fragments or by bullets travelling at a high rate of velocity and causing large destruction of soft tissues, give a more grave prognosis as regards the healing and ultimate return of function. The amount of destruction to the soft parts and the involvement of the nerves and tendons also complicate the prognosis as to function.

Treatment.—Treatment should follow along the same general lines which have already been laid down, and consist of control of the hæmorrhage, the drainage of the more extensive infected wounds, the removal of free bone fragments and any foreign bodies, and the immobilisation of the fragments by some form of apparatus which will allow of free drainage, and will at the same time hold the bones in proper position and alignment. If there be any nerve involvement, the apparatus should be such as will overcome any tendency towards deformity from relaxation of the muscles supplied by that nerve. Again, if there be much loss of substance of the muscles of the forearm, the apparatus should be so constructed as to bring the injured muscles into the best apposition, so that when healing takes place there will be a minimum of scar tissue interposed between the severed ends. The apparatus to be used will depend to a great extent upon the size and the locality of the wound of exit. Such a wound is usually of a large size, owing to the tearing effect of the secondary projectiles, such as bone fragments, which have been propelled through the tissues and have exerted a divulsive effect upon the muscles and skin, as is commonly seen in those injuries which have been caused by bullets, especially of shorter ranges. It is important that the wrist joint as well as the elbow joint should be immobilised, and that not only should the bone fragments be fixed, but the apparatus should be so arranged that dressings can be carried out without having to disturb the position of the arm.

Various forms of apparatus have been devised. Splints made of tin and so constructed as to conform to the shape of the arm and to keep the hand in proper position, and overcome any tendency which might result from the severance of the muscles or from injuries to nerves, afford one of the simplest forms of apparatus, but it is necessary that such splints should be built for each individual case, as the conditions vary in each instance. Such a splint is shown in Fig. 70, C and H. Splints made of wire and so constructed that there is a bridge at the site of the wound which will allow of easy access for dressings are also of use, and plaster of Paris forms one of the most efficient forms of apparatus, as it will allow of absolute fixation. This is best applied in the form of a bridged plaster with metallic bridges incorporated into the plaster in such a way as freely to expose the wound and yet allow of adequate fixation. With such an apparatus dressings of any nature may be easily applied. Later, when the wounds are healed, other forms of apparatus may be applied to overcome any deformity. It is important that all fragments of bone which show any attachment should be left in place, and only those which are detached should be removed.

Conservative treatment therefore should be the rule in those cases, and amputation should be performed only in those instances where there is complete destruction of the tissues and a resultant gangrene or where an infection which threatens the patient's life supervenes. In every case an attempt should be made to save as much as possible.

Wounds of Metacarpal Bones.—Wounds of the metacarpal bones consist of fractures by contact from shell fragments (Fig. 85), from shrapnel bullets or from rifle bullets with a low remaining velocity. They also consist of comminutions and destruction of tissue from projectiles moving at a high rate of velocity, and these may be caused not only by rifle bullets, but by small shell fragments which still retain a high velocity. Associated with injuries to the metacarpal bones there is usually extensive laceration of the soft parts, and the tendons and fascia become torn and split not only by the impact of the projectile causing the injury, but also on account of the comminution of the metacarpals themselves.

Complications.—The complications in these instances consist usually of destruction of the flexor and extensor tendons of the hand, of marked deformity due to destruction of tissue, and also of hæmorrhage from the deep or superficial palmar arch, caused either directly by the

FIG. 85. Contact fracture of 3rd, 4th, and 5th metacarpal bones by shell fragment, which is seen lying *in situ*.

projectile inflicting the injury or by secondary projectiles from the injured bone.

Owing to the anatomical structures which are found in this region, infection is most important. The structures which play the most important part here as regards infection are the tendon sheaths of the palm, for if an infection in this region be not local, it may mean involvement and loss of the flexor tendons of the palm with a consequent loss of function of the fingers. Associated also with this infection we may find a palmar abscess, or the infection may give rise to a secondary hæmorrhage in the deep or superficial palmar arches.

Late complications consist essentially of contractures and loss of function of the fingers from adhesions about the tendons.

Diagnosis.—The diagnosis of fractures of the metacarpals is as a rule easily made. There is deformity in the region of the wound associated with crepitation and pain. Frequently the fractured ends of the bone may be seen protruding from the wound, and again, especially in the case of shell fragments, a mass may be felt lying in the tissues and grating against the bones. The diagnosis is readily confirmed by X-Ray, which shows also the amount of destruction which has been inflicted.

Prognosis.—In the smaller wounds with a relatively simple fracture and very little destruction of soft tissue the prognosis is good, but in the more extensive comminutions, where there is destruction of the soft parts and tenderness associated with infection, necrosis may result and prognosis as regards function should be guarded.

Treatment.—The treatment of fractures of the metacarpals resolves itself into the treatment of the wounds of the soft parts, the overcoming of the infection, the removal of contaminated matter and foreign bodies and the removal of loose fragments of bone, the control of hæmorrhage, and finally the application of an apparatus which will hold the fractures in proper alignment and also overcome the tendency towards deformity. Adequate drainage also is necessary. Later, after the wounds have healed, and union has taken place, massage may be started and, if necessary, operation for the freeing of tendons from adhesions and the formation of new tendon sheaths by means of fascia or fat may be done.

Apparatus in these cases may consist of wire splints to hold the bones in alignment or some form of extension splint should be applied. If the wounds are small and there is little infection, or later, after the wounds have healed, and before union has taken place, the deformity may be best overcome by using a roller bandage splint and flexing the fingers over this. But no hard-and-fast rule can be laid down concerning any apparatus, as existing conditions must govern the best types to be used.

Fig. 86. Shows grooving fracture of phalanx with radiating fissures, caused by bullet.

Wounds of the Phalanges.—Wounds of the phalanges consist of fissures, of grooves (Fig. 86) or perforations (Fig. 87) with comminution, and of extensive comminutions with many small detached bone fragments (Fig. 88). Such injuries are usually caused by bullets, and more extensive injuries caused by shell or grenade fragments consist in most cases of a total loss of the phalanx as well as of the surrounding soft parts.

Complications.—The principal complication which we

Fig. 87. Shows perforation of proximal phalanx simulating a butterfly fracture. Wound caused by bullet.

Fig. 88. Shows comminution of terminal and proximal phalanx of thumb with complete destruction of the interphalangeal joint, caused by bullet.

have to consider in these regions is infection and loss of function of the finger.

Diagnosis.—The diagnosis is easily made by inspection and by means of the X-Ray, and the severity of the injury determines to a great extent the treatment to be followed.

Prognosis.—In the smaller uncomplicated wounds the prognosis is good. With the more extensive wounds associated with infection and involving destruction of tendons, prognosis as to function is poor.

Treatment.—Grooves of the phalanges and perforations with slight comminution and little separation of the fragments are best treated by conservatism, especially if the wound be situated towards the centre of the diaphyses. The fracture should be immobilised on a splint which will allow of easy access to the wound for dressings, the loose detached fragments of bone should be removed, and adequate drainage established if infection be present. Some of these wounds may heal aseptically, and in such the prognosis is better as regards function, unless there be associated with the injury a destruction either of the flexor or of the extensor tendon.

In the more extensive wounds, associated with a considerable degree of comminution or with infection and destruction of the tendons, amputation gives the best result. In the more simple cases later operations may be done for the freeing or repair of adherent or severed tendons.

Fractures of the Femur.—These consist of contusions or erosions and perforations due to projectiles striking tangentially, to projectiles of a low velocity striking directly, and to rifle bullets of low velocity. Rifle bullets and shell fragments of low velocity cause contact fractures and fissures, and rifle bullets travelling at a high velocity cause gutters or furrows (Fig. 89) and also extensive comminutions (Fig. 90). Shrapnel bullets and shell fragments cause fissured fractures and comminutions, as do also deformed and deflected bullets (Fig. 91). Indirect fractures are also occasionally seen and are caused by trauma elsewhere, such as from a severe blow of the lower leg by a larger shell fragment (Fig. 92).

Complications.—Complications here as elsewhere consist of hæmorrhage, either primary or secondary, due to involvement of the femoral vessels, of injuries to the

Fig. 89. Shows shell wound of femur. Shell fragments may be seen lying in soft parts. Fragments carried away part of the cortical bone of the shaft and caused a deep furrow.

sciatic nerve, and of infection. Other complications consist of extensive lacerations of the muscles of the thigh and the formation of hematoma from injuries to these muscles or to the blood-vessels.

Diagnosis.—The diagnosis is made by the direction and nature of the wounds in the soft parts, by the deformity or shortening of the thigh, by crepitation which is palpable, and by the finding of spicules of bone in the aperture of exit. It is important here, as it is in the case of all fractures, that no undue manipulation should be made in order to determine the severity of the fracture, and X-Ray

FIG. 90. Comminuted fracture of femur caused by rifle bullet. Marked deformity and displacement of fragments.

should be used to confirm the nature and extent of the lesion.

Prognosis.—In the more simple fractures caused by the small projectiles and where there is little or no comminution of the shaft, or where there is a perforation or gutter wound or even an oblique fracture, the evolution may be relatively aseptic, but with the larger lacerated wounds where there is marked destruction of the soft parts, associated with infection and extensive comminution of the shaft,

Fig. 91. Oblique and fissured fracture from deflected bullet, fragments of which are seen still embedded in bony tissues.

the condition may become very serious, either owing to the rapid spread of the infection through the fascial planes, or to erosion of the blood-vessels or the formation of a large infected hematoma. Furthermore, the amount of resultant deformity or shortening is dependent upon the degree of comminution which has occurred, and upon the severity of the infection which takes place. If a severe sepsis be present or if there is evidence of infection by *B. perfringens*, the prognosis is grave, and this is especially so

Fig. 92. Shows an oblique fracture of the lower end of the femur with displacement downward and backward into the joint of the upper fragment. This was an indirect fracture which occurred coincidently with a shell wound of the lower leg which carried away the soldier's foot. Amputation was later done on account of infection in the joint.

if there be any disturbance of the circulation. Often when there is no infection but there is a marked lesion of the blood-vessels and disturbance of the peripheral circulation, the outlook as regards the saving of the leg is not good.

Treatment.—The treatment of the uncomplicated fractures of the femur consists of disinfection or excision of the wound, of the application of an occlusive dressing and of proper fixation or extension apparatus. In the larger lacerating wounds where there is much infection or much comminution of the fragments, much more extensive treatment is required. Wounds should be thoroughly excised and drained, all contaminated matter and foreign

Fig. 93. Shows Page aluminium extension splint for fractures of the lower leg and thigh.

bodies and detached fragments of bone removed, and any incident hæmorrhage controlled. The leg is then immobilised in some form of fixation and extension apparatus and every attempt made to overcome any shortening. In such cases as the latter, various forms of apparatus may be used, depending to a great extent upon the nature of the fracture and the position and condition of the external wounds. Reduction under ether and the application of a plaster spica with metal bridges over the site of the wound affords one of the best forms of apparatus. Other forms of apparatus consist of a modified Thomas Splint with extension, a Page Extension Thigh Splint (Fig. 93), and in some cases a simple Buck's Extension with the patient on a Bradford Frame will suffice.

In some instances, where the wounds in the soft parts are extensive and considerable added trauma would be caused to the patient by the removal of apparatus or by moving him in order to dress the wounds, a suspension apparatus (Fig. 94) gives the most satisfactory result.

Fig. 94. Shows suspension frame for fracture of the thigh. This frame was constructed in order to facilitate dressings, as the thigh was very badly infected and any movement caused extreme pain to the patient. A Bradford frame is supported on two crossbars and over the frame is a hammock which can be suspended to the hooks on the upper bar. When it is required to do a dressing the hammock is caught over the hooks, the Bradford frame is dropped out and the patient remains suspended. By this method the wound is freely accessible for dressing, while at the same time the patient is disturbed very little.

With such an apparatus the patient may be kept on a Bradford Frame with constant extension applied to his leg. To facilitate dressings the patient lies on a hammock which is placed over the frame, and this can be suspended to the hooks placed on the apparatus and the frame dropped, leaving the patient suspended in the air. The wound is then easily accessible for dressings, and this method can be carried out without disturbing the position of the limb or causing any undue pain to the patient. As healing takes place in the wound, spontaneous sequestration of loose fragments will result, and these should be removed as they occur, and later, after callus formation begins to take place, a more simple form of apparatus may be applied.

In the more extensive wounds, where there have been laceration of the soft tissues and involvement of the blood-vessels, ligation for the control of hæmorrhage should be immediately performed, hematoma should be evacuated, and, if a severe sepsis supervenes and secondary hæmorrhage constantly recurs and, further, if there be evidence that there is an occlusion of the circulation, amputation should be done. Amputation is also indicated even in cases of indireet fracture if the infection extends and persists, and this is shown by the following case, in which the patient received an indirect fracture of the lower end of his femur caused by a shell wound which amputated his lower leg just above the ankle.

F. C. S., aged eighteen, 19th London Regiment, wounded on September 26th, 1915, by a shell, while making a charge at Loos. Shell carried away his left foot and at the same time his left knee was injured by the force of the blow on his leg. A circular amputation was performed at one of the ambulances. Patient was finally admitted to the American Women's War Hospital on October 19th.

Examination at that time was as follows: Left leg presents at a point 9 inches below the tibial tubercle a circular amputation stump. Wound clean and granulating, but skin edges have retracted and end of tibia is exposed. Skin adherent and tender. Left knee is held in a position of semi-flexion and the relation of the long axis of his lower leg to that of the femur simulates a case of genu varum. Knee swollen and painful, and deformity very apparent. Patella displaced outward. Passive motions of knee very much limited and leg cannot be extended. Active motions nearly absent. Patient rather anæmic, and not in specially good condition physically. X-Ray shows oblique fracture (see Fig. 92) through the condyles with marked displacement of the upper fragments downwards and backwards to a level of the condyles. Considerable bony union. The problem in this case was to reduce the fracture, and to immobilise it when reduced. This was especially difficult on account of the amputation stump, which would not allow of the application of any efficient traction apparatus. It was therefore decided to perform an open operation to reduce the fracture and to plate it.

October 25th.—Ether: Incision 6 inches long on outer end of thigh. Fracture exposed. Moderate callus formation found. Fracture exposed, reduced, and held in position by a Shermann's bone plate. Wounds closed in layers. Posterior and anterior flaps made over amputation stump. Tibia and fibula shortened and wound closed with drainage.

November 1st.—Amputation wound healing satisfactorily, small amount of drainage at angles where drains had been inserted.

November 16th.—For past few days patient has complained of considerable pain in femur over site of wound. Since operation has been running an irregularly elevated temperature. Examination of leg shows some swelling about wound, which has healed by primary union. Lower end of scar swollen and fluctuant.

November 17th.—Gas anæsthesia: Incision through scar and 3 ounces of pus evacuated. Wound drained.

November 20th.—Wound clearing up, swelling and tenderness have entirely disappeared.

December 1st.—Wound entirely healed. There is still some swelling about knee joint. Motions of leg fair. Alignment excellent. Is now having massage and passive motions. X-Ray shows fracture to be in excellent position.

December 28th.—Up and about on crutches. Wounds healed solid. Some swelling in knee still persists, but there is no pain. Movements of knee fair.

January 15*th*.—About a week ago a small discharging sinus developed in wound on thigh. Considerable pain in knee. There was also a slight elevation of temperature. Movements of knee are good, but there is considerable general tenderness about the knee joint, especially on the outer side, and a small amount of a thin purulent discharge may be expressed from this sinus.

January 30*th*.—Ten days ago temperature became much more elevated. Scar became swollen and fluctuant. Again incised under gas anæsthesia and a large pus pocket was found and evacuated. Since that time knee has been swollen and tender and motions very much limited. X-Ray shows marked proliferation of callus. Amputation deemed advisable on account of patient's general condition, as he was showing signs of toxic absorption.

January 31*st*.—Ether : Long anterior flap made with lower border just above patella ; short posterior flap. Muscles and deep tissues found to be edematous and porky, and when femur was exposed a distinct osteomyelitis was found. Soft tissues retracted until normal bone was exposed, which was at a point 4 inches above the condyles, at which point amputation was done. Bleeding points ligated and sciatic nerve cut short. Muscles sutured with interrupted catgut and cigarette drains inserted to end of femur and to either angle of wound. Skin closed with interrupted sutures. Good ether recovery.

February 10*th*.—Wound healing by primary union except at site of drains, where there is a slight serous discharge.

March 5*th*.—Wound healed solid. No pain or tenderness. Since amputation patient has gained steadily in weight and now looks much improved. Up and about on crutches and ready for discharge.

March 27*th*.—Discharged for invaliding. Examination of femur after amputation showed a marked condition of osteomyelitis with proliferation into the knee joint. There was also a fissured fracture extending down between the two eondyles into the joint and the articular surfaees were eroded, and whether or not the infection of the wound in the thigh was the result of infeetion from the lymphaties at the time of operation eould not be absolutely determined, but seemed probable in view of the faet that every possible preeaution had been taken to perform an aseptic operation in this region.

The following ease illustrates the need for radieal treatment where no union takes plaee after a prolonged eonvaleseenee, and where there is an extensive neerosis with no attempt at regeneration.

T. H., aged twenty-seven, 2nd South Staffs, was wounded on May 16th, 1915, at Festubert, by a shell fragment whieh struek him on left thigh just above knee. Was transferred to hospital at Rouen and operated upon there on May 19th; the shell fragment was removed and drainage instituted.

June 6th.—At Rouen was operated upon again and wound ineised and drained.

Admitted to the Ameriean Women's War Hospital on July 30th, 1915. Examination at that time was as follows: Left thigh just above knee shows mueh thiekening; 3 inehes above patella is a praetieally healed granulating wound 2 inehes by 2½ inehes; at same level on outer side is a wound 1½ inehes long whieh is draining thiek pus and in whieh is a rubber-tube drainage. On inner side, at the same level, is a healed granulating wound; and on outer side of thigh in upper third is a healed wound 1½ inehes long and 1½ inehes wide; all tissues indurated and edematous, and the sears are rather pale and elevated. Palpation of knee painful; some abnormal mobility and erepitus.

X-Ray shows oblique and eomminuted fraeture through the eondyle of femur and displaeement inward and downward of fragments.

August 14*th.*—Wound on inner side became swollen and fluctuating yesterday. Gas anæsthesia. Incision and drainage and a large amount of pus evacuated.

September 1*st.*—Wound on outer side healed. Wound on inner surface still discharging a considerable amount of pus and also some necrotic bone fragments.

October 1*st.*—Condition practically the same.

October 29*th.*—Ether. Operation : Incision 6 inches long carried through outer side of thigh and fracture exposed. Necrotic bone removed and fracture reduced. Wound closed with drainage, and leg immobilised on Thomas Extension Splint. At time of operation the bone at site of fracture was found denuded of periosteum and pitted. Chances of union seemed very remote, but it was decided to see if any repair would take place.

November 6*th.*—Wound discharging freely; patient comfortable in apparatus.

November 21*st.*—Wound still discharging freely, but is gradually closing in.

December 21*st.*—Condition practically the same.

January 5*th.*—Gas. Incision on outer aspect of thigh re-opened ; considerable amount of necrotic bone removed. Denuded bone could be felt and there was apparently no union between the fragments.

January 15*th.*—Discharge much diminished since last operation ; condition satisfactory.

January 30*th.*—X-Ray shows fragments to be in good position, but there is no evidence of any union. Considerable necrotic bone could be made out by means of the X-Ray. In view of the fact that after so many months there had been no attempt at regeneration of the bone, amputation was deemed the only possible solution.

February 8*th.*—Ether. Operation : Long anterior and short posterior flaps were made. Subcutaneous tissue was found to be very edematous and porky. As soon as the muscles were severed, the lower portion of the femur separated at the site of fracture. Lower end of upper portion of femur found to be very much necrosed, and there was absolutely no evidence of repair. Soft tissues dissected back until normal bone was found, which was at a point about 4 inches above the condyles, and the femur was resected at this point. Wound closed with drainage.

Fig. 95. Perforating bullet wound of tibia. *A* shows small oval aperture lying just in front of fibula. *B* shows the track made by the bullet, with a few fragmentary parts of bones about aperture of exit.

February 28th.—Much more comfortable since operation; stump draining small amount of pus.

March 5th.—Wounds in angle discharging slightly; remainder of wound healing primary union.

March 20th.—Discharge much less; up and about on crutches.

April 2nd.—Stump slightly œdematous. Wound entirely closed except for a small sinus from which there is a little sero-purulent discharge. Patient showed an

Fig. 96. Shows perforation of tibia by rifle bullet. Considerable loss of substance around wound in tibia, as may be shown by the thinning of the shadow; and two long fissured fractures may be seen radiating from the wound through tibia.

uneventful convalescence and was finally discharged for invaliding.

Fractures of Tibia and Fibula.—Often one or other of these two bones may be injured alone, depending upon the nature and the direction of the projectile causing the lesion, and this may occur especially with rifle bullets, shrapnel bullets, shell and grenade fragments of varying size, as well as deformed and deflected bullets. Such injuries are usually caused by the projectile striking in an

FIG. 97. Shows perforation and splintering of fibula caused by rifle bullet. This fracture has a tendency towards the so-called "butterfly" type.

antero-posterior direction, although it may happen that lesion of a single bone may occur when the projectile strikes laterally. Fractures of both bones may result from rifle bullets travelling at a high rate of velocity and striking laterally or tangentially, or, in the case of shell fragments, striking laterally and with considerable force. Occasionally the tibia may be fractured in such a manner, and a fracture by indirect violence be caused at the same time in the fibula, and we may also find that the fibula may be

FIG. 98. Shows contact fracture with radiating fissures caused by the lead core of a deformed bullet. Bullet was found embedded in bone, and was removed.

fractured in two places at a distance from each other The severity of the injury of these bones depends upon the nature of the projectile inflicting the wound. Rifle bullets travelling at a moderate rate cause perforations (Fig. 95) or grooves (Figs. 96 and 97), whereas rifle bullets travelling at a high rate of velocity may cause extensive comminutions, as may also some of the larger shell fragments travelling at a high velocity. Deformed and

FIG. 99. Shows erosion of the tibia just below the tubercle, caused by a small shell fragment, which may be seen lying just above the erosion.

deflected bullets (Fig. 98), striking the bone direct and at a low rate of velocity may cause fissured fractures, as may also smaller shell fragments. Rifle bullets with a low remaining velocity and small shell fragments (Fig. 99) may perforate one side of the bone and cause fissures, this being more especially true of the tibia. Contact fractures may be caused in one bone or the other by small shell fragments (Figs. 100, 101, 102), by shrapnel bullets, by

FIG. 100. Shows splintering of tibia caused by small shell fragment. Contact fracture.

rifle bullets either deformed or deflected and travelling at a low rate of velocity. Grenade fragments cause a varying degree of comminution (Fig. 103) or splintering of one or of both bones, depending upon the nature of the fragment causing the injury and the force with which it strikes the tissues.

Complications.—The complications which we have to consider in this region consist of infection, depending upon the nature of the projectile causing the injury, and the size of the external wounds, hæmorrhage either primary or secondary from the anterior and posterior tibial arteries,

Fig. 101. Contact fracture of fibula caused by small shell fragment, which is seen lying against fibula.

involvement of the external peroneal nerve, if the fracture be near the head of the fibula, and also involvement of tendons near the lower end of the leg.

Diagnosis.—In the simple wounds caused by rifle bullets, where there may be merely a perforation of one or other of the bones of the leg or an erosion or contusion or simply a groove without complete fracture, the diagnosis is confirmed by means of the X-Ray. In the more extensive

Fig. 102. Contact fracture by large fragment of shell, seen lying in tarsal region. There is very little splintering of the tibia, and fracture is of the long oblique type.

lesions if both bones be involved, the deformity is apparent and fragmented pieces of bone may be felt subcutaneously, and crepitation is discernible on palpation. If one bone only be involved, abnormal mobility and crepitus of that bone furnishes the diagnosis, which, however, should be confirmed by the X-Ray.

Prognosis.—The prognosis of the more simple types of injuries is good, as such wounds may heal aseptically.

Fig. 103. Grenade wound of tibia showing complete fracture with very moderate comminution. Grenade fragments seen embedded in tissues.

With the more extensive wounds, where there is any degree of comminution, the prognosis as to the ultimate outcome, especially if there be much infection, should be guardedly careful, as often delayed or non-union may result. If there be any disturbance of the circulation of the foot, and especially if infection be present, the prognosis should be guarded.

Treatment.—With the more simple types of injury, where a complete fracture does not exist, disinfection of the wound, an occlusive dressing and fixation by means of a posterior wire splint or by plaster of Paris will suffice (Fig. 104). Where fracture of one or both of the bones exists, the treatment should be as has already been de-

Fig. 104. Shows bridged plaster applied for an infected gunshot wound of the leg in order to facilitate dressing and at the same time to immobilise the fragments.

scribed, namely, disinfection of the wound, the establishment of adequate drainage if infection be present, the removal of foreign bodies and of detached fragments of bone and the proper fixation. If no deformity exists, a simple posterior splint, such as a Liston (Fig. 105) or a Cabot Posterior Wire Splint (Fig. 106) or a plaster applied so as to allow of the dressing of the wound will suffice. In the more extensive wounds involving both bones, where there is over-riding of the fragments and deformity, and when infection is present, the wound should be thoroughly disinfected and drained and all loose fragments of bone and all foreign bodies should be removed and reduction effected while the patient is still under the anæsthetic. A bridged plaster should be applied, as this is a

Fig. 105. Shows a Parker suspension apparatus and method of application. Patient's leg is immobilised on a Liston splint and is suspended on the travelling crane and counterbalanced by the weights. Patient is able to raise and lower his leg himself, and also to sit up or to lie down in bed, all motions which he makes being counteracted by the travelling of the crane and by the rise or fall of the weights. In this position the suspension cord should be exactly perpendicular. It was held in this position to facilitate the taking of the photo and to show the different cords.

most efficient form of fixation apparatus and also allows of ready access to the wound for inspection and for dressings.

It is important in all fractures of the leg that the position of the foot be maintained at a right angle, for if this is not done a considerable degree of disability may follow when the apparatus is removed, and this is especially true of those cases in which there is any nerve involvement. In such cases the foot should be if anything over-corrected in order to prevent undue stretching of the muscles supplied by that nerve. Conservative treatment will usually suffice

A

B

FIG. 106. *A*. Cabot posterior wire splint. *B*. Splint covered and applied.

in such cases, and it is important here as elsewhere that all bone fragments which show any attachments whatsoever should be left in place, as they form an important adjunct in the healing of such wounds.

In cases where there has been extensive comminution and destruction of tissue, as well as involvement of the vessels, amputation may be necessary, especially if there be a severe infection or if gangrene supervenes.

Fractures of the Metatarsals.—These are caused by bullets striking directly or tangentially, by shell and grenade fragments and by shrapnel bullets, as well as by deformed and deflected bullets. Such fractures may be caused merely by contact and may be simple in nature, or there may be extensive comminution and solution of continuity, especially in the case of rifle bullets travelling at a high rate of velocity or from deformed or deflected bullets and shell fragments.

Complications.—The complications consist of hæmorrhage, of destruction of the plantar muscles or of the tendons of the foot, together with necrosis and also a possible resulting deformity.

Diagnosis.—The diagnosis is made by inspection, by palpation and by X-Ray, and here also the degree of injury may be determined by the severity of the external wound.

Prognosis.—The prognosis of the more simple injuries is good, but with the more extensive injuries should be guarded, as sometimes a painful foot will result, which will detract from the man's usefulness as a soldier.

Treatment.—Conservatism should be the rule in such injuries, as it may so happen that wounds which seem hopeless, so far as the saving of the foot is concerned, yield to conservative treatment, and a foot which is functionally good may result. The treatment consists, as has already been described, of adequate drainage, the removal of contaminated matter and foreign bodies and detached fragments of bone, the correction of the deformity and the immobilisation of the foot by means of a plantar splint.

In those cases in which there has been so much destruction of tissue that the outlook is hopeless, or in cases which do not yield to conservative treatment or in which the result will be a foot so deformed as to render the patient unable to walk, an amputation should be done, as a man with a good modern artificial leg will be more able to perform his duties than will a man hampered by a painful foot on which he is unable to walk.

The value of conservative treatment in such cases is well illustrated by the following case, in which the condition of the foot on entrance seemed hopeless.

W. D., aged twenty-two, 5th North Staffs, was wounded on October 13th, 1915, at Hulluch, by a rifle bullet which perforated the soft parts of his left leg about 4 inches above his ankle and then became apparently deflected and ploughed a furrow across the dorsum of his right foot.

Was admitted to the American Women's War Hospital on October 16th, 1915, and examination at that time was as follows: Dorsum of right foot presents an extensive lacerated wound of the whole of the upper surface extending transversely across the foot (Fig. 107 *A*). The edges of this wound are everted and blackened and are widely gaping, and from this wound the fractured ends of the metatarsal bones are seen protruding. There is a fracture of first, second, third, and fourth metatarsals with a loss of substance of the first and second metatarsals (Fig. 107 *B*), the direction of the bullet when it struck the right foot apparently being from the plantar surface outward and upward. Wound moderately infected. There is complete severance of the dorsal tendons, but the circulation of the toes is only slightly impaired. Left leg presents about 4 inches above ankle an infected perforating wound through the muscles in the posterior aspect of tibia. There is no bone involvement in the left leg.

October 20th.—Ether. Operation: All necrotic and devitalised tissues excised. First three metatarsals badly comminuted, and all detached and loose fragments of bone removed. Wound packed wide open for drainage.

November 20th.—Wound clean and granulating except

A

B

C

Fig. 107. A furrow wound of foot caused by a deflected bullet which passed through the left leg, and then struck his right foot. *A* shows appearance of wound with widely gaping furrow with averted edges. *B* shows the condition as shown by X-Ray, with loss of continuity of the first and second metatarsals. *C* shows appearance on discharge seven months after being wounded. Condition described in text.

for some sloughing of tendons and fascia, which were removed.

December 20th.—Wound granulating in rapidly, a small amount of a sloughing tendon over the fourth metatarsal was removed.

January 6th.—Ether. Wound clean and granulating, edges freshened and wound curetted. Closed by secondary suture.

January 15th.—Wound healing well except for two small sinuses over first and fourth metatarsals. Since that time sinuses have gradually closed in. Occasional small fragments of bone have been removed, and patient was discharged for invaliding on May 19th with the following note: "Wounds entirely closed (Fig. 107 *C*). Foot of good formation but considerably shortened, especially over the first and second metatarsals. Union of third, fourth, and fifth metatarsals firm. Fibrous union of first and second metatarsals, but patient is able to walk without discomfort and for all purposes has a good functional foot."

In addition to the general lines of treatment which have been discussed in the treatment of fractures of the diaphyses, conditions also arise which necessitate more extensive measures, not only for the reduction and immobilisation of fractures, but also as a form of treatment in cases where there is loss of continuity in the bone shaft, or where there is delayed, partial, or non-union of the fragments.

We will, therefore, consider such treatment under two headings:

1. The Reduction and Fixation of Open Fractures by means of a *Bone Plate.*
2. *Bone Grafting*, for Delayed or Non-Union, or for Loss of Continuity.

1. Bone Plating.—Open fractures caused by gunshot injuries give rise to many complex problems in their treatment, and often such fractures are seen in which proper apparatus for the fixation and the alignment of the fragments cannot be applied, owing to the size and the location of the external wounds.

With such wounds there are two methods of treatment. The first method is to reduce the fracture as well as possible, to immobilise it and to hold it in as good a position as possible under the circumstances, to promote efficient drainage, and to wait until the external wound has entirely closed and all infection has subsided before instituting further measures for the correction of the deformity or for the alignment of the fracture. The second method in such wounds consists of immediate reduction of the fracture and the holding in alignment and position by means of a bone plate, the application of an efficient fixation apparatus with the bones held in good alignment, and the promotion of free drainage. With such treatment there will be no necessity for subsequent operations to overcome any existing deformity, as proper alignment is secured from the beginning.

This latter method has been more or less universally condemned, and the reasons which have been given for its condemnation are that such a procedure increases necrosis, that no union takes place in the presence of the infection, that convalescence is protracted, or that union may be unduly delayed.

Over a year ago I tried this method on some of our cases here, as it was the only way in which proper position and alignment could be obtained, and the results which I obtained were so satisfactory that it seemed to me a justifiable procedure; and since that time fifteen cases of this type of wound have been plated with no failures and with excellent functional results. If the existing conditions, the limitations and dangers from the application of the bone plate are taken into consideration and guarded against, it would seem to be an ideal method of treating such fractures, especially in the hands of the more experienced operators.

We have had here in hospital the opportunity of comparing this method with methods which have been advocated, and the conclusions at which I have been able to arrive are these :

(1) Even if an infection in the wound be present, union will take place.

(2) Little more, if any, necrosis occurs than takes place in those cases which are allowed to heal in a deformed position.

(3) Early removal of the plate is indicated as soon as there is any callus formation, and this is an important point, as callus will not form at the site of the plate, but will form everywhere else.

(4) Convalescence is not protracted much longer, if at all, than in other cases.

(5) Better alignment and position are obtained from the very beginning with less resultant deformity.

(6) Adequate drainage should be established in all cases, not only of the soft parts, but of the medullary canal itself.

This treatment seems rational, when we consider the process which takes place in fractures which are treated simply by conservatism, and are later operated upon for the correction of the resultant deformity. In such a group, if complete reduction cannot be effected and the fragments brought into apposition, the fracture is immobilised, the wound healed, and the fracture allowed to unite in a deformed position. In these cases, too, there is very apt to be a necrosis of the over-lapping ends of the bones, especially if they have been denuded of the periosteum, and later measures have to be instituted for the removal of these necrosed fragments and for the correction of the alignment and the holding in position of the refractured bone. Then, too, we must always take into consideration the fact that in such fractures, even if the wound is healed and there is union of the fragments, operative procedures for the refracture of the bone may start up a severe latent infection, and we shall then be in exactly the same position, as far as the healing of the wound is concerned, as we were months before when the patient was admitted with the original infected wound.

It would, therefore, seem reasonable to assume that, if such a condition of infection exists or is inevitable following operative procedures, it would be better to effect an early reduction and to allow the infection to clean up and the unavoidable small amount of necrosis to take place with the bones already in proper position and alignment. It would certainly seem preferable to allow union to take place from the beginning with the bones held in good position, than to allow the wound to heal and necrosis and union to take place in a mal-position, and then again to light up infection by operative procedures. It must be clearly realised that in these extensive gunshot fractures union and return of function are a matter of many months at the best, no matter which method of treatment is instituted.

A certain degree of judgment is, of course, necessary in the selection of the case suitable for this method of treatment by bone plating. By no means all cases of fracture should be treated in this way, many of them being readily reduced and held in proper position and alignment by means of a simple fixation apparatus. But this method of treatment would seem to be indicated in those cases where there are marked deformity and over-riding of the fragments with little comminution, and in which reduction and fixation in proper alignment and position can be effected in no other way. If the limitations of the use of the plate in such cases are recognised, together with its attendant dangers, the fragments may be held in good alignment and an efficient fixation apparatus applied until such time as the plate may be removed. In such cases union takes place with the bones in good position rather than in poor alignment.

These facts are perhaps best illustrated by the following cases:

H. S., aged twenty-eight, 4th Middlesex, was wounded on April 19th, 1915, at Hooge, by a high-explosive shell which wrecked the trench where he was standing. Admitted to the American Women's War Hospital on July 30th, 1915.

Examination on entrance was as follows: On middle third of lower leg there is a large infected shell wound about $2\frac{1}{2}$ inches long and 1 inch wide; leg swollen and ecchymosed. Abnormal mobility and deformity of leg at this point, together with crepitation. Marked deformity of leg, and lower fragments displaced outward and upward with about 2 inches shortening. X-Ray shows wedge-shaped fracture of tibia with a large detached triangular piece from the posterior portion of tibia lying transversely at level of wound. Leg very painful and tender. Fibula shows two indirect fractures—one on the level with the fracture of the tibia and one about 3 inches above. It was found impossible to reduce and hold the fragments in proper position and alignment even under an anæsthetic, and it was, therefore, decided to hold the fragments in position by means of a bone plate.

August 3rd.—Ether. Operation: Wound on inner side of leg slightly enlarged to give better exposure and all granulating tissue removed. Ends of tibia exposed and found to be necrotic and denuded of periosteum. Necrotic ends were removed with a saw. A large splinter of bone which was seen by the X-Ray was found to be detached and lying free in the tissues. This bone fragment was necrotic and was entirely removed and, as a consequence, there was a large V-shaped solution of continuity left in the posterior portion of the tibia. The ends of the bone were brought into apposition and held in alignment and position by a Shermann bone plate, as this was the only method by means of which fixation could be maintained. Wound left open and packed with gauze saturated with saline. Bridged plaster applied from toes to mid thigh.

September 1st.—X-Ray shows fragments in good position and alignment, wound cleaning up rapidly.

September 20th.—X-Ray shows some callus formation. Plate removed and also a small piece of necrotic bone.

October 1st.—Wound clean and granulating; some slight union; leg in good position and alignment.

November 1st.—Wound entirely healed save for small sinus which leads down to original wound in bone. Good union.

November 22nd.—Sinus curetted out and a small amount of necrotic bone removed. Union solid.

December 15th.—Patient up and about on crutches; union solid; no deformity of leg except for some thickening about site of injury. Wounds entirely healed.

January 15th.—Leg solid; patient walking well; alignment and position of leg excellent; wound healed solid. There is $\frac{1}{4}$ inch shortening of left leg measured from tibial tubercle to internal malleolus, due to trimming off of necrotic ends of the tibia.

Patient discharged to duty on January 17th, 1916.

The following case also illustrates very strikingly the importance of leaving in position any fragments of bone which still show any periosteal attachments and which play an important part in the re-formation of bone:

G. M., aged twenty-six, 2nd Royal Sussex, was wounded on October 13th, 1915, by a bullet which struck him on his right arm just above his elbow. Admitted to the American Women's War Hospital, October 16th, 1915.

Examination at that time was as follows: Right arm on the outer side about 4 inches above the elbow shows a small wound of entrance, and on inner side is a wound of exit 2 inches by 1 inch, the edges of which are everted. Both wounds infected. Marked abnormal mobility of humerus at this point. No disturbance of circulation and no involvement of nerves.

X-Ray shows transverse fracture of shaft of humerus

3 inches above condyles, some comminution, and also one long splinter attached to the upper fragment (Fig. 108). Upper portion of lower fragment displaced forward so that when forearm is held horizontally the angle between this

A *B*

Fig. 108. Bullet wound of humerus. Some comminution and splintering of posterior portion. Distal fragment tilted forward so that forearm is relatively in the position of flexion. *B* shows condition six months after operation; union is solid and there is a marked formation of callus, especially on the posterior aspect, which has taken place from the long splinter which was left in place. In centre may be seen a small cavity which later was curetted out.

lower fragment and the forearm is about 45 degrees. Arm immobilised, but lower fragment could not be held in proper alignment.

November 10th.—Wound healing; still some slight discharge. It was decided to reduce the fracture and hold it in proper alignment by means of a plate.

November 15th.—Ether. Operation: Incision made through original wound and outer side of arm. Musculo-spiral nerve found to be lying across site of fracture, but was uninjured. This was pushed aside and fracture exposed. There was no union of the bony fragments, but a considerable number of necrotic fragments were found lying loose, as well as some necrosis of the distal and proximal ends of the humerus. Necrotic fragments removed, and a large spicule of bone, which was shown by the X-Ray, was found to be attached and was left. Necrotic ends of humerus trimmed, fracture reduced and held in position by means of plate. Wound closed with drainage.

December 1st.—Wound healing rapidly; still some slight purulent discharge. X-Ray shows fragments in excellent alignment and position.

January 1st.—X-Ray shows considerable callus formation; wound entirely healed save for a small sinus which leads down to the site of fracture, at bottom of which some necrotic bone may be felt.

January 10th.—Ether. Plate removed; union solid. Formation of callus, especially about spicule of bone in posterior portion. Small amount of necrotic bone lying between fractured ends of humerus was removed.

February 1st.—Wound entirely healed; patient having massage; very little motion in elbow joint.

March 1st.—Motions of elbow gradually increasing. Motions of rotation and supination improving.

June 1st.—Union of fragments absolutely solid. X-Ray shows large callus formation; movements of forearm gradually increasing.

Patient still in hospital and having exercise for the improvement of function of his elbow joint.

These cases illustrate the essential points as regards the holding of fractures in position by means of Shermann's or Lane's plates in the presence of infection.

Technique.—The technique is important in all those cases in which the bone plate is inserted in the presence of infection, for if certain general principles are not strictly adhered to, untoward results may occur and the conditions be rendered worse. In large lacerated wounds the operation may often be done without enlarging the wound, as this may already be large enough to give sufficient exposure.

After the patient has been anæsthetised, the wound should be thoroughly disinfected with iodine and alcohol or carbolic acid followed by alcohol, and all soft granulation tissue removed—preferably by means of curetting with gauze. The fracture should be sufficiently exposed to allow of thorough inspection and also an easy application of the plate. The condition of the bone should be carefully inspected and the amount of necrosis noted, and whether or not the bone has been denuded of periosteum.

As little trauma as possible should be done to the bone fragments. The ends of the shaft, which are usually necrotic, should be removed, just sufficient of the ends being resected to remove the necrotic tissue. Even if the bone be denuded of periosteum, no attempt should be made to remove this portion, as it will be needed for the insertion of the screws to hold the plate and, even if it is not viable, spontaneous sequestration will later take place.

Necrotic and detached fragments of bone, which are lying loose in the tissues, should be removed; but all fragments which show any viability or any attachments of periosteum should be left alone.

After the loose fragments have been removed and the necrotic ends of the bone resected, the exposed portion of the medullary cavity should be disinfected with carbolic acid and by alcohol or iodine followed by alcohol, and any necrotic detritus removed. The ends of the bone should then be brought into apposition and held in place by an adequate plate. It is important, however, in these cases, that a close approximation of the ends of the bone should not be made, as otherwise an increased amount of necrosis and possibly an osteomyelitis will result, owing to the imperfect drainage of the medullary canal. In many instances, and especially in those cases where there is a V-shaped fracture, adequate drainage will be established by this type of fracture ; but if the fracture be oblique or transverse and the fragments come closely together, it may be necessary, after the medullary cavity has been disinfected and the bones have been placed in apposition and fixed, to drill a hole into the cavity which has already been disinfected in order to establish free drainage at this point.

After the plate has been applied, the wound should again be thoroughly disinfected.

Unless the wound be very extensive, no attempt at closure should be made, and even in the larger wounds the closure should be partial and only at the ends. The fixation apparatus—preferably of bridged plaster—is then applied, with the bridges so arranged that the wound is readily accessible for frequent dressings. Following the operation the wound should be constantly dressed with hypochlorous acid solution or with salines. Constant irrigation, until such time as the infection clears up, gives us the best results.

As soon as there is sufficient callus formation to immobilise the fracture, the plate should be removed, but on no account should an attempt be made to remove any more bone fragments until spontaneous sequestration has occurred.

These points are of importance, and good results may be obtained if these few general principles are followed. If due care is not given to technique, especially in regard to free drainage in the medullary canal and the early removal of the plate, and the limitations of this procedure are not fully recognised, poor results may occur.

2. **Bone Grafting.**—In some cases, owing to extensive necrosis or a considerable solution of continuity, non-union or only partial union takes place. Such cases lend themselves very readily to treatment by insertion of autogenous bone grafts.

This method of treatment has not only the advantage of holding the bone in position, but also has a marked osteogenetic effect and, as a result, a firm bony union takes place within a very short time.

The method which we use at this hospital is that advocated by Albée in his work on "Bone Graft Surgery," and the technique of such procedure is so well known as to need no further description. It is essential, however, that in all cases where a bone graft is required, a sufficient interval of time should elapse after the wound is healed before operative procedures for a bone graft are instituted, otherwise the operation may be a failure, owing to the lighting up of latent infection. A slight amount of infection, however, if properly drained, does not seem to have any untoward effect upon the viability of the graft, providing that the graft fits tightly and is held firmly in place.

The results obtained by bone-graft surgery are perhaps best illustrated by the following two cases, in the first of which a latent infection was lighted up, but, notwithstanding, the graft remained viable.

R. A. McG., aged thirty-five, Wellington Infantry, was wounded on June 2nd, 1915, on the Gallipoli Peninsula, by a bullet which struck him on the right leg and emerged through the tibia. He was sent to Malta and later was transferred to England, and was admitted to the American Women's War Hospital on August 26th, 1915.

Examination at that time was as follows: At middle of posterior surface of calf there is a small healed wound of entrance. On anterior surface of the leg at the same level is a large wound of exit 2 inches by 1 inch in diameter, at the bottom of which can be seen the ends of bone fragments. Wound infected. Abnormal mobility present in tibia. At same level a deformity of fibula can be felt subcutaneously. Union of fibula apparently firm. Right leg 1½ inches shorter than the left leg. X-Ray shows comminution of the tibia and solution of continuity of the anterior portion. Alignment of tibia good. Practically no callus formation. Fracture of fibula at practically the same level as fracture of tibia healed with an angular deformity.

After admission leg immobilised on Cabot's Posterior Wire Splint and wound dressed with hypochlorous acid solution.

September 18th.—Ether. Operation: Wound over tibia enlarged; considerable loss of bone found, also much necrosis. Detached fragments and necrotic tissue curetted out. Slight deformity of tibia corrected. Bridge plaster applied from toes to mid thigh.

October 15th.—Wound entirely closed; tibia in good position and alignment. Moderate union.

October 20th.—Operation for correction of deformity of fibula advised. X-Ray shows mal-position and shortening of fibula, and upper part of lower fragment can be felt subcutaneously.

October 26th.—Ether. Operation: Incision 3 inches long over deformity of fibula and fibula exposed; good union found; fibula resected and brought into good position and held in apposition and alignment by a Shermann's plate. Wound closed in layers.

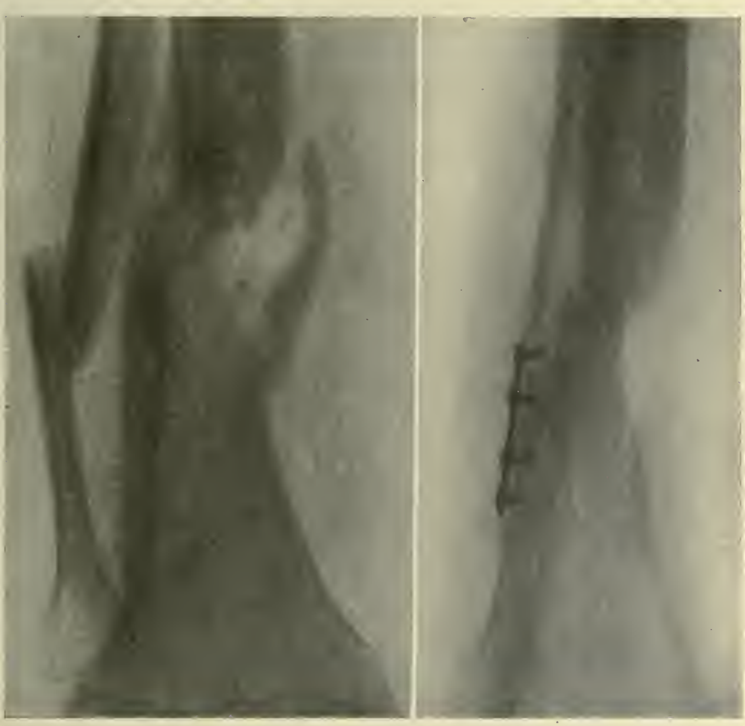
November 6th.—Wound over fibula entirely healed. Wound over tibia closing in. Patient up and about on crutches.

November 20th.—Wound over tibia healed, but there is still some slight mobility.

December 20th.—Still slight abnormal mobility in tibia. Under gas anæsthesia 1 oz. of blood injected into callus with the hope of stimulating the growth.

January 1st.—Mobility same as at last note and it was deemed advisable, in view of the long-delayed union, to insert a bone graft to fill in the loss of tissue.

January 5th.—Ether. Operation: Incision carried through old scar; a considerable amount of fibrous tissue



A *B*

FIG. 109. *A* shows transverse indirect fracture of fibula and grooving and comminuted fracture of tibia due to bullet. In this case there were marked infection and a large amount of necrosis, together with 1 inch of shortening. There was very little bony repair in the tibia. Later after the infection had subsided and necrosed bone fragments removed, the fibula was shortened 1 inch and plated, as is shown in *B*, and later a bone graft taken from opposite tibia was inserted to bridge over the gap in the injured tibia. Bone graft is shown in *B*, as is also some regeneration about the graft. Patient was transferred to the New Zealand Hospital before the end result could be observed.

was found filling cavity at ends of bones. This was curetted out and a channel cut in the distal and proximal parts of the tibia. Graft 3 inches long (Fig. 109) removed from left tibia and inserted into the channel. Graft fits tightly. Wounds closed with drainage.

January 7th.—Temperature slightly elevated. Some slight serous discharge from wound on right leg. Two sutures removed and small drain inserted. Wound on left leg clean.

January 15th.—Wound on right leg discharging a small amount of sero-purulent material. Irrigated with saline and packed. Graft partially exposed. Wound on left leg healed by first intention.

January 30th.—Wound on right leg slowly closing in. Small portion of the graft is still exposed. About the graft is some thickening.

February 15th.—Condition practically the same as at last note.

February 27th.—X-Ray shows some apparent callus formation.

March 5th.—Small sinus developed in lower end of wound which leads down to graft. Tissues about wound slightly reddened. The upper portion of wound is still open. Leg, however, feels solid and graft is apparently holding well.

March 20th.—Graft holding; apparently firm union; but there is still some slight discharge from the wound, which is, however, diminishing.

March 30th.—Wound closing in. Considerable thickening along the course of the graft. No abnormal mobility of tibia. Apparently good union. Small portion of graft still exposed, and there is 1 inch shortening of tibia.

X-Ray shows graft in good position, and there is some apparent callus formation about it.

Patient unfortunately had to be transferred to another hospital before any further observations could be made on him, but apparently he was on the road to recovery and should eventually have a good functional leg.

The second case illustrates the use of a bone graft in cases where there is no union.

A *B*

Fig. 110. *A*. Appearance of fracture on admission. Fragments in poor position and alignment. Plate loose and there is very little callus formation. *B*. Appearance six weeks after bone graft had been inserted. Moderate callus formation; union firm. Alignment and position good.

H. L., aged twenty-five, 19th Royal Fusiliers, was wounded on January 2nd, 1916, by being buried under falling débris following a mine explosion. Right humerus was fractured by stones falling upon it. Was operated on on February 10th, while in France, and bone plate inserted to hold fragments in position.

Admitted to the American Women's War Hospital on March 13th, 1916.

Examination at that time was as follows: Right arm presents a scar 4 inches long on outer surface about middle. This scar is healed. There is a slight angular deformity of the upper arm, the deformity being outwards and backwards, and at this point there is considerable abnormal mobility. X-Ray shows transverse fracture of midshaft of humerus, united by means of a bone plate (Fig. 110 *A*). Fragments in poor position and alignment. No evidence of callus formation and plate appears to be loose.

Following admission the condition remained practically the same, and there was no evidence of regeneration of bone taking place. It was, therefore, decided to do a bone-graft operation.

April 13th.—Ether. Operation: Incision made through old scar and humerus exposed. Bone plate exposed and found lying in a small pocket of pus; this pus was localised and there was no clinical evidence of any infection. (Bacteriological examination later proved that there were no bacteria present.) Plate found loose and removed. No evidence of any bony union between the fragments of the humerus, but there was some slight necrosis of the ends. Ends of humerus sawed off and fragments brought into apposition and alignment. Channel 3 inches long was cut in humerus and a bone graft, taken from the tibia, was inserted into this channel, and held in place by bone pegs. Wound closed tightly without drainage and arm immobilised on Osgood-Penhallow splint in good position and alignment.

May 1st.—Wound entirely healed; primary union.

Considerable thickening about site of graft, and moderate union.

X-Ray shows callus formation but still some slight backward bowing at site of injury. This, however, was corrected by changing the position of the pads on the splint.

June 1*st.*—Union solid. Alignment excellent. Patient having massage and is now recovering the use of his arm (Fig. 110 *B*).

Patient still in hospital at time of writing.

These two cases illustrate well the advantages of such treatment in cases of non-union or delayed union. This treatment in such cases would seem to give the best results in a comparatively short space of time.

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CHAPTER IX

WOUNDS OF HEAD, FACE, AND NECK

I. Wounds of the Head

Owing to the fact that the present war is essentially a trench warfare, it is not strange that a large proportion of the wounds seen are head injuries. The use of the steel helmet mitigates to a certain extent the wounds from the smaller shell fragments and from shrapnel bullets, and also from spent rifle bullets, but in spite of this form of protection the proportion of head wounds to wounds of other parts is still high. While it is true that many of the injuries seen are apparently trivial and superficial, nevertheless every head wound should be viewed with suspicion, even though the patient shows no symptoms of cortical disturbance. In such cases as these the fact may be overlooked that there may be a definite bone lesion, and sometimes such patients are sent into hospital as ambulatory cases and later develop grave symptoms, as has been seen in many instances where men have been admitted with apparently only small scalp wounds and have later developed cerebral symptoms which necessitated immediate operation, when depressions of the inner table have been found, and, in one instance, a large cerebral abscess. We should therefore be extremely cautious in all cases of gunshot wounds of the head of making a diagnosis of a scalp injury alone, especially if there be any history of the patient having been rendered unconscious from the force of the blow, for it is very probable that in all such cases, particularly if the period of unconsciousness be prolonged for any length of time, there will be associated with the wound in the scalp a fracture of the skull or possibly a localised intracranial hæmorrhage. Again, owing to the fact that shell fragments and shrapnel bullets have a lower velocity than have rifle bullets, the glancing blows caused by the former probably cause less severe trauma than do rifle bullets, and it is probably safe to say that in all wounds of the head caused by glancing rifle bullets, especially at the proximal ranges where the velocity of the projectile is still great, there is a fracture of the skull. It is far better to assume that there is such a fracture until a more careful examination can be made and the possibilities of a fracture excluded. Every case, therefore, of gunshot wounds of the head, even though it appear that the scalp alone be involved, should be carefully examined and the presence of fissures, erosions of bone, and depressions noted; the pulse rate and the blood pressure should be carefully watched and radiographic pictures should be made, although one cannot always exclude the possibilities of a fracture on this evidence. The patient should be kept in bed and under close observation for several days, and this is important even though the signs are negative on admission.

For the purposes of discussion we will divide gunshot wounds of the head into:

(1) Wounds of the Scalp, and
(2) Wounds of the Skull.

(1) **Wounds of the Scalp.**—These vary from wounds which

are nothing more than slight abrasions or contusions to deep erosions or lacerated wounds, and the nature of the wound depends upon the type of projectile causing it. Rifle bullets and shrapnel cause contusions, erosions, or gutter wounds, whereas shell fragments cause lacerated wounds, often with considerable loss of tissue. The wounds may involve only the outer layers of the scalp, but more often extend through the deeper layers and expose the skull. Scalp wounds should all receive careful attention, for, even if there be no associated fracture of the vault, the dangers from sepsis alone are grave and the infection may either undermine the loose areolar tissue of the scalp or the epicranial aponeurosis, or we may get a severe resulting erysipelas. Furthermore, if the infected scalp be not sufficiently drained, we may get, due to the sepsis, an erosion of the bone or an osteomyelitis. There may also be an extension of the infecting processes through the diploe to the meninges and brain and intracranial sinuses with resulting complications such as a cerebral abscess or thrombosis. Again, if a small scalp wound is not carefully examined and injuries to the periosteum noted, we may overlook a fracture which later may cause serious trouble. All infected wounds of the scalp, therefore, should be carefully watched and constant wet dressings of hypertonic saline or hypochlorous acid solution applied to overcome the infection.

Wounds of the scalp when seen early and before any evidence of infection has manifested itself, and when too it has been proved that no fracture of the scalp exists, may perhaps best be treated by a thorough disinfection by means of carbolic acid and alcohol or with iodine; the wound should then be excised as a whole and the skin edges approximated in order to save time of healing and also to avoid the dangers of sepsis. This method also gives us a better opportunity of inspecting the cranial wall for fissures and abrasions which if found will determine to a great extent our further treatment.

(2) **Wounds of the Skull.**—These are most important, for, as has been repeatedly shown in the present war, even though the external evidence of bone injury be trivial, there is always more extensive injury to the inner table with resultant pressure on the dura or even laceration and consequent injury to the vessels and brain substance. Injuries to the skull and brain occur very frequently; their proportion is commonly considered to be from 12 to 15 per cent. of the total number of injuries. More than half of the wounded succumb on the battlefield. (Delmore.)

In considering fractures of the skull even in war time one must remember that we see not only those caused by projectiles, but also fractures caused by falls or by blows from rifle butts, and these are of a similar nature to those seen in civil hospitals. We have therefore to deal both with simple or compound fractures of the skull, either fissured, comminuted, or perforated, and either with or without depression of the fragments, and also with or without injury to the brain or vessels; but for our purposes here we will confine ourselves to those fractures which are caused by projectiles and are therefore compound. The severity of the injury, as has been said before, depends upon the type of projectile causing the wound, the velocity at the time of impact, the weight of the projectile and the way in which it strikes the tissues, whether by a glancing blow or a direct one; and we therefore find conditions varying from contusions or abrasions to depressed and comminuted fractures associated not only with considerable destruction of bone, but also with marked laceration of the brain tissue of such a degree that surgical measures are of no avail. We will first of all consider the various forms of wounds of the skull and the projectiles causing them (Fig. 111):

(*a*) Contusions and Fissures.
(*b*) Grooves and Erosions.
(*c*) Penetrating and Perforating Wounds.
(*d*) Depressed Fractures.

(*a*) **Contusions** of the cranial vault, as well as fissured fractures, are caused either by glancing or tangential blows from projectiles travelling at a high rate of velocity,

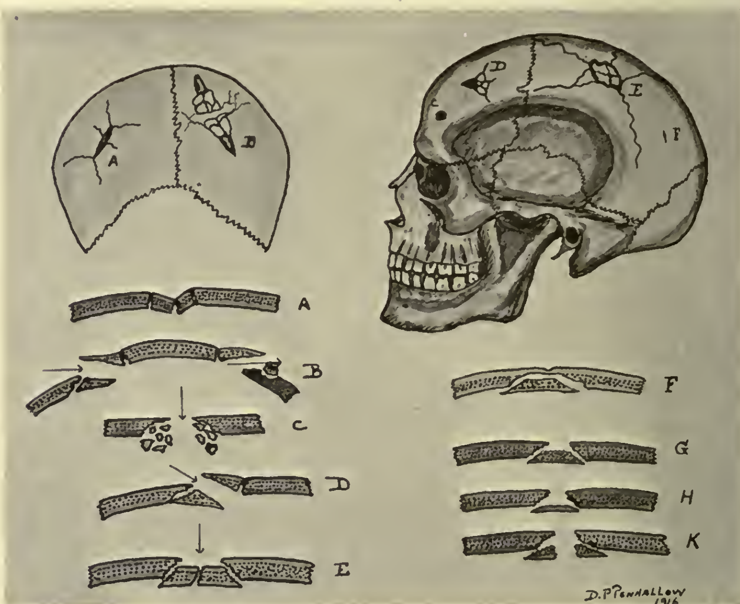

FIG. 111. Diagrammatic representation of various types of fractures of the skull, showing the appearance both on the skull and in section. *A*. Small gutter wound showing small radiating fissures. *B*. Tangential perforating wound, showing elevation of outer table and small radiations. *C*. Simple penetrating wound. *D*. Tangential penetrating wound. *E*. Fracture by contact, showing longer radiations and depression of fragment. *F*. Erosion of skull with separation and depression of inner table. *G*, *H*, *K* show various types of gutter wounds—*G* with loss of outer table and separation and depression of the diploe and inner table; *H* loss of outer table and diploe and depression of inner table; *K* loss of substance through the whole thickness of the bone with depressed and separated fragments of diploe and inner table.

such as rifle bullets, or by direct blows from projectiles with a low velocity, such as shrapnel bullets or shell fragments. Contusions vary from simple denudation of the periosteum in some cases to small abrasions or erosions of the bone, but even with such apparently trivial injuries of the outer table, much more serious damage to the inner table must always be suspected. Fig. 111, F, shows the condition where there was only a simple abrasion of the outer table, but at operation a portion of the inner table was found to be separated and depressed and had also punctured the dura. Fissures usually involve both tables,

Fig. 112. Erosion of the skull following blow by glancing shell fragment. Injury consisted principally of denudation of periosteum with some bony erosion partly due to infection following a lacerating wound of the scalp.

and while they may appear simply as cracks on the outer table, we usually find loosened or depressed portions of the inner table. Fissures also are generally found radiating from the larger abrasions or grooving fractures, from perforations, and in those fractures where there is considerable involvement of the cranial vault with depression.

(*b*) **Grooves and Erosions** (Fig. 111, A) are a frequent type of injury and may consist of superficial abrasions of the outer table in the less severe forms (Fig. 112), or of grooves extending from the outer table alone (Fig. 111, G), through the outer table and the diploe (Fig. 111, H) or, in the more severe types, through both tables (Figs. 111, K, and 113).

In all such fractures, even though the external evidence of injury be slight, there is always a certain amount of

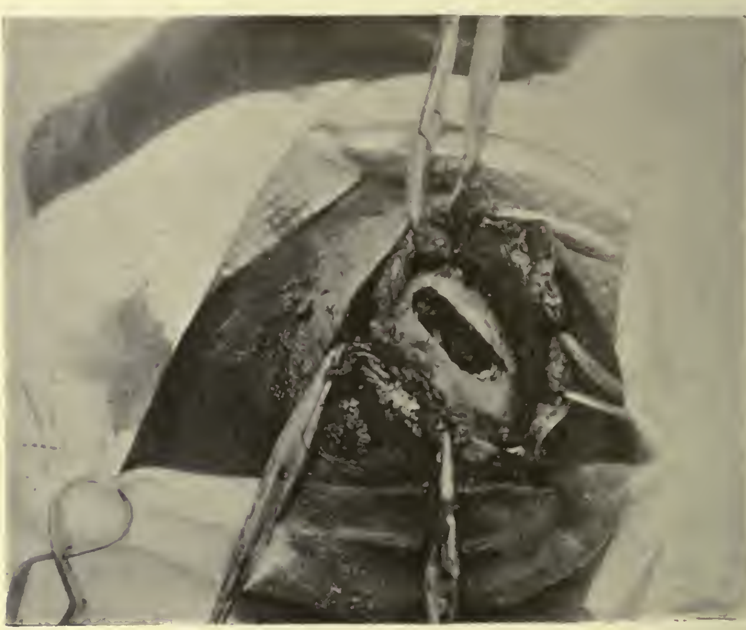

FIG. 113. Gutter wound of skull in fronto-parietal region. External wound in scalp resembled a seton, and there were no evidences of intracranial injury, but on incising the scalp wound for drainage the condition as shown in the photograph was found. At the ends the fragments of the outer table may be seen driven downwards, and at centre is some protrusion of brain tissue.

splintering of the inner table, and a consequent depression of the fragments, which are forced downward on to or through the dura. Such injuries as these usually occur on the least convex surfaces of the skull and are caused by rifle bullets and occasionally by shrapnel bullets which strike the skull at a tangent.

(*c*) **Penetrating and Perforating Wounds.** — Penetrating wounds are characterised by a single perforation or wound of entrance and are usually caused by shrapnel bullets or by rifle bullets with a low remaining velocity, or by bullets which have ricocheted. In such wounds the projectile remains in the cranial cavity. Such wounds show a small circular or oval aperture with some splintering and loss of substance of the diploe and inner table (Fig. 111, C). Perforating wounds, which are much more common than are the penetrating wounds, show a circular or oval wound of entrance similar to that observed in penetrating wounds, but the conditions are reversed where the bullet emerges, and we find a smaller aperture on the inner table and then an increase in size through the diploe and outer table with comminution of the latter. There is considerable contusion of the brain substance, and the cerebral track

FIG. 113A. A longitudinal section of condition found at operation. There were fragmentation of outer table at both ends of the gutter and some destruction of diploe (2), separation and depression of the inner tablo (3) covering a larger internal area than is indicated by the wound in outer tablo; (4) represents dura which is shown as torn in tho centre, and through the opening thus caused is a protrusion of contused and lacerated brain tissue (5). Wound was enlarged, depressed fragments removed, dura was not sutured on account of marked infection. Patient has shown no cranial symptoms at any time and is making an uneventful convalescence.

contains many comminuted fragments of bone which have been detached from the wall and driven through by the force of the bullet. The amount of cerebral injury depends to a great extent upon the velocity of the projectile—the greater the velocity, the greater the amount of cerebral laceration—and at short ranges where the velocity is high the effect on the soft cerebral tissues is out of all proportion to the bone injury, and we find masses of brain substance escaping from the wound of exit.

There is still one other type of perforating wound, *i.e.* the wounds in which the apertures of entrance and exit are close together. They are caused by bullets striking obliquely or tangentially and causing a groove, then burrowing through the cranial wall and emerging in another groove (Fig. 111, B). In such wounds there is considerable fragmentation of the outer table at the points of entrance and exit, and these fragments are often still held together by the periosteum. There may also be with such fractures marked fissuring of the skull, the fissures radiating from the points of entrance and exit (Fig. 114). In such injuries the damage to the brain tissues is much less, as it is more superficial than in the perforation described before, and such wounds present greater chances for recovery. This type of wound is caused by rifle bullets.

(*d*) **Depressed Fractures.**—These are usually caused by direct contact by shell fragments and may show a small area of depression on both tables or marked comminution and depression, and also radiating fissures (Fig. 115), together with considerable destruction of cerebral tissue (Fig. 111, E).

Diagnosis.—In every case of head injury which we see the general condition as well as the local condition should be carefully noted. The amount of shock, the pulse rate, and the blood pressure should be investigated; any paralyses should be noted and also whether there is any disturbance of reflexes from pressure or from cortical irritation. In the larger depressed fractures, and also in the penetrating and perforating wounds, the diagnosis is comparatively easy, as the bone destruction is so great, and in such cases we find either protrusions of lacerated brain or of cerebro-spinal fluid. Then too with such wounds,

Fig. 114. Tangential perforating bullet wound of skull. Exit is shown on vertex, where a few small fragments can be seen. From point of entrance and from separated fragments, radiating fractures may be seen.

especially if the wound of aperture be small, we are apt to find signs of compression, whereas in the larger wounds these signs are apt to be absent owing to the fact that part of the cranial wall has been destroyed, and, for this reason, the intracranial pressure will not become greater. In the grooves and erosions we find the lines which have already been described on the surface of the skull, and with this

Fig. 115. Small shell wound of frontal region, showing radiations down towards orbital plate. The depressed portion of bone was removed from this region.

type of fracture we are more apt to get signs of increased pressure and disturbance of reflexes than we are with the larger comminuted fractures where there is loss of tissue.

Contusions and fissures are sometimes difficult to diagnose and often a good deal must be assumed, especially with the knowledge we now have of the effects upon the skull of modern projectiles. Pressure on the skull at a distance from the wound will often cause pain, where there is simply contusion or a fissured fracture either with or without depression of the inner table, and if we find any evidence of cortical irritation it is fair to assume that the inner table has been injured and is pressing upon the dura. Again, we see cases where there is no external evidence of injury to the skull, but the patients complain of severe radiating headaches, often of disturbance of vision and photophobia; such conditions are usually associated with a depression of the inner table.

This may be shown by the following case:

W. J. B., aged thirty-seven, 7th Durham Light Infantry, was wounded on May 25th by a small shell fragment while in the reserve trenches at Ypres. This fragment was removed at the first dressing station, and the wound was dressed. Patient was transferred to England and was admitted to the American Women's War Hospital on June 1st, 1915, at which time he showed an infected gutter wound 2 inches long over the parietal region, exposing the bone. No signs of fracture or decompression could be made out at this time, but the patient complained of severe headaches.

Following admission, the headaches became much more severe and patient showed typical signs of intracranial injury. Examination of fundi showed some slight choking of the right disc. Reflexes normal; pulse slow and full. In view of the type of injury and that the patient had constant headaches together with a head pulse, it was suspected that he might have some slight fragment of the inner table pressing on the dura and it was decided to operate. X-Ray showed slight depression of the inner table in region of wound.

June 28th.—Skin incision made through wound and skull trephined. Cranial wall found to be extremely thick, and when trephine button was removed a small depression of the inner table was found. This was removed and wound closed. Good ether recovery. Following operation patient made an uneventful convalescence. Wound healed by primary union and headaches entirely disappeared. Patient discharged on July 23rd.

Again, the location of the injury is important, for, as has been repeatedly seen, injuries in the frontal region cause less disturbance than in other regions. Wounds of the parietal and temporal regions may be associated with paralyses and disturbance in the reflexes of the muscles, but these are sometimes absent.

Prognosis.—In all wounds of the head, especially where the brain is involved, the prognosis is grave. According to Delorme from 40 to 55 per cent. of the wounded die on the battlefield, and 26 to 28 per cent. succumb in the ambulances or in the hospitals. Prognosis of through-and-through cranio-cerebral perforations is the most grave of all. Recoveries from single perforations by bullets are least exceptional, and of the bone lesions grooves are the least serious when they are properly treated. Non-penetrating wounds heal in most cases.

In lesions produced by bullets the prognosis is in general in close relationship to the velocity of the projectile and to the importance of the parts involved, frontal wounds being the least severe.

Extensive injuries from shell fragments lead as a rule to immediate death. Penetrations from shrapnel are grave owing to the large diameter of the projectile and the presence of foreign bodies.

The mortality is 1·7 per cent. for the non-infected and 41·8 per cent. for the infected wounds, and among those who recover 25 per cent. succumb to sequelæ and at least one-half of the remainder are left permanently infirm.

Treatment.—Much has been written as to whether it is better to pursue conservative measures in head wounds or, in view of the fact that practically all gunshot wounds of the head show depressions of the inner table, often with resulting injury to the dura and cerebral tissue, to operate immediately and remove the depressed fragments, to relieve intracranial pressure and control hæmorrhage. The consensus of opinion in this present war, however, seems to be that all injuries of the skull should be operated upon, provided that the proper appliances and implements with which to do an aseptic operation are at hand, and this is more especially true of these cases which show only slight injury to the outer table but present signs of intracranial compression. In all cases the wound must be thoroughly cleaned with ether and iodine, and in the case of comminuted and depressed fractures the removal of the fragmented portions of the bone may be sufficient. In cases where there are signs of compression and only a slight injury to the outer table, a trephine opening should be made and enlarged enough to enable us to remove easily the fragmented and depressed portions of the inner table. The opening in the skull should also be made large enough to enable us to inspect the dura thoroughly to see whether or not it has been injured by puncture or by lacerations, or, if it be intact, whether there is any bulging due to injuries to the meningeal vessels or to the brain substance itself. If the dura has not been injured and there is no apparent sign of bleeding from the meningeal vessels, removal of the depressed fragments without opening of the dura will probably be sufficient. On the other hand, if the dura bulges and there is evidence of injury to the brain tissue or to the vessels, the dura should be opened, extravasated blood removed, and the hæmorrhage controlled by gauze packing. In wounds where there is involvement of the sinuses, hæmorrhage from these is best controlled by packing unless the laceration can easily be reached and sutured. It must, however, always be borne in mind that in the more extensive wounds, where there is much laceration of the brain tissue, no matter what measures of treatment are instituted, patients usually do badly, and in the less extensive wounds where there is only a small wound in the dura or a depression of the inner table, operative measures relieve symptoms, and such patients do reasonably well.

Complications.—These consist essentially of meningitis, cerebral abscess, cerebral hernia, and osteomyelitis of the skull.

Meningitis.—In spite of free drainage and the removal of infected material, patients often develop septic meningitis, due to the inclusion of contaminated matter in the cerebral tissue.

Cerebral Abscess.—Cerebral abscesses may also develop from the inclusion of contaminated matter or by direct extension from an infected scalp wound, from an abrasion of the skull where there is depression of the inner table or laceration of the dura, as is shown by the following case:

J. H., aged thirty-two, Wellington Mounted Rifles, wounded on August 27th at Gallipoli by a bullet, which struck him on the right frontoparietal region and caused a long gutter scalp wound. Was unconscious for some time; showed no subjective symptoms except severe frontal headache and some pain in eyes. Was transferred to England and admitted to the American Women's War Hospital on September 15th. Came in as an ambulatory case. Was conscious, rational, and able to bathe himself on admission and showed no objective signs other than a large infected gutter wound 3 inches long extending down to pericranium. The day following admission the patient became unconscious, pupils showed no reaction to light and distance, pulse rate 50, blood pressure 150. Knee jerks on left exaggerated, ankle clonus and Babinski present on same side. X-Ray showed small depression of inner table.

September 17th.—Operation: Scalp wound cleaned and all necrotic tissue removed. Examination of skull showed denudation of bone together with a small erosion ¼ inch long by $\frac{1}{8}$ inch wide. No fissures made out in skull. Trephine opening in region of erosion, and when button was removed it was found that a considerable portion of inner table had been detached and depressed. Trephine opening enlarged with bone-cutting forceps. It was found that inner table had been separated and depressed over an area of about 1 inch and that a spicule of bone had torn the dura. As soon as the trephine button was removed a large amount of pus under pressure oozed out, and when opening in dura was enlarged an abscess cavity 2 inehes in diameter was found in right hemisphere. Pus evacuated and wound drained. Fair ether recovery. Following the operation patient's condition became gradually worse and there was a marked hemiplegia of left side. Large amount of soft eerebral tissue constantly protruded from wound and it was found neeessary to trim this away as it became eonstantly ncerosed. Large amounts of pus also were discharged daily from the wound. This condition persisted for four weeks, patient gradually growing weaker each day until he died on October 17th.

Cerebral Hernia.—This is a frequent complication of gunshot wounds of the head, espeeially in the larger types where it occurs spontaneously, and also after operative procedures in which it has been found necessary to make a large opening in the skull for the removal of depressed comminuted fragments. It may oecur very shortly after the wound has been reeeived or may eome on later. This forms a very serious complication, as it is not specially amenable to treatment.

Various methods of treatment of this condition have been recommended, one being to apply light pressure over the growth or to perform periodic lumbar punctures to aid in the recession of the hernia, and later when it has receded to cover it in by means of a skin flap. Another method which has been recommended as a method of last resort is that of contra-lateral decompression, which consists of making a large trephine opening on the opposite side of the skull, which relieves pressure on that side and allows of recession of the original hernia.

Hernia cerebri is illustrated by the following case :

T. F., aged thirty-three, South Wales Borderers, wounded July 20th while making a charge at Gallipoli. Wounded in head by shell. Was unconscious for three days. Shell fragment apparently caused a contact fracture with depression and comminution of fragments. Was operated upon very shortly after the injury and depressed fragments removed ; was then transferred to Malta and later to England. Admitted here August 26th, 1915.

Examination at time of entrance showed a small cerebral hernia in superior parietal region, 1 inch in diameter and protruding from scalp for a distance of ½ inch. Extensive loss of cranial wall extending over an area of 3 inches by 2 inches (Fig. 116). On admission he presented a left hemiplegia which had been present since the time of injury. Was able to talk, but when tired became somewhat irrational. Patient remained in this same general condition for some weeks, hemiplegia still persistent. In September became irrational and later on had long periods of unconsciousness.

October 10*th.*—He now has complete left hemiplegia ; during the past month has been conscious only at intervals, but has been noisy, excitable, and violent at times. General condition is much weaker, locally—hernia of brain is larger and slightly septic.

November 4*th.*—Condition has gradually become worse since last note. Hernia larger ; patient violent, noisy, and has rare intervals of semi-consciousness. During afternoon suddenly became cyanotic, dyspnœic, and remained in this condition until 2 a.m. when he died.

Autopsy showed a large trephine opening in skull 3 by 2 inches in posterior parietal region. The inferior half of opening was closed over with a fibrous covering continuous with the bone. Dura was firmly adherent round the neck of the protruding brain hernia. Hernia involving post central gyrus at its junction with the longitudinal fissure.

Osteomyelitis of the skull is a late complication which is occasionally seen, especially in those injuries where there is simply an abrasion or a fissure associated with a septic scalp wound. Such patients often do not present any symptoms of head injury for a long time, and then gradually become apathetic and drowsy and often show increased

FIG. 116. Loss of substance following the removal of depressed fragments, leaving an aperture in the skull 3 inches by 2 inches. Wound caused by shell fragment. Radiating fissures may be seen at various points extending from the periphery of this aperture.

intracranial pressure. There is also a slowing of the pulse and increased blood pressure. Treatment consists of trephining and removing all infected bone by bone-cutting forceps. Skin may be closed except for small drainage and dressed with salines. This is perhaps best illustrated by some cases which we have seen at this hospital.

D. G., aged thirty, 5th North Staffs., wounded on October 13th at Loos while climbing over a parapet, when he was struck in the head by a bullet. He was unconscious for about ten minutes and was then carried back to a dressing station where the wound was dressed and he was given some antitetanic serum. He had no paralysis and no vomiting, and there was no disturbance of vision; no bleeding from nose, ears, or mouth, but he complained of violent headaches. Was admitted to the American Women's War Hospital on October 16th.

Examination at that time was as follows: Patient drowsy, answers questions slowly. There is a wound over upper part of frontal bone in median line 2 inches by 1 inch, which is infected and sloughing. Reflexes are normal and there is no anæsthesia or hyperanæsthesia. Left pupil slightly larger than right.

October 17th.—Operation; ether: Scalp cleaned; all necrotic tissue removed; no bony fracture found; wound partially closed by drainage.

October 25th.—Wound closing; patient complains of much pain over left eye and from left jaw radiating to left ear. X-Ray of skull negative. Blood pressure 120 systolic, 90 diasystolic. Ears normal, fundi of eyes normal, lumbar puncture at time of operation shows normal spinal fluid.

November 1st.—Pain severe and continuous; requires opiates.

November 9th.—To-day patient shows complete motor aphasia; reflexes on left side exaggerated.

November 10th.—Operation: Skin flaps turned back on either side of the original wound; bone exposed and trephined; bone found honeycombed with pus; there was also fracture of the inner table in the median line; organising clot found outside of dura. All diseased bone removed with bone forceps over an area of 2 inches by 1½ inches. Wound closed with drainage. Good ether recovery. From this time on the patient showed marked improvement, gradually regained speech and became able to read fine print. Headaches disappeared after operation. Discharged for invaliding on January 1st, at which time wound was healed and there was a decompression in scalp in median line over site of bone injury. Reflexes and fundi normal. Speech somewhat slow, but mentality is clear and general condition excellent.

W. B., age thirty-four, 7th Lincolns, wounded on October 2nd at Loos by being struck in the head by a piece of shell. He was unconscious for about half an hour, received his first-aid dressing very soon after being wounded, was transferred to the base and later sent to England and admitted to the American Women's War Hospital on October 19th.

At time of admission showed a healed shell wound 2 inches long in left frontal region in addition to several other shell wounds in various regions of his body. These wounds gradually healed. About December 1st the wound on skull began to show signs of infection; scalp became edematous and patient complained of severe headaches. Wound was opened and drained and bare bone could be felt at the bottom of wound. Condition became more exaggerated. Patient presented cerebral symptoms for which an operation was deemed advisable.

December 12th.—Ether. Operation: Trephine opening made in region of wound and a considerable amount of bone found which was honeycombed with pus. All diseased bone was removed with bone-cutting forceps over an area of about 1½ inches in diameter; skin flaps closed with drainage. Following operation all symptoms cleared up. Patient made an uneventful convalescence.

March 14th.—Was invalided with all wounds healed and general condition excellent.

Foreign Bodies in the Brain.—Foreign bodies in the brain or in the head are usually not well tolerated and even in wounds which heal aseptically may give rise to severe headaches, as may be illustrated by the following case:

J. M., aged thirty-seven, 4th Waikato Mounted Rifles, was wounded on July 15th, 1915, in the trenches at Gallipoli by shrapnel bullet. Wound was dressed immediately. Was transferred to Malta, later sent to England and admitted here.

At the time of admission showed a healed wound of

FIG. 117. Shrapnel bullet lying in the region of right orbit, probably in the ethmoidal cells. Patient was wounded in the scapula region—bullet passed upwards and forwards and lodged in the region shown in the X-ray. Condition as described in text.

entrance on back just opposite spine of his right scapula. Motions of neck painful and somewhat limited, and patient complained of severe headache, especially when walking. X-Ray (Fig. 117) taken showed shrapnel bullet under right orbit, probably in the ethmoidal cells. Owing to the location of the bullet, operative measures were deemed inadvisable. The condition persisted as at entrance, until

October 18th, when he was transferred to King's College Hospital for consultation and treatment. Since that time he has been sent home, the condition being practically the same.

In all infected wounds the dangers from retained foreign bodies is greatly enhanced, as contaminated matter, hair or dirt, has in all probability been carried in with the projectile and may give rise to a cerebral abscess or to encephalitis.

All foreign bodies should be carefully localised and if easy of access should be immediately removed. If, however, the foreign body is localised in a region difficult of access, a small drain inserted along the track may suffice until such time as the sepsis has cleaned up and the removal can be accomplished under more favourable conditions.

Oftentimes, when the cases are first seen and operated upon, the removal of the projectile may be done at this time in order to remove not only the missile but also contaminated matter. Furthermore, there will be a definite cerebral track to guide us and the bullet may be removed without further traumatising of the tissues. Great care, however, should be exercised not to increase the trauma, and the cerebral track should be carefully explored with the finger, and when the foreign body is located a blunt scoop should be passed along the track, using the finger as a guide, the projectile held between the scoop and the finger and removed; a small drain should then be inserted and the wound only partially closed.

II. Wounds of the Face

These wounds occur practically in the same proportion as do wounds of the head. While several different regions of the face may be wounded at the same time, nevertheless we should consider each region separately, and for our purposes here we will divide such wounds into seven groups, as follows :

(1) Wounds of the Orbit and Eye.
(2) Wounds of the Nose.
(3) Wounds of the Mouth.
(4) Wounds of the Ear.
(5) Wounds of the Superior Maxilla.
(6) Wounds of the Inferior Maxilla.
(7) Wounds of the Soft Parts.

(1) Wounds of Orbit and Eye.—These may be caused by rifle bullets, by shrapnel bullets, or shell or grenade fragments (Fig. 118). Injuries to the orbit alone may occur without involving either the optic nerve or the eyeball itself, and such injuries may consist of perforations or of grooving and fissure fractures. Such wounds may involve the walls of the orbit or the optic foramen, or they may extend into the anterior fossa of the skull, to the frontal sinuses, to the ethmoidal region, or they may involve the cribriform plate. If the optic nerve be involved, it may be either completely or partially divided or simply contused, with resulting temporary or permanent blindness. Furthermore, owing to the possibilities of injury to the internal carotid artery and the cavernous sinuses, there is always the possibility of the formation of an orbital aneurism. Such injuries are associated with edema, ecchymosis, and sometimes exophthalmos due to the large intra-orbital hæmorrhage. When the injury extends into the frontal or ethmoidal sinuses, suppuration usually results. This may be intensified by the presence of a contaminated foreign body and consequently the chances of a septic meningitis must be constantly borne in mind.

Wounds of the eye may consist of contusions, laceration, and destruction or loss of the globe. In such cases, in order to avoid subsequent complications, such as infection of the vitreous or even sympathetic ophthalmia, enucleation should be performed.

Wounds of the orbit, when suppuration exists, should be incised and drained and treated with hot boric or saline fomentations.

(2) **Wounds of the Nose.**—The nose may be severely

Fig. 118. Shrapnel bullet lying posterior to orbit. Wound of entrance may be seen just above orbit, and track of bullet may be definitely followed by means of the small metallic fragments which have become separated. Eye was enucleated, but bullet was not located at the time, and no search was made for it owing to the infection.

comminuted, completely or partially torn away by shell or grenade fragments, or simply perforated as by rifle bullets. All such wounds should be treated conservatively, bearing in mind the importance of saving as much tissue as possible for later plastic operations to correct the disfigurement.

(3) **Wounds of the Mouth.**—These are caused not alone by the projectile, but also usually by supplementary projectiles set in motion by the force of the blow, such as teeth or fragments separated off from the superior or inferior maxilla. With such wounds there is danger of hæmorrhage and also of infection. Cheeks and lips may be torn away or severely lacerated, as may also be the tongue, or this latter may be simply perforated.

With such wounds there is always the danger of extensive edema not only of the soft parts, but of the glottis, and we may occasionally also get glossitis. Constant irrigation of the external wounds, together with a mouth wash consisting of some mild antiseptic, should be frequently employed.

(4) **Wounds of the Ear, including the Mastoid.**—Wounds of the external ear alone are occasionally seen, but are usually associated with injuries of other regions of the face or head. The injuries may be caused by any type of projectile and consist of perforations, grooves, and lacerations with partial or complete destruction of the auricle. Perforations from bullets may be small, round, or slit-like apertures, which usually readily heal.

The complications from such wounds are injuries to the large vessels and their branches, the lateral sinus and brain tissue itself, involvement of either the fifth or the seventh cranial nerves, and also complete or partial destruction of the tympanum. Occasionally, however, quite extensive destruction may take place without any complication arising, as is shown in the case of a soldier I had at the American Women's War Hospital quite recently. This man was wounded by a rifle bullet which passed through and destroyed the tragus, then passed through the base of the helix and carried away the whole mastoid process. There were in this case no resulting complications and the hearing in the injured ear was not diminished.

These wounds are usually infected and should be treated by disinfection and drainage. Loose fragments of bone and any foreign bodies should also be removed. In the simple grooves of the external ear, much time may be

FIG. 119. Bullet wound of exit. Wound of entrance was in parotid region on right. Bullet passed completely through the superior maxilla and involved a considerable loss of bony tissue and some teeth. Gaping wound of exit caused by the secondary projectiles. Considerable subconjunctival ecchymosis of left eye. Wound closed by granulations, leaving no sinus into buccal cavity.

saved by suturing the parts together and applying a simple antiseptic varnish consisting of tincture of benzoin comp., collodium, and iodoform powder.

(5) **Wounds of the Superior Maxilla.**—Such injuries may be caused by any type of projectile and are naturally associated with injuries of the soft parts such as cheeks (Fig. 119), lips or buccal mucous membrane, and also the

FIG. 120. Perforating bullet wound of the superior maxilla. Track taken by bullet is shown by the lighter area just above the last upper molar teeth involving the antrum.

antrum which may be involved. Wounds of the superior maxilla may be gutter, perforating (Fig. 120), or comminuting. The maxillæ may also be separated from each other in the middle line or dislocated from the adjacent bones. When the alveolar processes are involved there is more extensive trauma due to the avulsion of the teeth and their consequent propulsion through the soft parts.

In such wounds all the soft parts should be carefully preserved as well as any adherent fragments of bone. Strict attention also should be paid to the cleanliness of the buccal cavity. It is not within our province to speak in detail of the treatment accorded to fractures of either the superior or inferior maxillæ, as such treatment falls more naturally to the prosthetic dental surgeon. As, however, some time may elapse before such patients are able to receive such specialised treatment, an attempt should be made immediately to relieve the conditions as much as possible and to correct as well as may be any existing deformities. Fragments of bone which are still adherent to the periosteum should be replaced as far as possible, and only such fragments as are absolutely free from attachments to the tissues should be removed. As many of the teeth as possible should be saved, splinting them by wiring when necessary, and retaining the whole by means of some simple dental splint such as a Matas, which will allow of liquid feeding. Later more extensive methods of treatment may be instituted to correct the alignment, but such alignment should be made before union of the bony fragments takes place. The patient should be kept quiet, fed on liquids, and strict attention should be paid to the cleanliness of the mouth.

(6) **Wounds of Inferior Maxilla.**—Owing to the fact that the inferior maxillæ are formed of denser bone than are the superior maxillæ, the lesions caused by projectiles are more comparable with those found in the shafts of long bones. We find here comminutions (Figs. 121 and 122) and radiating fractures due to shell fragments, shrapnel bullets, and deflected rifle bullets, perforations (Fig. 123) and radiating fissures similar to those seen in the diaphyses, and also gutter wounds and erosions caused by rifle bullets. Wounds of the inferior maxillæ are very apt to be more serious than are the wounds of the superior maxillæ,

owing to the fact that there may be extensive destruction of tissue and consequent disfigurement, together with considerable impairment of function. In the perforating

FIG. 121. Comminution of the lower border of the inferior maxilla caused by shrapnel bullet. Bullet passed through left cheek, took a downward and outward direction towards the right, comminuting the body of the inferior maxilla. Shrapnel bullet seen lying on a level with the hyoid bone.

and gutter wounds the amount of trauma to the soft parts may be relatively small, but, on the other hand, in wounds caused by shell fragments where there is much comminution of bony substance or in wounds caused by deflected bullets or even by bullets striking point on and having a divulsive and propulsive effect on the teeth and bone fragments, causing them to act as supplementary projectiles, the effect on the soft tissues, especially about the wound of exit, may be tremendous (Fig. 124). In such cases as the latter we sometimes see a small round wound

Fig. 122. Radiating fracture and separation of lower part of inferior maxilla. Wound caused by bullet. Point of entrance may be seen as a light area at centre just above the few dark metallic fragments.

of entrance and a large gaping wound of exit. Wounds of the jaw, then, may vary from simple perforations or erosions where there is very little destruction of tissue to wounds where the whole jaw and buccal cavity may be destroyed. Wounds of the inferior maxillæ which also involve the buccal cavity usually suppurate, and, consequently, we may get as a result of the infection a certain amount of necrosis which may be slight or extensive, depending upon the amount of bony destruction caused by the projectile. With jaw injuries too we sometimes find involvement of Stenson's duct, and this combined with a large wound into the buccal cavity may give rise to a persistent salivary fistula which may take a long time to heal.

Fig. 123. Perforating bullet wound of ramus of jaw. Bullet passed completely through the ramus in a tangential direction, and caused some separation of large fragments. Bullet emerged in mid line of neck, posterior aspect. There was little resulting impairment of function.

Treatment.—The treatment of wounds of the lower jaw must of necessity be conservative and at the same time efficient. Treatment of such wounds may be considered under the following headings:

(*a*) Treatment for the proper cleansing and disinfection of the buccal cavity.

(*b*) Sufficient drainage to prevent the backing up of infected material.

(*c*) The saving, especially in the more extensive fractures, of all pieces of bone which have adhered to the periosteum and which may act later as grafts in the process of repair.

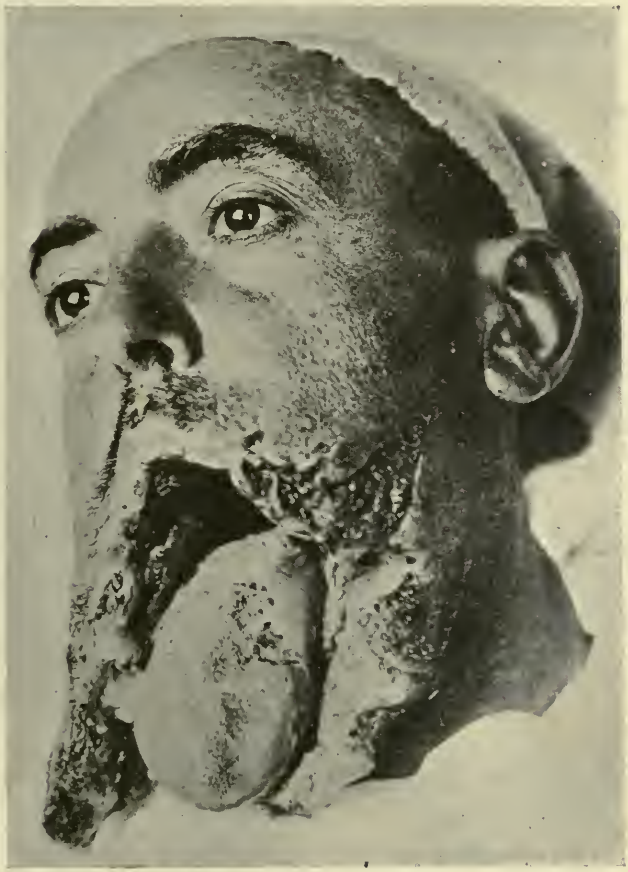

Fig. 124. Shell wound of face, showing extensive destruction of lower jaw, lower lips, and cheeks. (By permission of the American Ambulance.)

(*d*) The reduction and alignment of such fractures with due regard to the proper approximation of the teeth.

(*e*) The adoption of measures which will efficiently immobilise the parts, either by means of a dental splint or by wiring the teeth, and will at the same time allow of the feeding of the patient.

(*a*) *Treatment for the Proper Cleansing and Disinfection of the Buccal Cavity.*—The mouth should be thoroughly cleaned several times a day by means of some non-irritating disinfecting solution, or by a weak solution of hydrogen peroxide. Painting the gums and the wound with 2-per-cent. tincture of iodine is also an efficient procedure. In the more extensive fractures where there is usually an external wound leading into the buccal cavity, this can be easily accomplished by means of an irrigating syringe and a small soft rubber tube.

(*b*) *Drainage* is as important here as in any infected wound, and perhaps more so, for we wish as much as possible to prevent the patient from swallowing the septic discharges from the wound. In the more extensive wounds this is not difficult to accomplish, but in the smaller ones, especially if the suppuration be severe, it may be necessary to establish drainage through the sub-maxillary fossa into the mouth.

(*c*) The saving of even small pieces of bone is important, especially if they be adherent to the periosteum, as such fragments act as grafts and play an important part in the regeneration of new bone. Only bone fragments which have no connection with surrounding tissues or which present sharp spicules which may cause extensive damage to the soft tissues should be removed. Teeth which are loose or which interfere with the proper reduction and adjustment of the fracture should be removed.

(*d*) In all fractures of the lower jaw great care should be exercised in properly reducing and aligning the maxillæ. It is important that the teeth should oppose properly, for if this is not done the patient will be unable after the fracture heals properly to masticate his food, and, as a consequence, functional disturbances will result.

(*e*) Immobilisation of the fracture should be secured by wiring the teeth together or by holding the fragments by means of a dental splint such as a Matas. In the more extensive fractures, especially if there be much destruction of bone, specially constructed bridging splints will need to be made. These splints will not be described here, as such work falls rightfully to the dental rather than to the general surgeon; and it is to the former that we find it necessary to turn when such cases require later the more extensive prosthetic operations and the fitting of plates

FIG. 125. Gutter wound of soft part of cheek, not involving any bony tissue. Wound caused by bullet.

and artificial teeth. Fractures of the jaw may also be immobilised by means of various head and jaw appliances, of which perhaps the Barton is the best.

Complications.—In all fractures of the jaw, especially if there be involvement of the ramus or of the coronoid processes, we must always be on the guard against ankylosis. In many cases the ankylosis may be only temporary and will gradually disappear as the swelling of the tissues diminishes, but on the other hand it may be permanent.

(7) **Wounds of the Soft Parts.**—In addition to the wounds already described, we occasionally see those which

involve the soft parts such as cheeks or lips (Fig. 125), and which are not associated with any bony lesions. Such wounds are usually of the gutter type, are superficial, and

Fig. 126. Deformed bullet lying embedded in soft tissues of neck posteriorly. Bullet was removed. There was no involvement of nerves or vessels.

are caused by glancing blows from bullets or shell fragments. Such wounds may readily be sutured and will rapidly heal. Wounds which involve lips usually require plastic operations to correct the disfigurement.

III. Wounds of the Neck

These are seen in only a very small proportion of the wounded, probably owing to the fact that if there be any extensive injury to the cervical vertebræ, or to the vessels of the neck, death occurs before any surgical aid can be administered. As the main complications of wounds of the neck consist of injuries to the nerves and blood-vessels, these will be considered later in the chapters dealing with these subjects. Other lesions which complicate wounds of the neck are injuries to the trachea and œsophagus which are occasionally seen, and treatment in these cases consists principally of tracheotomy or, in the case of œsophageal wounds, of feeding the patient with nutrient enemata. Sepsis in this region is often a grave complication, and all infected wounds should be freely incised and drained, otherwise a severe edema or an extensive cellulitis may result. Smaller wounds of the neck (Fig. 126), if blood-vessels are not involved, usually heal aseptically, whereas, as in all gunshot wounds, the larger ones are prone to suppuration.

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CHAPTER X

WOUNDS OF THE TRUNK

I. Wounds of the Thorax

Shell wounds of the chest form one of the gravest types of injury, as a large proportion of the men so wounded die in a few moments and surgical measures are of no avail and, furthermore, cannot be carried out at the front. Men with the less severe injuries and who are able to be sent to the rear usually recover. A wound of the chest may involve the thoracic wall alone or else may penetrate and injure the lung as well. Chest wounds therefore may be divided into two classes :

(1) Non-penetrating Wounds.
(2) Penetrating Wounds.

(1) **Non-penetrating Wounds.**—In this group we include not only wounds of the soft parts, but also injuries to :

(*a*) Sternum.
(*b*) Ribs and Costal Cartilages.
(*c*) Clavicle.
(*d*) Scapula.

Wounds of the soft parts not involving the bones or pleura may be of a variety of types depending upon whether the anterior or posterior regions are involved, whether the soldier was prone or standing when hit, on the nature of the projectile and on its velocity at the time of impact. Shell and grenade wounds of the thoracic wall may consist of deep gutters or lacerations, extending through the muscles down to but not involving the ribs, cul-de-sac wounds, abrasions or contusions, and also small superficial wounds from minute shell fragments which involve the integument alone. Shrapnel and rifle bullets cause perforations when they strike tangentially. Such wounds are usually seen in the tissues of the back and in the pectoral regions. Again, we find instances where, owing to the low velocity, the projectile remains in the muscles either superficial or deep, and occasionally may be found lodged under the scapula (Fig. 127) in the subscapularis muscle or posterior to the scapula in the supraspinatous or infraspinatous muscles. We also find here, as we do with other forms of projectiles, superficial wounds, such as abrasions, erosions, and contusions, due to the projectiles striking the tissues tangentially and superficially. It will be seen therefore that wounds of the soft parts of this region present the same characteristics as do wounds of the soft parts in other locations. The treatment of such wounds naturally follows along the lines which have already been described, not only for the treatment of the infection, but also for the removal of any retained foreign bodies. It is important to bear in mind, however, the fact that in thoracic wounds, especially if the anterior portion be involved, there may be associated with the wound a varying degree of shock, and also conditions which may simulate injuries to the abdomen, and in such cases we sometimes find marked rigidity of the abdominal muscles. Associated too with the more extensive shell wounds of the thoracic wall, even though the ribs and pleura be not involved, we occasionally observe conditions, such as hæmoptysis, which would lead us to believe that the wound was of a more serious nature than had at first appeared. The hæmoptysis, however, is usually slight in such cases, although at times it may be very severe, and is due simply to the bruising of the lung tissue by impaction. It is essential that in such cases the possibilities of a more extensive injury to the chest wall should be carefully excluded both by a thorough physical examination and by means of the X-Ray, and that due conservatism should be practised in the treatment of such cases.

Fig. 127. Shows deformed rifle bullet lying embedded in muscles under the scapula. Bullet was later removed.

This may be illustrated by the following case:

J. T., aged forty-six, 3rd Worcesters, was wounded on April 29th. While advancing on the German trenches he was struck with a piece of shell, was knocked to the ground and experienced severe pain. The shell fragment was sticking out of his back and one of his comrades removed it. He was unable to receive any dressing for several hours, as he was lying between the trenches among other wounded and dead, and could not be reached by stretcher bearers. He remained there for about twelve hours before he could receive any aid. Very shortly after being wounded he spat up some blood and felt nauseated.

He was admitted to the American Women's War Hospital on May 7th, at which time examination was as follows: Right back presents (Fig. 128) just at lower border of scapula a wound 2 inches by 1 inch, and just below this and separated from it by an isthmus of skin 1 inch wide is a deep lacerated wound, 6 inches by 2 inches, extending down through deep fascia and muscles; no ribs exposed; both wounds sloughing and infected. There is considerable tenderness over the ribs on right side, especially on deep inspiration and on pressure, but no crepitus can be made out. There is also some slight hæmoptysis. Auscultation of chest shows breath sounds clear and distinct on both sides. Vocal and tactile fremitus normal. X-Ray taken shows no fracture. The wounds were dressed with saline, sloughing tissue removed and tight swathe applied to chest.

May 14th.—Wound closing in rapidly, hæmoptysis now very slight. Pains in chest wall persist on deep inspiration.

May 22nd.—Wounds clean and granulating, hæmoptysis has entirely ceased, pains in chest diminishing. Auscultation of chest negative. This patient is still in hospital at the time of writing.

Treatment.—Such cases do very well by immobilising the chest walls, by rest in bed, and by the application of an ice bag, especially if there be any hæmoptysis.

We will next consider those types of non-perforating wounds where there is involvement of the bony structures of the thorax without direct injury to the pleural cavity.

(*a*) **Wounds of the Sternum.**—Wounds of the sternum alone are uncommon and may consist of grooves or erosions from tangential wounds or of transverse fissures from contact.

(*b*) **Wounds of the Ribs and Costal Cartilages.**—Ribs may be fractured and costal cartilages loosened and injured by shell fragments striking directly or tangentially

FIG. 128. Shows shell wound of soft parts of back not involving the pleural cavity. There was some slight hæmoptysis, but no fracture of ribs made out.

and also by bullets. The wound in the bone may be an erosion or a groove, or it may be comminuted. In wounds involving the ribs we may get spicules of bone driven through the pleura and involving the lung, and in such injuries we may get pleurisy with effusion, hæmothorax, or even pneumothorax. In such wounds as these the treatment, especially when the wounds are infected, is of primary importance, for if these wounds be not sufficiently drained we may get an extension of the infection into the pleural cavity, where an ideal culture medium will be found, and, as a consequence, a resulting empyema. Immobilisation of the chest wall in these cases is important not alone for the comfort which it affords the patient, but also as an adjunct in the process of healing, especially when there is any hæmoptysis.

(*c*) **Wounds of the Clavicle.**—These may be caused by rifle or shrapnel bullets and by shell or grenade fragments. Such wounds may be caused by tangential blows, in which case the injuries may consist of grooves, erosions, or comminutions (Fig. 129). Direct blows cause transverse fractures, comminutions, perforations, and grooves.

Wounds of the clavicle are especially dangerous owing to the proximity of the subclavian and axillary vessels and nerves. Soldiers who present extensive lesions of these vessels usually die on the field.

Treatment consists in fixation of fragments by means of a sling and swathe, in removing loose spicules of bone which might injure the underlying vessels, and the promotion of free drainage.

(*d*) **Wounds of the Scapula.**—The scapula presents lesions similar to those seen in other bony structures, and these consist of perforations or grooves from bullets or of comminutions from shell fragments and from deflected bullets. Any portion of the scapula may be involved, and recently I had here a man who presented a perforation through the neck of the scapula, as is shown by the following case :

R. R., aged twenty-four, Royal Welsh Fusiliers, was struck in the left shoulder by a bullet, while in the trenches at Festubert, on May 16th, 1915. Felt a severe pain, and there was immediate disability of the left arm associated with some tingling of fingers, which, however, disappeared in a short time. A first-aid dressing was applied ten minutes after he was wounded and he was then sent back to a casualty clearing station.

He was admitted to the American Women's War Hospital on May 19th, 1915, at which time examination was as follows: Patient looks sick and toxic, temperature 102°; examination shows small wound of entrance $\frac{1}{4}$ inch in diameter just below clavicle in the outer third. This

Fig. 129. Shows bullet wound of outer end of clavicle and oblique fracture of the acromial end. A few fragments of metal are seen scattered about.

wound is discharging a large amount of pus and the surrounding tissues are badly swollen and ecchymosed. On back just below the level of the spine of the scapula and at the posterior axillary border is a wound of exit 2 inches in diameter which is discharging a large amount of pus; wounds dressed with hot saline fomentations. X-Ray taken a few days after admission showed a perforation through the neck of the scapula. Following admission the wounds healed uneventfully save for the fact that a persistent sinus occurred. There was marked atrophy of deltoids and of biceps as well as loss of motion in abduction. Sinus was curetted out several times, but refused to heal. Finally on November 12th he was operated upon and the sinus tracts both in back and in front were dissected out. Both wounds closed with drainage.

December 6th.—Wounds entirely healed, motions of arm limited especially in abduction and rotation, but those in other directions are nearly normal. Patient was given active and passive motions and exercises, and was discharged on January 15th for invaliding, as there was still marked limitation of abduction and rotation in shoulder.

The main complications in these cases are from injuries of the axillary vessels and nerves and also dangers of hæmorrhage from the scapular arteries. The treatment consists of free drainage, the removal of infecting elements, the control of hæmorrhage, and fixation.

Non-penetrating wounds of the thoracic wall in general and their treatment may be summarised as follows:

(1) Wounds may involve soft parts alone and with or without contusion of the lung.

(2) Effusion in the pleural cavity may be present or absent.

(3) When there are fractures, especially of the ribs, effusion or hæmothorax usually is present and there is also a varying degree of shock.

(4) All fractures should be immobilised.

(5) Infected wounds should be freely drained and all contaminated matter removed.

(6) The pleural cavity should not be opened unless empyema develops.

(2) **Penetrating Wounds.**—Penetrating wounds of the thoracic cavity are of interest not only from the viewpoint of the military surgeon, but also for purposes of comparison between the effects of modern projectiles and the older types used in former wars. Statistics of this present war are not yet available, but we can obtain some idea of the

injuries inflicted by modern high-power projectiles by the following information taken from Lagarde (1). In the Crimean War the French Army had a mortality of 91·6 per cent. from penetrating chest wounds, and in the same campaign the English troops showed a mortality of 79·2 per cent. In the American Civil War the percentage was 62·5 per cent., while in the Spanish-American War and the Philippine Insurrection the mortality with high-power rifles became reduced to 27·5 per cent.

The severity of penetrating wounds of the chest depends upon the projectile inflicting the injury and also upon the location of the wound. The location of the wound is important, for if the mediastinum be entered, death may quickly supervene, owing to the damage inflicted on the heart or on the large blood-vessels, whereas wounds located away from the mid line give rise to less grave symptoms. The amount of shock, too, depends upon the size of the projectile and is usually in proportion to the amount of injury inflicted. Shell fragments if of large size may cause extensive destruction not only of the chest wall itself, but of the contents as well, and will give rise to a great degree of shock. Rifle and shrapnel bullets, on the other hand, cause relatively little shock and may pass completely through the thorax without giving rise to any grave symptoms, or without causing any great amount of injury to the lung tissue, or they may be retained in the pleural cavity or in the lung itself.

It will be seen, then, that we have two types of penetrating wounds of the chest to consider, one where there is extensive destruction of the chest wall or where there is a free opening into the pleural cavity, and the other where the wounds are small and cause a relatively small amount of damage and which may heal aseptically. We may therefore divide penetrating wounds of the chest into two types :

(i) Open Wounds.
(ii) Closed Wounds.

(i) *Open Wounds.*—These are usually caused by shell fragments or by deflected bullets. There may be more or less severe comminution of the ribs with an open wound into the pleural cavity, allowing of free drainage, the entrance of air into the cavity and, consequently, the collapse of the lung. With this type of wound there is associated shock of varying degrees of severity. The more extensive wounds, where there is considerable laceration of the lung tissue, are not seen at the rear, the associated shock and hæmorrhage being so grave that such patients die very shortly after the injury has been inflicted.

The treatment of open wounds consists of adequate drainage and of dressings to overcome sepsis. The treatment of the existing shock is also an important factor.

Hernia of the Lung.—This is occasionally seen where a shell fragment has made a free opening through the thoracic wall and through this opening the lung tissue protrudes. Treatment consists either of reducing the hernia and draining the pleural cavity or, if the hernia is not easily reducible, ligating and removing the protruding portions.

(ii) *Closed Wounds.*—Closed wounds of the thorax are caused by rifle or shrapnel bullets and, as far as external evidence is concerned, present much the same appearance as do aseptic bullet wounds of other regions. The amount of shock from bullets of this region varies, sometimes being so slight that the soldier does not realise that he has been wounded, and again it may be extremely severe. The amount of shock is dependent upon the extent of the injury to the chest wall, and is greater when fractures of the ribs are associated with the wound in the chest. The amount of injury to the lung itself in simple bullet wounds is usually not great and may heal readily. There is very little bleeding from the external wounds.

Diagnosis.—The diagnosis of penetrating wounds of the chest is based upon the external signs of a wound together with hæmoptysis. No attempt should be made to confirm the diagnosis of perforating wounds by means of a probe, as by this procedure one is apt to carry into the wound more contaminated matter.

Hæmoptysis.—The amount of blood which the patient spits or coughs up varies to a great degree; it may be extremely slight in amount or it may be a large quantity. The hæmoptysis usually lasts only for a few days and then stops spontaneously. The principal points which we have to consider in any wounds of the chest are the secondary complications, these consisting generally of:

(1) Hæmothorax.
(2) Pneumothorax.
(3) Empyema or Pyothorax.
(4) Emphysema of the Chest Wall.

(1) **Hæmothorax.**—This occurs in practically all cases of penetrating or perforating wounds of the chest wall, and varies in amount from a slight exudate to a hæmorrhage which will fill the whole of the pleural cavity. According to Makins [2] hæmothorax occurred in 90 per cent. of all perforating wounds of the chest wall which were seen in the South African Campaign. The hæmothorax may come from the lung tissue itself, but in most instances it is due to hæmorrhage from the parietal pleura due to laceration or injury of the intercostal vessels, the internal mammary veins and arteries, and azygos veins. It may be seen therefore that the amount of hæmothorax which occurs depends directly on whether the pleura alone is involved or whether any of the vessels of the chest wall are injured.

Symptoms.—The severity of the symptoms varies with the amount of the effusion and also is dependent upon whether there is a gradual oozing or a rapid hæmorrhage. The amount of shock may be slight or severe, as may also be the severity of the pain, depending to a great extent upon whether there are associated with the wound fractures of the ribs. In some instances the soldier does not realise that he has been hit, while in other cases we find marked collapse and all the signs of an internal concealed hæmorrhage ; in many cases there is dyspnœa, especially in the early stages. The breathing is more rapid than normal, is painful, and the patients are apt to have a painful cough. Hæmoptysis is usually present, but this generally ceases in a week or ten days. The pulse rate is usually increased and there is also a rise in temperature to 101 or 102 degrees for the first few days and then a gradual return to normal.

Physical Signs.—We find here as with pleuritic effusions differences in mobility between the two sides of the chest walls. Sometimes there is slight mobility and at other times it is absent. There may also be some bulging of the chest wall on the affected side. The heart may be sometimes displaced, according to the amount of effusion and according to whether or not there is collapse of the lung. On percussion we find dullness varying from slight to absolute flatness, and if there be much effusion the flatness or dullness may extend as high as the scapula. Tactile fremitus is absent over the affected area. On auscultation the vocal fremitus may be diminished or absent over the base of the lung and increased towards the apex, the breath sounds may be absent or diminished or may be loud and bronchial in character. These physical signs may perhaps be best illustrated by some typical cases.

Case 1. **Perforating Bullet Wound of Chest.**—F. W., aged twenty-seven, 1st Worcesters, was wounded on March 13th, 1915, at Neuve Chapelle. Felt faint and giddy and fell to the ground when hit. There was some hæmoptysis for three days. Was kept in hospital in France until March 30th, when he was transferred to the American Women's War Hospital. Examination at the time of entrance was as follows : Patient showed a healed bullet wound at level of third costomanubrial junction on right (wound of entrance), and a healed bullet wound between ninth and tenth ribs in the extreme posterior axillary line on right (wound of exit). Chest well formed. Both sides move, but right moves somewhat less than left. This inequality on expansion is more marked on palpation.

Front of chest moves well. There is no swelling or adhesion of skin about the wound of entrance. Tactile fremitus is good in front, also felt behind to middle of right scapula, feeble below this. There is impaired resonance in front from the third rib shading into flatness in the axilla. In back there is flatness from the middle of right scapula downwards. Auscultation: breath sounds are feeble at the extreme base, on deep inspiration are feeble, distinct, and tubular, no friction rub. In front breath sounds are clear down to the fourth rib on right and below this they are feeble. Heart: Cardiac impulse visible in fourth interspace below nipple. Superior cardiac flatness begins with lower border of third rib. Percussion clear over wound of entrance. Patient had an uneventful convalescence, and was discharged on April 27th to duty with the following discharge note: "Greatly improved, all signs cleared up, although voice and breath sounds are still a little distant."

Case 2. **Perforating Bullet Wound of Chest.**—F. F., aged twenty-two, 2nd Rifle Brigade, was wounded on March 10th, 1915, at Neuve Chapelle; he walked for ten yards before he realised that he had been shot. Some blood came up in his mouth; he spat it out and sat down for about five minutes and was then carried to the dressing station, where he remained from ten o'clock in the morning till four in the afternoon. During this time he had considerable difficulty in breathing and was constantly coughing up blood. A few hours later he began to have considerable pain on breathing. About the fifth day after being wounded began to feel more comfortable. On March 17th chest was tapped, but very little blood was withdrawn. Hæmoptysis cleared up in five days; for the first six days he had a slight rise in temperature.

Was admitted to the American Women's War Hospital on March 30th. Examination at that time was as follows: There is a wound of entrance in left mid axilla in fifth interspace. Wound is of the oblique gutter type about

1 inch in length and almost healed. There is a wound of exit in the first interspace on left side close to the edge of the sternum and this also is practically healed. Chest appears normal, movements good although the left moves slightly less than the right; intercostal spaces on the left are slightly obliterated. Tactile fremitus good in front, but distinctly diminished at extreme base behind on left. Percussion of left back shows diminished resonance from angle of scapula shading to flatness at base. In front it is impaired from the second rib. On auscultation the breath sounds are completely suppressed in the back even with deep breathing. Patient made an uneventful convalescence and was discharged to duty on April 16th.

Case 3. **Perforating Bullet Wound of Chest.**—T. C. G., aged thirty-five, 2nd Warwicks, was wounded on March 11th, 1915, at Neuve Chapelle. Was knocked down by the force of the blow and felt a considerable amount of pain. There was some hæmoptysis.

Was admitted to American Women's War Hospital on March 30th, at which time examination was as follows: There is a healed wound of entrance just below the middle portion of right clavicle and in back is a superficial granulating area 1½ by 3½ inches just at lower angle of right scapula. Associated with the wound of entrance X-Ray shows a grooving fracture through the edge of second rib. Examination: Chest well formed. Expansion on left is slightly greater than on right. Percussion shows impaired resonance in front in second interspace shading into flatness at fourth interspace and in axilla. Behind there is slight blurring of interspaces and on percussion there is absolute flatness. Tactile fremitus is barely felt. Auscultation: Over whole of right back the breath sounds are clearer, no friction rub, no bruit over point of entrance, heart is clear.

Returned to duty on April 16th, examination at that time being as follows: Expansion of right chest still somewhat less than left, but much better than on entrance.

Tactile fremitus still slightly diminished. On auscultation breath sounds are clearer.

With all wounds of the chest, and more especially with the penetrating wounds, we must always bear in mind the fact that there may be associated with the projectile a certain amount of contaminated matter which may give rise to an infection in the pleural cavity.

Treatment.—Treatment in all cases of gunshot wounds of the chest consists primarily of a thorough disinfection of the wound and of the application of an occlusive dressing which will prevent the wound from becoming contaminated from without. Rest and absolute quiet are most essential not only for the palliation of the pain, but also to prevent as far as possible any increase in the amount of intrapleural hæmorrhage, and, for this reason, all soldiers who present penetrating or non-penetrating wounds of the chest should be kept either in the ambulances or at the clearing stations for several days before any attempt at transportation is made, for if they are transported when they are in more or less acute stages, there may be an increase in the amount of hæmorrhage or, if the bleeding is entirely stopped, it is possible it may again be started by the jolting incident to travel by stretcher or ambulance. The movements of the chest wall should be limited by means of a swathe and the patient should be kept quiet with adequate doses of morphia. Ice applied to the chest is also an adjunct in controlling the hæmorrhage. There should be as little interference as possible with these wounds, as a large proportion of the wounds caused by rifle or shrapnel bullets heal aseptically. If, however, signs of infection become evident, the wounds should be thoroughly drained and any contaminated matter and bone fragments removed in order to prevent if possible the extension of infection into the pleural cavity. In cases where there is marked dyspnœa, aspiration of the chest may be advisable, but if possible this should never be undertaken before the tenth or twelfth day, as otherwise there is danger of recurrent hæmorrhage. Furthermore, the aspiration of chest should never be done in one stage, but should extend over several days. The fluid should be withdrawn slowly and only in small amounts every other day. If this procedure is not adhered to, severe symptoms may arise; and if at any stage of the withdrawal of the fluid the patient begins to cough, the aspiration should be immediately stopped. In cases of hæmothorax where there is much distress Bradford (3) recommends aspiration of the chest with replacement of oxygen, and it may be well if I quote here his own experience of this method.

"Aspiration with oxygen replacement to avoid the too sudden expansion of the lung suggested itself as a suitable method of treatment in simple hæmothorax, and in the autumn of 1914 Major Elliott and I began treating cases of hæmothorax in this manner, and we have used it ever since. Two distinct benefits ensue: the lung rapidly re-expands and the pyrexia that is so often present rapidly subsides, so that the patient quickly regains his health, and his invalidism is measured by weeks rather than by months. Aspiration with oxygen replacement is a much more satisfactory operation than ordinary paracentesis thoracis. With ordinary paracentesis it is scarcely ever possible to remove all the fluid at one sitting, and the operation has to be repeated. This is not the case when the oxygen replacement method is employed, and in a large series of such cases it was very exceptional for the operation to have to be repeated. Further, if local anæsthesia is efficient it is possible to remove even very large collections, *e.g.* 90 ounces, with no serious discomfort to the patient. The fluid is withdrawn, and so soon as the patient experiences a sense of tightness from the change in the pleural pressure the oxygen is allowed to flow in, and when the discomfort has passed off a further quantity of the fluid is withdrawn, and so on until the operation is completed. Difficulties may arise from the cannula becoming blocked with clot, and then the usual methods must be adopted to clear the cannula. If there is much cough, or if the patient is nervous and anxious, a preliminary small dose of morphia is very useful.

"This treatment has been, according to our experience, very successful; no untoward results have been observed, and in a large series of cases not one of secondary hæmorrhage has occurred, and I feel confident that it is the proper treatment for any case of sterile hæmothorax of moderate or large size.

"It is of course needless to say that the most scrupulous care should be taken as regards disinfecting the patient's skin and cleansing all instruments used. Further, an efficient local anæsthetic must be used. In cases so treated there is no reaccumulation of fluid, and I am of the opinion that where this is described in simple sterile hæmothorax, it is really a redistribution of fluid owing to imperfect and incomplete aspiration with some partial re-expansion of the lung."

(2) **Pneumothorax.**—This may be due either to the projectile injuring the lung and allowing of the escape of air from a bronchus or the bronchioles into the pleural cavity or it may be due to operative interference for the removal of a projectile. This is a severe and often fatal condition. In pneumothorax there are severe pain and dyspnœa associated with a feeling of suffocation, respiration is shallow and rapid, pulse is weak and often irregular. Examination shows the affected side to be distended and immobile and on auscultation the breath sounds are diminished or absent. On percussion we get marked tympany and with coin percussion we find a bell sound.

Treatment.—The treatment is essentially the same in most points as that followed in hæmothorax, rest and morphia being essential. Patient should be put in the position of greatest ease and should be given inhalations of oxygen. Fluid in the pleural cavity is also present. If the circulation becomes impaired the chest should be aspirated and the contained air drawn off. In such cases as this there may be direct extension of infection either from the wound in the chest wall or from the injured lung itself, and we must watch such patients carefully for any signs of infection, and if these occur the pleural cavity must be adequately drained.

(3) **Pyothorax.**—This may occur in any case where there is effusion and may be due either to contaminated matter being carried in with the projectile, by direct extension from an infected wound of the chest wall, or by direct infection through an injured bronchus or bronchiole.

Treatment in such cases consists of a rib resection which will allow of adequate drainage and the removal of any contaminated matter or projectile which can be easily removed from the pleural cavity.

(4) **Emphysema of the Chest Wall.**—This occasionally occurs where there is a direct communication between the small wound of entrance and a wound in the lung. There may be considerable edema of the tissues surrounding the wound, associated with a crackling in the skin. It is usually not a very serious condition, as the air will generally absorb in a few days.

Retained Foreign Bodies in the Chest.—Missiles may perforate or may penetrate the chest wall and be retained. The projectiles which are retained are those of a low velocity, either shrapnel or rifle bullets which have only a slight remaining velocity and also smaller shell fragments. Shrapnel and rifle bullets (Fig. 130) may be retained and cause relatively few symptoms, and with such missiles the dangers of infection are as with other wounds. Wounds caused by shrapnel bullets and by rifle bullets may heal aseptically and give rise to no signs of infection, whereas, on the other hand, wounds caused by shell fragments with the associated contaminated clothing and foreign substances which may be carried in are much more prone to infection. Missiles may be found either lying embedded in the lung tissue or else may be found free in the pleural cavity. The X-Ray or fluoroscopic examination gives us the best means of confirming the diagnosis in these cases. Foreign bodies which are retained in the lungs do not move freely as the patient changes his position, but may be seen to move with respiration, whereas projectiles which are free in the pleural cavity will move only when the

FIG. 130. Shows rifle bullet lying in the lung.

position of the patient is changed. Foreign bodies in the lungs, if they give rise to no symptoms, should be left alone. Foreign bodies in the pleural cavity, if they give rise to no symptoms, may be left *in situ*, but if there are much pain and discomfort associated with them they may be removed after all pulmonary symptoms have subsided. If, however, infection occurs and it is necessary to drain the chest for pyothorax, the foreign bodies if easily found at this time should be removed.

It may therefore be seen that gunshot wounds of the chest divide themselves into two stages, the initial stage at the front where death is due largely to primary hæmorrhage, and the secondary stage at the base where wounds may heal aseptically or may give rise to secondary complications such as pneumothorax and infection.

The following cases illustrate instances of wounds of the chest in which there were retained foreign bodies :

Case 1. **Shrapnel Bullet Wound of Chest with Retained Foreign Body.**—G. L., aged thirty-seven, 1st Dorsets, was wounded on March 14th, 1915. He fainted very shortly afterwards. There was a marked degree of pain with some hæmoptysis for a day, associated with a slight cough ; at no time had he any fever. Admitted to the American Women's War Hospital on March 30th.

Examination at time of entrance as follows : General condition good, chest well formed. Wound of entrance on left chest over third rib 2½ inches above and to left of nipple. This wound was 1·5 cms. in diameter and was covered with a scab. Intercostal space immobile, expansion of both sides good and equal. Breath sounds clear in front and behind. Vocal fremitus evident everywhere. Percussion shows no dullness, no friction rub over side of wound, heart sounds clear. Fluoroscopic examination shows shrapnel bullet lying nearer to the anterior chest wall than to the posterior. Bullet moves with lung on respiration, on expiration it goes behind the heart shadow, and on inspiration it travels apparently about 1½ inches clear of the heart shadow upwards and towards left axillary line.

April 27th.—Since entrance patient has had some slight pain in chest, which has now practically disappeared, and he is now fit to be discharged for duty.

Case 2. **Shrapnel Bullet Wound penetrating Chest with Retained Foreign Body.**—G. A. B., aged thirty-two, 6th

Yorks and Lancs, was wounded on August 28th, 1915, at Gallipoli while in a trench at Chocolate Hill at the Dardanelles. There was considerable hæmoptysis for the first few days, but this gradually diminished. Was admitted to the American Women's War Hospital on September 10th, 1915. Examination at that time showed a small wound of entrance in right upper back about on a level with third dorsal vertebra and about 2 inches to right of spine. Wounds practically healed. No hæmoptysis and no pain

FIG. 131. Shows retained shrapnel bullet in lung which moves with respiration as is described in the text.

on respiration. The breath sounds clear, vocal and tactile fremitus present. There is no dullness on percussion. Fluoroscopic examination shows bullet moving with respiration (Fig. 131). Patient showed no symptoms and was discharged on September 24th.

There is also one other type of thoracic wound which should be mentioned, and that is the thoracic abdominal type which occurs in the lower part of the chest, where the projectiles first enter the pleural cavity and then pierce the diaphragm and cause injury to the abdominal viscera. The treatment here is conservatism.

Wounds of the Heart.—These are occasionally seen and are usually fatal. Such wounds, however, sometimes recover, and Murphy cites a case in which he saw an injury to the right ventricle and the right auricle caused by a comminution of the sternum, and in this case the patient recovered.

II. Wounds of the Abdomen

Wounds of the abdomen form one of the most important types of injury seen in warfare, not only as regards the mortality, but also on account of the constantly recurring problem of what is the best form of treatment. While it is true that we will probably never know the exact number of abdominal wounds, as so many of the men thus wounded die within a short time and are never seen in the hospitals, nevertheless we are able to gain some idea of the incidence of this type of wounds by comparing the figures of the total number of wounded received into the ambulances and casualty clearing stations. The figures which are available show that of the total number of wounded received into ambulances and clearing stations the proportion of those having abdominal wounds is approximately 2 per cent. Abdominal wounds, so far as the gravity of the lesions is concerned, are in about the same proportion as are head injuries. The mortality of this type of wound has always been disappointingly high, and while it is true that the mortality when the older armaments were used was much greater than it is now with the present high-velocity projectiles, nevertheless the injuries caused by the latter are often of such a severity that no treatment, conservative or operative, is of avail. While it is also true that very few statistics are obtainable at the present time, yet enough figures have been collected to give one a slight knowledge of the comparative results.

In the Crimean War wounds of the abdomen gave a mortality of 92·5 per cent., in the American Civil War 90 per cent., in the Franco-German War 69 per cent., in the Spanish-American War and the Philippine Insurrection 67·1 per cent., and approximately 66 per cent. for the Russian wounded in Manchuria. (Lagarde.) Makins gives the incidence of such wounds as 9·74 per cent. in the South African War, and this higher percentage may probably be accounted for by the reason that much of the fighting was in the open, whereas in the present war the men are to a great extent sheltered by the trenches, which may account for the lower incidence of 2 per cent. Makins also gives a mortality of 73·3 per cent. With what figures are available, Wallace gives a mortality of 70 per cent. for this war, but these figures will probably need revising at the end of the war.

Wounds of the abdomen may be of varying degrees of severity depending upon the regions involved, upon the type of projectile causing the injury, and also upon the amount and nature of infection carried in by the missile. It is also dependent upon the position of the man at the time he was hit, whether he was lying prone or was standing erect, and also upon whether the projectile causing the wound strikes the tissues directly or obliquely.

Wounds of the abdomen are divided into:

(1) Wounds of the Abdominal Wall.
(2) Contusions.
(3) Penetrating Wounds.

(1) Wounds of the Abdominal Wall.—The abdominal wall may be injured without the projectile inflicting any peritoneal or visceral damage. Such wounds may be caused by projectiles of low velocity, such as rifle bullets with a low remaining velocity, shrapnel bullets, shell and grenade fragments, and by bullets travelling at a high rate of velocity. They consist of perforations or setons of the extraperitoneal tissues, non-penetrating wounds of the same tissues, and also gutter wounds. Shell and grenade fragments if of low velocity and of small size may become embedded in the skin or in the muscles and form cul-de-sacs, or, if they strike the body tangentially, may cause gutters or erosions, lacerations, and even superficial perforations or seton wounds (Fig. 132). Rifle bullets travelling at a low rate of speed and shrapnel bullets penetrating into the muscles or striking superficially or tangentially cause gutter wounds and setons. Deflected and deformed bullets

Fig. 132. Shows tangential perforation through abdominal muscles by bullet. Wound of entrance is on right hypochondrium and the wound of exit is on left on level of umbilicus. Bullet passed through the abdominal muscles and did not enter the abdominal cavity.

cause lacerations. Rifle bullets with a high remaining velocity and which strike the tissues tangentially or laterally cause gutter wounds and perforations through the muscles.

Treatment.—The treatment of such wounds differs in no respects from similar wounds in the soft parts of other regions, although the possibilities of more serious injury involving the viscera should be carefully excluded, and the same considerations apply in regard to infection and the carrying in of contaminated matter by the various projectiles as in other wounds.

(2) **Contusions.**—Even in war surgery where we expect that the injuries which we see will all be caused by projectiles, nevertheless we occasionally come across certain types of injuries which simulate those seen in civil life. Contusions of the abdomen may come within this category, as such injuries are sometimes seen which have been caused by the kick of a horse or a mule, a blow from a rifle butt, or by some form of trauma other than that caused by a projectile. Abdominal contusions are also caused by shell fragments of low velocity which strike the body tangentially, by rifle bullets with a low remaining velocity, or by shrapnel bullets which strike directly against the body or against some part of the equipment which is over the abdomen, such as the belt buckle. Contusions caused by factors other than projectiles may be associated with injury to the abdominal viscera, such as rupture of some part of the intestinal tract, as well as injuries to the spleen, kidneys, liver, and the urinary bladder. Injuries to the viscera associated with contusions of the abdominal wall by shell fragments are uncommon. We may, however, find in such cases rupture of the muscle fibres at the site of injury associated also with hæmatoma or simple ecchymosis.

Symptoms.—If the injury be at all extensive it is immediately followed by signs of shock or collapse. The pulse is rapid and weak and there are nausea and vomiting. Occasionally the contusion of the abdomen, especially if in the region of the sympathetic plexus, may be severe enough to cause death without causing any injury to the abdominal contents. There are also marked rigidity and tenderness of the abdominal muscles.

Diagnosis.—In the early stages it is often extremely difficult to determine whether the injury is simply a contusion or whether there is associated with the contusion some injury to the viscera. Such patients should be carefully watched for several hours and should be kept absolutely quiet. It is essential that no morphia should be given during the first few hours after the injury has been received, as this will only tend to mask the symptoms and will obscure the diagnosis. If after several hours of rest and quiet the nausea and vomiting cease, the pain and rigidity of the abdominal muscles become lessened, and the pulse becomes less rapid and of a better quality, we are justified in feeling that the injury is one of contusion of the abdominal wall, and that the abdominal viscera are intact; in such cases rest and quiet will suffice. If, however, the symptoms persist and there is no diminution of tenderness or rigidity, an immediate operation should be performed either for the control of hæmorrhage from one of the mesenteric vessels or for the closure of a laceration in the intestine. The diagnosis of injuries to individual abdominal organs will not be considered at this time, as these injuries will be dealt with later.

(3) **Penetrating Wounds.**—With penetrating wounds of the abdomen we find two distinct types of cases:

(*a*) Those in which the projectile passes through the abdominal wall but does not cause any visceral injury.

(*b*) Those in which the missile not only perforates the wall or walls, but also causes a varying degree of injury to the abdominal viscera.

The amount of injury thus inflicted upon the viscera is directly dependent upon the velocity and the type of projectile causing the wound. The same general principles hold good for wounds of this region as for wounds of other locations, and the larger the projectile the greater the severity of the wound.

(*a*) **Penetrating Wounds of the Abdomen without Involvement of the Viscera.**—These occasionally occur and give rise to no apparent gross injury of the intestines or mesentery. Such wounds are caused by rifle bullets or by shrapnel bullets with a low velocity which enter the abdomen in a transverse and oblique direction. This may be illustrated by the following case :

G. F., aged twenty-two, 2nd South Wales Borderers, was wounded by a shrapnel bullet on July 24th, 1915, while in a dugout at Gulley Beach, Gallipoli. Had some nausea for a few days and considerable pain, which gradually diminished. Was transferred to Malta and later to England ; admitted to the American Women's War Hospital on August 26th. Examination at that time showed wound of entrance over mid portion of back about opposite fifth lumbar spine with some tenderness extending down into buttocks. There was partial anæsthesia of both legs from hips down and the knee jerks were somewhat exaggerated ; no ankle clonus.

October 7th.—Patient comfortable, wound entirely healed, anæsthesia is entirely diminished. The patient has some signs of bladder irritation. X-Ray shows shrapnel bullet localised below left Poupart's ligament (Fig. 133).

October 9th.—Operation for the removal of the shrapnel bullet, left inguinal incision made and inguinal ring incised. Finger inserted into abdomen and the bullet palpated just below Poupart's ligament and close to the peritoneum. Incision into abdomen was enlarged downward and bullet removed. Wound closed in layers. On November 10th patient was discharged to convalescent home, wound healed solid ; all bladder symptoms have disappeared ; patient feels perfectly well. This case illustrates what is probably a penetration of the abdominal cavity from the back without causing any visceral injury, but it is also of interest as showing a slight concussion of the cord or sacral plexus in addition.

Various theories have been advanced in explanation of the reason why a bullet which has entered the abdominal cavity should cause no apparent visceral injury. Makins from his experience in the South African Campaign gives one theory as follows :

" The small intestine is exceptionally well arranged to

Fig. 133. Shows shrapnel bullet lying in region of Poupart's ligament. Wound of entrance was in back, and bullet apparently traversed abdominal cavity without giving rise to any visceral injury.

escape injury. First of all it is very movable; secondly, it is so arranged that in a certain direction a bullet may pass almost parallel to the long axis of the coils; thirdly, it is elastic, capable of compression, and light, and hence offers but a small degree of resistance to the passage of the bullet across the abdominal cavity."

Another theory is that advocated by Lagarde, who states:

"The small intestine is suspended by the mesentery in a way to promote free movements, and as the coils of gut are superimposed when the bullet track takes certain directions the missile is able to travel parallel to the long axis of the coils without perforation."

These theories are supported by the fact that in such cases there is no later development of peritonitis such as takes place when the small intestine is known to be perforated. Such wounds, when the possibility of peritoneal infection or perforation has been excluded, do well with conservative treatment of the local condition and also with rest and quiet.

(2) **Penetrating Wounds with Involvement of the Viscera.**— In such wounds as these there is not only a wound in the abdominal wall and in the peritoneum, but there is also associated with this injury a lesion in some part of the intestinal track or to some other of the abdominal viscera and, possibly, multiple wounds involving different organs and regions. In such wounds the direction taken by the bullet is more apt to be anteroposterior or oblique than transverse or lateral as in the former case.

Wounds of the abdominal viscera may be caused by any type of projectile, and it is essential to bear in mind certain facts regarding the type of missile causing the injury. Undeformed bullets travelling at a low velocity cause only small perforations which tend to close spontaneously owing to the action of the muscular fibres of the intestine or stomach, and, further, with such wounds there is even a certain amount of protrusion of the mucous membrane, especially of the small intestine, which retards the escape of the intestinal contents, and thus tends to prevent the spread of the infection and so allows it to wall off and become localised. On the other hand, rifle bullets with a high velocity or from proximal ranges inflict more serious damage and cause large gaping wounds in the intestines. These may also have an extensive effect when they strike hollow organs filled with incompressible fluid substances. Bullets which have become deflected or deformed cause much more extensive injury than do undeformed bullets, and they also carry in with them contaminated matter such as clothing. Shrapnel bullets and shell and grenade fragments owing to their larger size and, in the case of shell and grenade fragments, owing to their jagged and irregular shape, cause wounds in which the perforations are much larger and where there is much laceration; furthermore, such wounds are complicated by the presence of substances already contaminated, which are carried in by the projectiles. The gravity of the injury also depends to a great extent upon the anatomical region involved, and this is shown by the fact that perforations of the small intestine cause a high mortality, while injuries to the large intestines, with the exception of the transverse colon, rank next, and that perforations of the stomach are the least serious or, in other words, wounds of the epigastric, umbilical, and hypogastric regions are more serious than wounds of the hypochondria, lumbar, and iliac regions, and of all of those wounds those of the umbilical region cause the gravest results.

The following table, which is based upon observations made close to the firing line by Wallace ([4]), may prove of interest as giving some pertinent facts concerning abdominal wounds:

Total number of cases	511
Arrived moribund	145
Total mortality, excluding the moribund	45·8 per cent.
Total mortality, including moribund .	61·25 ,,
Considered with view to operation .	366
No operation considered advisable .	56
Total operations	310

Total operative mortality . . .	53·9	per cent
Total hollow viscera mortality . .	64·5	,,
Stomach (uncomplicated) mortality .	43·75	,,
Small gut	63·8	,,
Great gut	60·0	,,

Diagnosis.—In every abdominal wound the diagnosis of the exact lesion is not of so much importance as is the recognition of the fact that a perforation has been caused by the projectile. The appearance of the external wound does not necessarily indicate the degree of injury which has been caused intra-abdominally, but the relation of the wound to the anatomical structures should always be carefully noted as well as the direction of the track of the projectile. Shock and collapse may be slight or extremely severe, but as it also occurs in those cases where there is no peritoneal involvement, too much reliance should not be placed upon this sign unless it persists for a considerable length of time. Rigidity of the abdominal muscles, a rapid weak pulse, nausea and vomiting, the passing of blood by rectum or the vomiting of blood are the main symptoms upon which we must base our diagnosis. Not all of these are conclusive, however, as many of them may occur in other conditions, such as contusions, and often the diagnosis of perforation may have to be based upon the relation between the external wound and the anatomical region involved. In certain instances, however, there may be a hernia of the wounded intestine through the abdominal wound, or, if the patient is not seen for several hours, signs typical of peritoneal infection may have developed. In cases where there is a noticeable effect on the intestine, and also where there are more extensive lesions caused by shell and grenade fragments and by shrapnel bullets, fecal matter or gas may escape from the external wounds. Hard fecal matter escaping from the abdominal wounds suggests injury to the large intestine, while soft or liquid fecal matter indicates a perforation of the small intestine.

Some indication too of the location of the lesion may be gained by the blood which is passed, fresh blood pointing to an injury of the colon, while old blood indicates a lesion of the small intestine. Hæmatemesis indicates either a wound of the stomach or a contusion of the gastric mucous membrane. Again, we may find injuries of the mesenteric vessels or lesions of the outer coats of the intestines from stomach, which give rise to signs only of an internal concealed hæmorrhage.

Treatment.—The treatment of abdominal wounds in the present war has undergone a considerable evolution as compared with the treatment accorded such cases in former wars and even in the beginning of this present war. Up to the time of the present war the indications have all been in favour of conservatism as regards the operative treatment of such cases in the field, on account of the high mortality attained by operating under unfavourable conditions. It was found also that many men who had been wounded by high-velocity bullets of small calibre, especially in the Spanish-American War and in the South African Campaign, often made uneventful recoveries if not operated upon, while, on the other hand, those upon whom operation was performed did not do so well. In the Russo-Japanese War abdominal operations were given up on account of their want of success, and on the Japanese side operations upon the abdomen were forbidden. At the beginning of the present war, as in other wars, the local conditions were such that operations were inadvisable owing to the lack of aseptic facilities, and then too the question of transportation was such that the men were received into the hospitals many hours after being wounded and were usually in such a state of collapse as to render operation inadvisable. Much of this has been changed, and now, with well-equipped hospitals close to the firing line where the soldiers may be received in two to six hours after being wounded, and with every facility for the performing of an operation under aseptic conditions, it is apparent that many lives are being saved by early operation, especially those cases in which there is hæmorrhage.

The treatment of all abdominal cases should be selective, as many of the men received into the hospitals will be moribund and beyond all surgical aid, and there will also be many who present such extensive injuries that the chances of recovery are very remote and where operative procedures do not seem justified and may do more harm than good.

There is still a third group of cases, and these are the wounds with which we are principally concerned and from which group we should make our selection. Such cases are in better condition than those first mentioned and offer a better chance for operative success. Cases which present intestinal wounds and peritoneal symptoms as well as all cases of hæmorrhage should be operated upon as quickly as possible, wounds in the intestines closed, hæmorrhage controlled, and the abdominal cavity drained. Those cases which have been caused by bullets and which show peritoneal symptoms, and in which there are no signs of hæmorrhage, may be treated by the expectant method, which consists essentially of rest and quiet induced by morphia, and abstention from food except for small amounts of water until such times as adhesions will have had a chance to form and thus localise any infective process. Delorme([5]) advocates Murphy's treatment in all extensive wounds of the intestines, both on account of the rapidity with which it may be performed and the results obtained. The operation consists essentially of a small buttonhole incision above the pubis. The incision can be made under a local anæsthetic and through it the pelvis is drained. Patients are then kept in the Fowler position and are treated by continuous rectal salines. He also cites seventeen cases of perforation which were treated by this method and all of which recovered.

Foreign bodies in the abdominal cavity should be removed together with any contaminated matter which has been carried in with them, as otherwise septic foci may form about these foreign bodies and give rise to severe trouble later. Undue prolongation of the operation should not be allowed if the foreign body is not easily found, but should be reserved for a later time.

It may be well at this time to outline briefly the injuries and the treatment of some of the more important abdominal organs other than the intestines.

Wounds of the Liver.—Wounds of this region may consist of perforations or lacerations. Hæmorrhage is the important factor and may be controlled either by packing as in the case of bullet wounds or by suturing in the case of the more extensive lacerating wounds. The blood should be removed from the abdominal cavity, which should be closed except for a drain.

Wounds of the Spleen.—The spleen may be perforated or lacerated and the indications here are to control the hæmorrhage by sutures if the wounds are small. If the wounds be large and the hæmorrhage cannot be easily controlled, the splenic vessels should be ligated and the spleen removed. The parietal wound here too should be drained.

Wounds of the Kidney.—These may occur alone or in connection with wounds of other organs and may consist of contusions, perforations, or lacerations with the accompanying hæmorrhage. The location of the wound together with blood in the urine determines the diagnosis. The kidney should be exposed and examined, wounds should be sutured and any contaminated matter removed. If the kidney is lacerated beyond repair, the pedicle should be tied and the kidney removed and the wound closed with drainage.

Wounds of the Rectum.—The rectum may occasionally be entered by projectiles which have penetrated the abdominal cavity. We may also find lesions caused by missiles which have entered through the back and buttock without penetrating the abdominal cavity. The wounds may be perforated or lacerated and, as a result, there is a discharge of fecal matter from the wound and later a fistula results. Such wounds should be freely drained and any foreign bodies and projectiles removed, and later, when the sepsis has subsided, an attempt may be made to close

FIG. 134. Shows shell fragment in lower portion of pelvis, lying in ischiorectal fossa. This shell fragment caused an extensive injury to the rectum and was later removed and the laceration of rectum sutured.

the fistulous track. This may be illustrated by the following case:

J. T., aged forty-two, Royal Munster Fusiliers, was wounded in the back by a piece of shell on June 9th, 1915, at Gallipoli. Was admitted to the American Women's War Hospital on August 26th, 1915.

Examination on entrance shows an infected wound of entrance over the sacrococcygeal joint; there is a marked odour of colon bacillus from the discharge. Rectal examination negative. X-Ray shows shell fragment lying on right side of pelvis below level of head of femur (Fig. 134).

September 16*th*.—Wound still persists, and this morning patient passed some fecal matter and gas through the wound.

October 15*th*.—Probe passed through original wound enters the right ischio-rectal fossa for a distance of about 6 inches.

November 1*st*.—Still discharging fecal matter, gas, and pus. Shell fragment probably traversed the right ischio-rectal fossa, lodging beneath right descending ramus of pubis. Operation not deemed advisable at present.

December 1*st*.—Fecal discharge from sinus still persists.

December 20*th*.—Condition the same. X-Ray taken at this time shows shell fragment in same position; considerable pain in back. Operation deemed advisable.

January 5*th*.—Operation: Rectal examination shows a depressed cone-shaped opening in posterior rectal wall 2½ inches above anus. Probe enters this area from the external wound. A 4-inch incision was made from coccyx through the right ischio-rectal fossa anteriorly. Underneath the coccyx a pus cavity the size of a walnut was found. Sinus was followed anteriorly to the right descending pubic ramus, beneath which the shell was located and removed. Sinus curetted, rectal wall freed about fistula and the opening sutured. Rubber dam drains to side of rectal wound and to depths of ischio-rectal fossa.

January 13*th*.—Excellent recovery; stitches out; bowels open. Fistula has re-established itself. Patient free from pain, temperature normal.

February 1*st*.—Patient up and about, has no pain. Fistula is closed. Three sinuses persist and are slowly closing.

February 20*th*.—Two sinuses remain, one extending from the anterior extremity of the operation wound backwards through right ischio-rectal fossa; no fecal discharge.

March 20th.—Patient in excellent condition, can walk and sit, though open sinuses persist.

April 15th.—Left sinus gradually closing, other sinuses practically healed.

May 10th.—Condition slightly improved since last note; patient still in hospital.

Wounds of the Bladder.—Wounds of the bladder may be simple perforations due to rifle or shrapnel bullets, to laceration from larger projectiles or from a deformed bullet, or rupture of the walls due to contusion of the abdominal wall while the bladder is distended. The wounds may be either extraperitoneal or intraperitoneal, and the treatment consists of an exploratory operation, the finding and suturing of the wound in the bladder wall, the drainage of the abdomen and constant drainage for the bladder. Foreign bodies may occasionally be found free in the bladder. These consist usually of rifle bullets or of shrapnel bullets which may be easily removed through a suprapubic incision. Occasionally the missile may enter the bladder through the back as is illustrated by the following case:

Shrapnel Bullet in Bladder ([6]).—W. R., aged twenty, sapper, was wounded at Ypres on May 26th, 1915, by a shrapnel bullet from a shell which burst about fifty yards from where he was standing. Following his being wounded he walked a distance of six hundred yards to the dressing station, where the wound was dressed, and then two hundred yards farther to the ambulance. In the ambulance he was taken to a general hospital and kept for four days; then sent to England, where he was admitted to the American Women's War Hospital on June 1st, 1915, with the following history and examination:

Well-developed and nourished youth; able to walk without discomfort. Temperature and pulse normal. In median line of back at lower end of sacrum is a small penetrating wound $\frac{1}{2}$ inch in diameter (Fig. 135). About this wound there is an area which is somewhat reddened.

No pain or tenderness on palpation or when he walks. No discharge from wound save very slight amount of sero-purulent exudate. No sinus made out. Patient feels perfectly well, but states that he has difficulty in urinating, especially when he stands erect. At such times the stream will start normally and will then be checked suddenly, and this is associated with considerable pain. When he lies on his side he has no difficulty in urinating. He also states that when he is lying down and turns over he can feel something moving about in his bladder.

Fig. 135. Shows perforating or penetrating bullet wound of sacrum. The bullet in this instance passed through and entered the bladder as described later.

For the first two days after being wounded urine was slightly red in colour and the first bowel movement was slightly streaked with blood, but there is now no macroscopic blood in urine or stools.

Rectal examination reveals a firm sinus tract adherent to rectum, passing around to the left and then straight towards the bladder. No opening in rectum; no tenderness and no masses felt.

Urine examination shows normal urine save for a slight amount of blood and pus.

Cystoscopic examination shows a rounded mass lying just to one side of urethra. Mass moves when patient turns. Wound in bladder wall not made out.

Stone searcher passed into badder shows the presence of a metallic foreign body.

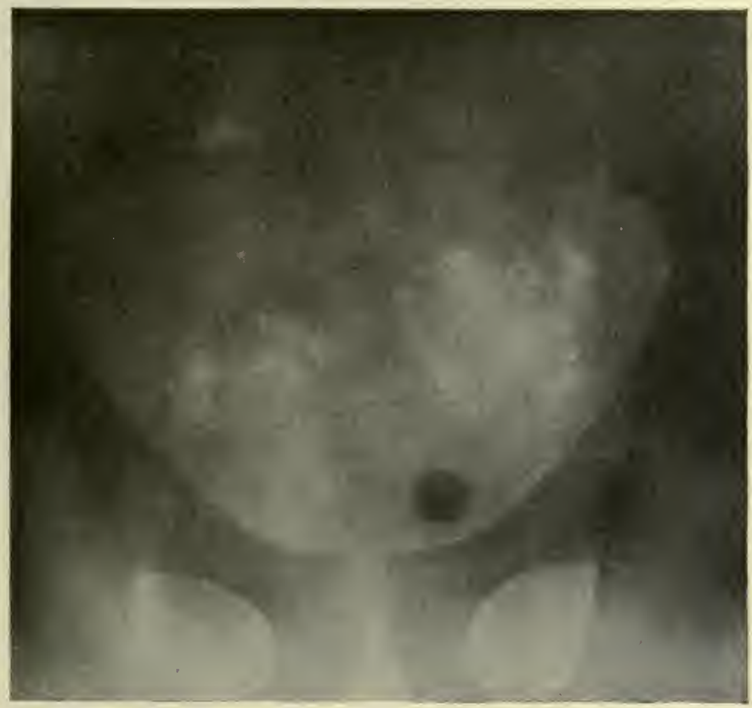

Fig. 136. Shrapnel bullet lying free in bladder. Bullet passed through from back as is described in text and shown in Fig. 135.

X-Ray examination taken in different planes shows a foreign body in bladder region (Fig. 136).

June 29*th*, 1915.—Ether and operation. Suprapubic cystotomy. Bladder opened through a small incision and bullet located and removed by bullet forceps. Wound in bladder closed tightly. Small drain to prevesical space. Constant drainage.

The foreign body removed was a lead ball ½ inch in diameter, and at the time of removal was becoming encrusted in several places with salts.

Following the operation patient had an uneventful convalescence and the wound was entirely healed in two weeks. Since that time the patient has felt well; he can pass urine without any further trouble and will soon be able to return again to duty.

III. Wounds of the Spine

Wounds of the spine as with wounds of other parts may vary from slight wounds to extensive destruction not alone of the vertebræ, but also of the spinal cord itself. Gunshot wounds of the spine form one of the most fatal types of injury seen in warfare. Some of the men thus wounded may live to reach the hospitals, but there many of them succumb to their injuries. Injuries of the spine and spinal cord may be caused directly by the projectile inflicting the wound, by fracture of the vertebral column and consequent pressure on the cord by loose fragments of bone, and also by concussion from high-velocity projectiles, usually bullets which may touch the vertebræ but do not damage the cord. Wounds caused by bullets consist of perforations of the bodies of the vertebræ either with or without associated injuries to the cord (Fig. 135), fractures of the transverse processes, or spinous processes and contusions of the laminæ. Shell fragments cause contusions, comminutions, and destruction of the cord. The region wounded determines also the gravity of the lesion, and cases wounded in the cervical region are much more serious than those in the dorsal or lumbar regions. In the American Civil War 642 cases of wounds of the spine were seen and the aggregate mortality is given as follows:

Cervical Spine—70 per cent.
Dorsal Spine—63 per cent.
Lumbar Spine—45·5 per cent. (Lagarde.)

Wounds of the vertebral column and spinal cord may be divided into two groups :

(i) Concussion of the Spinal Cord.
(ii) Injury to the Spinal Cord by the projectile inflicting the wound or by depressed bone fragments.

(i) **Concussion of the Spinal Cord.**—Concussion of the spinal cord is caused by bullets of a high velocity which strike or pass through the vertebræ without causing any direct injury to the cord itself. The concussion to the cord is caused by the vibratory impulse which is transmitted by the passage of the projectile and which may give rise to a hæmorrhage in the cord tissue. Concussion may be either slight or severe and, in the more extensive types, may simulate a complete division of the cord itself with its associated paralysis. It is important both as regards the prognosis and the treatment that concussion should be differentiated from an organic lesion, and the main reliance in the differentiation between the two conditions is in the transient nature of the symptoms shown by cases of concussion, as is illustrated by the following two cases :

Case 1.—E. V., 1st Royal Warwicks, was wounded in the back by a bullet at Ypres on June 7th, 1915. At the time he was struck he felt a tingling sensation in his right hip, leg, and foot, and thought at that time he had been shot in his foot and reported his injury as such. He walked for some distance and was then picked up by the stretcher bearers. He was then sent to Rouen, where he was kept for a short time, and was then transferred to England and admitted to the American Women's War Hospital on June 28th.

Examination showed a healed bullet wound in right lumbar region on level with crest of ilium and about 2 inches from the middle of back. At entrance there was a slight anæsthesia in his right foot; no disturbances of reflexes. X-Ray taken showed a bullet in back at junction of fifth lumbar vertebra and sacrum (Fig. 137). There were no symptoms from the retained bullet and the anæsthesia in foot gradually cleared up. Patient was discharged to duty on July 28th.

Case 2.—G. S., aged forty-three, 2nd East Lancs, was wounded in the back by a bullet on March 29th, 1916, while in the trenches. Was knocked down by the force of the blow and he says that his legs felt numb. Was admitted to the American Women's War Hospital on April 7th.

FIG. 137. X-Ray taken of patient lying on abdomen, shows bullet on level of 5th lumbar vertebra and to right of vertebral column.

Examination at that time was as follows: There is a wound of entrance in the back about the level of the third lumbar vertebra and 3 inches to the right of the mid line; there is a seropurulent discharge from the wound and considerable redness and induration of the adjacent tissues. There is an area of anæsthesia over the tibial region and dorsum of right foot and also pain referred to thigh and knee. Reflexes exaggerated. X-Ray shows bullet lying just to left of fourth lumbar vertebra and also shows a fracture of the transverse process (Fig. 138).

April 9th.—Operation. Wound excised and incision carried down exposing vertebra. Transverse process of fourth lumbar vertebra found fractured and comminuted. Loose fragments of bone removed ; tip of bullet could be

Fig. 138. Rifle bullet on level of 4th lumbar vertebra and on left side. Fracture of left transverse process. X-Ray was taken with patient lying on abdomen.

felt with finger, lying deep down against the peritoneum, but could not be removed. There was apparently no pressure upon spinal cord. Wound closed with drainage.

May 2nd.—Wound entirely healed except for a small sinus at site of drain. Symptoms are abating and there are less pain and anæsthesia.

May 22nd.—Symptoms improving.

June 9th.—Ether operation. Bullet located in same position as formerly and was removed.

July 1st.—Patient up and about ward, now able to walk with aid of cane. Symptoms abating.

(ii) **Injury to the Spinal Cord by the Projectile inflicting the Wound and by Depressed Fragments of Bone.**—This type of injury may be caused by rifle bullets, by shrapnel bullets, or by shell fragments, and here, as with other wounds, the nature of the projectile is important on account of the associated infected material which may have been carried into the wound and also on account of the nature of the lesions which are caused by the different projectiles. Rifle bullets, shrapnel bullets, and even small shell fragments may penetrate the spinal canal and exert pressure on the cord without giving rise to any gross pathological changes, but the same projectiles, on the other hand, may cause extensive destruction. In such injuries, especially those caused by shrapnel bullets and by small shell fragments, there are associated with the projectiles comminutions and splintering of the walls of the neural canal, and such fragments may themselves exert pressure or may be driven into the cord. Large shell fragments cause extensive destruction of the vertebræ and of the cord itself.

The following case illustrates the slight degree of injury which may be exerted by depressed bone fragments :

W. A., 1st Buffs, was wounded on October 23rd, 1914, by a bullet which struck him just behind the level of the left anterior superior iliac spine. He was knocked down by the force of the blow and felt a marked pain down left leg and thigh, and there was also immediate disability of his left leg, which he was unable to move.

He was admitted to the American Women's War Hospital on October 31st. Wound healed on entrance. There is marked pain over his coccyx, over the sacral iliac joint and in his right hip. There is numbness of his left foot and ankle, and left knee jerk is exaggerated. X-Ray

(Fig. 139) shows bullet in median line on level with fifth lumbar vertebra.

November 26th.—Operation; median longitudinal incision 4 inches long over lower spine, muscles retracted and

FIG. 139. Shows rifle bullet in region of 5th lumbar spine. In this case there were fracture of the neural arch and pressure upon the cauda equina. Bone fragments, however, are not shown in X-ray.

vertebral column exposed. Fracture of fifth lumbar spine was found with some fragments depressed and exerting pressure upon the cauda equina. Depressed fragments were removed, bullet was not found, wound was closed.

November 30th.—Wound healing; there is increased active motion of left leg. Sensation has returned to normal in foot, and left knee jerk is less active.

December 19th.—Patient still has some pain in the region of coccyx. Knee jerk still slightly exaggerated, sensation in foot practically normal, but there is still a slight ataxic gait of left leg. Discharged to Devonport for invaliding.

Symptoms.—When there is compression or laceration or even contusion of the cord there is more or less shock associated with complete or partial loss of conductivity of the cord, the amount of which is dependent upon the degree of injury inflicted. There is also paralysis below the injured segment, and the severity of the paralysis depends upon the amount of destruction of cord tissue and whether the blocking off is complete or only partial.

Diagnosis.—The diagnosis is based upon the location and severity of the wound, upon the degree and location of the paralysis, and upon X-Ray examination, which will give us some evidence as to the severity of the lesions in the vertebræ and also as to whether or not there is a retained missile compressing the cord.

Prognosis.—In all cases where there is total loss of conductivity the prognosis is extremely grave, and even when the symptoms of a transverse lesion are incomplete the prognosis must be guarded. Foreign bodies lying in the canal and exerting pressure on the cord may not necessarily be fatal unless sepsis supervenes, but even in such cases severe secondary changes in the cord may take place after the projectile has been removed, and these changes will add to the gravity of the prognosis.

Treatment.—The external wound should be carefully disinfected in order to prevent if possible any extension of infection into the canal, for if this occurs a severe and usually fatal meningitis may result. Operative measures in these cases where pressure is being exerted by the projectile or bone fragments compressing the cord give the best chance for an ultimate recovery, especially if the pressure on the cord can be relieved before secondary changes have taken place, but even in such cases the results are not always gratifying. In cases where there are extensive laceration of the cord and a total loss of conductivity, operative measures will be of no avail and should not be undertaken. Where there is partial conductivity laminectomy should be done for the removal of the depressed bone fragments or for the removal of a projectile or to relieve pressure on the cord caused by an intradural hæmorrhage. It should, however, always be borne in mind that in such wounds, and especially in those caused by the larger projectiles, the dangers from secondary infection are very great, and meningitis may occur as a result of having to drain the wound. Following the operation the patient should be carefully watched and kept quiet, using opiates if necessary, and, further, in such cases time alone will determine the question as to whether the loss of conductivity in the cord is complete or only transitory.

A most important factor in all such cases is the after care and the nursing, especially the latter, as men suffering from injuries to the spinal cord are very prone to decubitus unless extreme care is exercised to keep the skin dry and clean. Undue pressure on back and buttocks should be prevented by change of position, by air rings, and by the avoidance of creases in the sheets. These cases too are particularly prone to a severe cystitis due to constant catheterisation, and this should be done only with the greatest care, as otherwise an ascending infection, resulting in a pyelitis, may occur due to faulty technique in passing the catheter.

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CHAPTER XI

WOUNDS OF THE NERVES

I. Types of Injury :
  (1) Physiological :
    (*a*) Concussion.
    (*b*) Contusion.
  (2) Anatomical :
    (*a*) Partial Division.
    (*b*) Complete Division.
  (3) Pathological :
    (*a*) Compression by Scar Tissue.
II. Treatment :
  Expectant—Operative.
III. Treatment after Operation.
  Massage—Electrical—Ionisation.

I. Types of Injury

Gunshot wounds of the peripheral nerves afford us a large subject for study and discussion, not only as regards the actual lesion, but also as regards the ultimate functional result of the part supplied by a given nerve. In wartime with the great diversity of injuries which we find we are constantly meeting conditions and lesions which are rarely seen in civil practices, and injuries to nerves which in normal times would seem impossible are constantly encountered. Fortunately, though wounds to the nerves are seen in large numbers, they are rarely fatal, and the main considerations with which we have to deal are the questions of treatment and the functional end result.

Formerly injuries to the nerves were regarded as a type of case in which we are expected to get a more or less permanent disability. With our present-day knowledge, however, of the repair of nerves and our methods of nerve suture, many cases which in former times would have been regarded as hopeless may be cured or at least improved. We know that the conductivity of a severed nerve may be restored by suturing the separated ends together, and that severe neuritis caused by a nerve being caught and compressed in scar tissue can be alleviated by freeing that nerve. With our present-day methods of diagnosis of nerve lesions by means of the electrical reaction of the muscles, and also by our application of aseptic surgery, we are able to do much for such cases. Initial injuries to the nerves may be either physiological or anatomical, and may be caused either by transmitted impulses or by direct injury to the nerve itself, and later we find secondary degenerations due to pathological changes in the tissues surrounding the nerve, such as the formation of scar tissue or callus.

We will first of all consider the initial lesions which occur when the tissues in the vicinity of a nerve are wounded, and also the secondary complications which arise at a later date. The loss of conductivity of a nerve may be:

(1) Physiological:

- (*a*) Concussion.
- (*b*) Contusion.

(2) Anatomical:

- (*a*) Partial Division.
- (*b*) Complete Division.

(3) Pathological:

- (*a*) Compression by Scar Tissue.

(1) **Physiological**: (*a*) **Concussion.**—Concussion of a nerve is generally due to the effects produced by modern rifle bullets, and the severity of the concussion is dependent upon the velocity at which the projectile was travelling at the time of impact. It is not necessary for the bullet to

come in direct contact with the nerve to cause concussion, as this condition is due essentially to the vibratory impulses transmitted through the tissues by the passage of the bullet. This condition may be associated with all the signs of a complete severance of the nerve and may persist for weeks or months.

Symptoms.—The symptoms in nerve concussion vary from slight to severe, and may consist of complete or partial loss of function or of sensation in the part supplied by that nerve. These symptoms are transient and usually disappear in ten days to two weeks. In the more severe cases there is loss of muscular function associated with muscular atrophy, and such cases often simulate a complete division of the nerve trunk. In these cases, however, even though the injury to the nerves appears extensive, we get a gradual return of sensation followed later by the restoration of muscular function, as is shown by the following case:

R. M., aged twenty, 7th Norfolks, was wounded in the neck by a bullet on October 13th, 1915, while advancing at Hulluch. Patient did not feel much pain, but there was immediate disability of his right arm. Was admitted to the American Women's War Hospital on October 16th. Right shoulder presents just above superior angle of scapula a small healing wound of entrance ¼ inch in diameter. On the anterior surface of the neck just above middle of clavicle is an infected granulating wound 1 inch long and ½ inch wide. Patient complains of tingling sensation in fingers and is unable voluntarily to abduct arm, but is able to extend it anteriorly and posteriorly. He is also unable to flex his forearm. Wounds dressed with hypochlorous acid and arm supported by a splint with arm abducted at right angles to body.

November 1st.—Wound practically healed, patient now being massaged and having electric treatment. Tingling in arm and fingers has disappeared. There is no muscular atrophy, but patient is still unable to abduct his arm.

November 20th.—Wounds entirely healed, sensation in hand and fingers normal, patient is now able to flex his forearm, but is still unable to abduct the upper arm. Transferred for more extensive electrical treatment.

(*b*) **Contusion.**—Contusion of the nerves is produced not by the vibratory effects on the tissues as in concussion, but by direct slight contact with the projectile, either a rifle or shrapnel bullet, shell or grenade fragments, or by secondary projectiles such as a spicule of bone which may have become detached and projected against the nerve. In such cases we may find slight intraneural hæmorrhage.

Symptoms.—The symptoms in nerve contusions are often associated with pain and hyperæsthesia, especially if there be intraneural hæmorrhage. The symptoms resemble to a great extent those seen where there is a partial division of the nerve, but the loss of sensation is irregular and is not well defined. Trophic changes also occur and there is muscular atrophy. The muscles supplied by the nerve exhibit a diminished reaction to the electrical current; and while some muscles supplied by the nerve may show a complete paralysis, others may still respond to the faradic current. Often it is extremely difficult to differentiate between contusions of a nerve and concussion. Such cases usually recover, but it may be many months before there is any marked improvement.

(2) **Anatomical**: (*a*) **Partial Division.**—Partial division of a nerve is usually caused by a rifle bullet which either causes an abrasion or groove of the nerve or else perforates it. Perforations are commonly seen in the larger nerves, but there have been instances where bullets have been known to perforate nerves with a diameter smaller than the calibre of the bullet.

Symptoms.—In partial divisions of the nerve the parts supplied by the uninjured fibres show transitory symptoms similar to those seen in cases of nerve concussion. In the parts supplied by the divided fibres the electrical reaction is incomplete, and there is also prolonged loss of sensation and motion over the area of distribution of these fibres.

(*b*) **Complete Division.**—This type of injury is usually seen in the smaller nerves which have been injured by bullets or by shell fragments. It is also seen in the larger nerve trunks which have been injured by deformed or deflected bullets and also by shell fragments, and the loss in continuity of the nerve depends upon the size of the projectile inflicting the injury.

Symptoms.—With a complete section of a nerve there is a loss of muscular power and sensation over the area which that nerve supplies. There is no reaction to the faradic current, and later we get reactions of degeneration, atrophy of the muscles and trophic changes in the skin.

(3) **Pathological:** (*a*) **Compression of the Scar Tissue.**—In this class we include those secondary involvements due to compression of the nerve by scar tissue even though the nerve was not originally injured. Such conditions are seen where a nerve has become involved in callus following a fracture, as, for instance, the musculospiral nerve, or where there is scar formation in the soft tissues adjacent to a nerve, the result of a former wound.

Symptoms.—The symptoms in this case are similar to those of partial division and are usually insidious in their onset if there has been no previous nerve involvement. In those cases where there has been contusion of the nerve it may be compressed by the newly forming scar tissue before the original symptoms have abated.

Diagnosis.—The diagnosis of nerve lesions, then, is based upon the presence of a wound in the vicinity of a nerve, by loss of movement of the muscles supplied by that nerve, and by sensory changes in the skin. These changes are of a varying degree of severity depending upon whether the injury is a contusion or whether there is a complete division of the nerve. Time will, however, often make the diagnosis clear, especially the difference between concussion or contusion and complete or partial division, for the reason that the paralyses in the former conditions are only transitory, while in the latter they are prolonged.

Infection.—In every gunshot wound involving nerves we must always bear in mind the possibilities of infection, and the same general considerations apply in this case as apply in gunshot wounds of other regions. Infection has an important bearing on these cases, for, if it is allowed to persist, a severe neuritis may result and, furthermore, the process of healing will be unduly prolonged. Active sepsis therefore should be dealt with as in other wounds, and later, when operative procedures for the repair of the nerve are being considered, we must bear strongly in mind the possibilities and dangers of latent sepsis, even in those wounds which have apparently healed aseptically.

II. Treatment

In the treatment of injuries to the nerves one of the first requisites is patience, both on the part of the surgeon and on the part of the patient. The operative treatment of such cases belongs essentially to the base hospitals and should not be undertaken at the front on account of the risks of infection. The only exception to this rule may be in those cases in which, if it is found necessary to ligate the blood-vessel, the nerve may be found severed, and in such instances may be sutured. Treatment at the front therefore should consist only of disinfection of the wound, the prevention of sepsis, occlusive dressings, and fixation, while the more extensive treatment should be reserved for a later time.

At the base surgical zeal should not displace conservatism, especially during the first few weeks, as more harm than good may thus be done. All cases of nerve injury should be carefully watched and every effort made to diagnose carefully the exact condition. Later, when the diagnosis has been made and all transitory symptoms have subsided, the question of operation may be considered.

Treatment at the base resolves itself into:

(1) Expectant Treatment.
(2) Operative Treatment.

(1) **Expectant Treatment.**—This consists essentially of support by some form of splint to prevent undue stretching of the paralysed muscles, and of rest and the employment of warmth. The skin should be carefully washed and

FIG. 140. Modified Jones splint for the correction of wrist-drop, due either to muscular injury or to nerve injury.

bathed with alcohol each day, and any undue pressure on any part of the affected skin should be avoided. Opiates may be given when this is absolutely necessary in order to overcome the pain. The wound should be treated symptomically—the prevention of infection in the smaller wounds and the overcoming of sepsis in the larger and already infected wounds. After the pain has subsided the nutrition and tone of the muscles should be maintained as much as possible by means of light massage and by the galvanic current. Joints should be massaged and should receive passive movements in order to prevent the formation of joint adhesions.

(2) **Operative Treatment.**—Operative treatment should be considered only in those cases which show a complete or partial compression of the nerve fibres and also upon those cases where there is compression due to the nerve being caught in scar tissue or callus. In no instances should an operation be considered in the presence of sepsis, and further, owing to the dangers of latent sepsis even in an apparently aseptically healed wound, no operative procedures should be instituted in less than three months. If these rules are not adhered to, more harm than good will often be done, and we may stir up a virulent latent infection which will undermine all the benefits which are possible by operation.

When operative measures have been decided upon, the skin should be carefully prepared as follows: Shave and scrub well with soap and water and apply a soap poultice. On the following day wash again and apply an alcohol dressing, and on the third day, the day of operation, paint the area of operation with 2-per-cent. iodine and apply a sterile dressing. When the patient reaches the operating room and has been anæsthetised, iodine should again be applied. An incision long enough to give free exposure of the nerve should be made over the site of the injury, and should be made if possible through healthy tissues and the scar of the healed wound avoided. The nerve should be well exposed on either side of the injured area, and the condition of the adjacent tissues and the appearance of the nerve itself should be carefully noted.

The subsequent treatment depends upon the conditions and the amount of injury to the nerve and whether it has been simply perforated or partially divided, and is lying in cicatricial tissue, or whether there is a loss of continuity of the nerve substances.

We may therefore consider operations on nerves as divided into:

(1) The freeing of the nerve from constricting scar tissue—Neurolysis.

(2) The repair by Anastomosis of the loss of continuity.

(1) **Neurolysis.**—In those cases where there has been a partial division of the nerve or a perforation, or in those cases where, following a fracture, the nerve becomes embedded and constricted by the surrounding scar tissue or callus and where there are signs of compression, it is essential that the nerve should be freed from this constriction. Often in such cases it will be found impossible to identify the nerve among the dense scar. In such cases the nerve should be freed by gradual dissection either proximally or distally to the mass of the scar tissue, and then with the freed nerve as a guide the dissection may be carried carefully through the cicatrix until the nerve is entirely free. Whether there has been a perforation or a partial division, a fusiform swelling will be seen at the site of injury. A considerable degree of judgment must be exercised at this time to determine whether the mass in the nerve should be removed and an end-to-end anastomosis performed, or whether it will be sufficient simply to free the nerve from the surrounding scar tissue and to protect it from being again involved in scar tissue.

Opinions differ to a great extent as regards the advisability of dividing the nerve and then suturing it, and the decision rests to a great extent upon the amount of injury to the nerve and its state of conductivity to electrical reactions. If there is marked impairment of function it may be advisable to divide the nerve on either side of the neural mass and to suture the ends together. This is best done by Lembert sutures of fine catgut or of Pagenstecker linen thread. The division in the nerve should then be surrounded by a covering of Cargile membrane or by some fascia from the patient himself.

Fullerton [1] advocates the use of a sleeve made from a vein from the same patient. A length of vein 2 inches long is excised and then slipped over the nerve before it is sutured. The vein sleeve is then placed so that it covers the junction in the nerve and thus prevents the ingrowth of scar tissue. If the nerve is simply freed from the scar tissue the roughened surfaces on the nerve must be protected from the formation of a new cicatrix by Cargile membrane or by fascia. This latter procedure, as well as the conditions found at operation, may be perhaps best illustrated by the following case in which there was a perforation of the sciatic nerve by a bullet.

J. M., aged nineteen, 24th London, was wounded on May 24th, 1915, by a bullet which passed in an antero-posterior direction through his left thigh. At the time he was hit he felt a sharp pain in his left leg and there was immediate disability so that he was unable to walk. Was admitted to the American Women's War Hospital on June 1st.

Examination on entrance showed a small clean wound of entrance $\frac{1}{4}$ inch in diameter at middle of left thigh on anterior border of vastus externus. On posterior aspect of thigh at the same level and in median line is a wound 1 inch in diameter. Both wounds clean. Patient able to flex his lower leg, but is unable to move foot or toes. There is anæsthesia of the whole of the lower leg and foot. Knee jerk on left slightly exaggerated.

June 15th.—Foot has been hypersensitive for the past few days ; knee jerks on left lively. To-day there is some slight plantar reflex and patient is able to move his toes, but cannot move his foot. Foot slightly swollen and skin rather glossy. From this time on patient showed a slight amount of improvement, which was not as marked as would have been expected if the injury were that of contusion. There was also considerable atrophy of muscles of calf, and muscles did not respond well to the faradic current. There was, however, no complete loss of reaction.

September 27th.—Operation : The sciatic nerve was

A

B

Fig. 141. Osgood toe-drop splint. This splint is constructed of spring-wire and then covered as in *A*. It will overcome any tendency to toe-drop, on account of its spring action. Even when the foot is extended in a plantar direction the action of the splint will bring it back again to right angles. *B* shows splint applied.

exposed for a distance of 3 inches. There was a scar track where the bullet had passed through the tissues and through the centre of the nerve. Nerve was freed from this scar tissue and was found to present a marked fusiform swelling ½ inch in length. It was decided that as the nerve was only partially divided, and had also been compressed by the scar tissue, a neurolysis to free the nerve would be sufficient. A new sheath was formed from the fascia of the biceps muscles to surround the nerve and to prevent if possible further formation of scar tissue. Wound closed in layers. Following the operation the wound healed uneventfully, but there was very slight improvement. Toe-drop persisted, and was corrected by means of a splint (Fig. 141). It was finally decided to transfer the patient to London for a more extensive electrical treatment. He was discharged on October 18th with the following note: "Complete paralysis persists except for a slight amount of motion in the flexion of great toe; considerable atrophy of muscles; general condition excellent."

(2) **Repair by Anastomosis of the Loss of Continuity.**—In cases where the nerve has been completely divided as is proved by the total loss of conductivity to the electrical current, the nerve will be found lying in the mass of scar tissue usually with the ends widely separated. Complete division is characterised by the finding of a loss of continuity together with a bulb of growing nerve axons on the proximal end of the severed nerve. The operative procedure has already been described, but the condition found may be illustrated by the following cases.

A. W., aged eighteen, 2nd Hants, was wounded on June 29th, 1915, at Gallipoli by a bullet which struck his right elbow. There was an immediate loss of sensation and function in his arm.

He was admitted to the American Women's War Hospital on August 26th, 1915. At that time his right elbow presented a healed wound over both the external and the internal condyles with marked deformity of whole elbow (see Fig. 53). Movements of forearm limited in flexion and extension; rotation fair. There were complete paralysis and loss of sensation over the area supplied by the ulnar nerve. Following entrance there was no improvement in symptoms, and it was decided to free the nerve from the surrounding scar tissue.

November 2nd.—Operation: Incision made over course of ulnar nerve and over the condylar area. Nerve found completely divided and the ends firmly bound down in scar tissue. Nerve found to be very much enlarged, and on proximal end there was a large bulb. Nerve carefully freed from scar tissue, the ends resected and sutured with fine catgut. Spicules of bone from the olecranon and from the internal condyle which were found pressing upon the nerve were removed. Nerve surrounded by fascia and wound closed. Following the operation patient showed very few signs of improvement and was transferred on November 26th for electrical treatment before any further observations could be made.

R. J., aged twenty-one, 6th North Staffs, was wounded on October 13th, 1915, at Hulluch, by a shrapnel bullet which perforated his thigh just above patella and emerged in the apex of the popliteal space. Admitted to the American Women's War Hospital on October 19th. Showed complete loss of flexion and extension of foot and also complete loss of sensation in his foot and leg. Following entrance there was no improvement in the nerve condition.

On November 12th operation was decided upon. Popliteal nerves exposed. The tibial nerve was found to have a slight abrasion and was bound down in scar tissue. The common peroneal nerve was found to present much fusiform swelling which involved the whole diameter of the nerve. Both tibial and peroneal nerves were freed from the scar tissues. The mass was removed from the peroneal nerve and anastomosis performed, but, owing to the small amount of scar tissue in the tibial nerve, resection was not done. A surrounding envelope of fascia was placed about both nerves and wounds closed. Following operation patient had a toe-drop splint applied.

December 26th.—There was some return of extension and abduction of foot. Patient was discharged for more extensive electrical treatment on January 8th, 1916. At that time he showed only a slight return of function in the area supplied by the peroneal nerve, while in the area supplied by the tibial nerve there was very little restoration of function.

III. Treatment after Operation

Treatment following the operation is most important as regards the end functional result, and every care possible should be taken to aid the nerve and also the muscles during the process of restoration. The muscles should be massaged and passive movements employed to prevent adhesions. Electricity is also an important adjunct at this time as well as in the early stages before operation, and should be employed either as the galvanic or direct current, or else in the form of the faradic or interrupted current, but should only be employed by those accustomed to its uses. Ionisation is also of value, especially in those cases where the nerve is involved in scar tissue, and this cicatrix can often be rendered less dense by the use of chlorine ions from sodium chloride. The application should be made directly over the scar tissue. In those cases where there is much pain, considerable relief may often be obtained by ionisation with salicylates.

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CHAPTER XII

WOUNDS OF THE BLOOD-VESSELS

I. Lesions caused by Projectiles.
  (1) Contusions and Abrasions.
  (2) Perforations.
  (3) Incomplete Division.
  (4) Complete Division.
II. Hæmorrhage :
  (*a*) Primary Hæmorrhage :
    (i) External Primary Hæmorrhage.
    (ii) Internal Primary Hæmorrhage.
  (*b*) Secondary Hæmorrhage.
    Treatment—Hæmatoma.
III. Aneurisms :
  (*a*) False Aneurism.
  (*b*) Arterio-venous Aneurism :
    1. Aneurismal Varix.
    2. Varicose Aneurism.
  Symptoms—Treatment—Prognosis.
IV. Sequelæ :
  Gangrene from Ligation.

Injuries to the blood-vessels form most important sequelæ to the effects caused by modern projectiles, not only on account of the immediate result on the soldier as regards his life, but also on account of the secondary complications which may ensue following such an injury. Gangrene, secondary hæmorrhage, and aneurism comprise the most important factors to be guarded against or watched for in all wounds in the regions of blood-vessels of any size.

I. Lesions caused by Projectiles

Lesions of blood-vessels may be caused by any form of projectile, and the character of the lesion varies to a great extent with the velocity, the type, and the size of the missile. Injuries to blood-vessels are seen in larger proportions in modern warfare, and this is apparently due to the fact that with the older types of projectiles which were large and had a low velocity, the blood-vessels were more frequently pushed aside than they are by the present high-velocity bullets which penetrate the tissues so rapidly that the vessels are injured before they can be pushed aside. In considering the injuries to arteries we must also bear in mind the fact that the veins lie in close proximity to the arteries and are usually injured at the same time also, therefore the same general considerations will apply to both.

Injuries to blood-vessels are divided into :

(1) Contusions or Abrasions.
(2) Perforations.
(3) Incomplete Division.
(4) Complete Division.

(1) **Contusions or Abrasions.**—Contusions or abrasions of an artery comprise any degree of traumatism to the tissues of the vessel without opening the lumen. They may consist of a simple bruising or tearing of the outer coats of the vessel or may be more extensive and later cause the walls of the vessel to slough. Such injuries therefore may heal without giving rise to any symptoms, or there may be later the formation of an obliterating thrombus or, in the severe contusions, there may be a rupture of the walls of the vessel due to necrosis, which will give rise to a secondary hæmorrhage. Such a complication as the latter is more prone to occur in those cases where there is marked infection of the wound. Traumatic aneurisms may also appear later as a result of the weakening of the outer walls of the vessel, which allows of the gradual forcing out of the intima by the pressure of the blood in the artery. Contusions or abrasions may be

produced by any form of projectile, such as a rifle or shrapnel bullet, or a shell or grenade fragment, which simply grazes the vessel.

(2) **Perforations.**—These usually consist of perforations of both walls of the vessel and are caused by bullets. Such wounds present rounded or oval apertures of entrance and exit. Occasionally, however, perforations of one wall of the vessel may occur due to a small piece of shell or grenade fragment or even a small spicule of bone driven through into the lumen, as will be shown in a case which will be described under Aneurisms. Such an injury may give rise to a severe hæmorrhage into the tissues, which either forms a hæmatoma or later becomes a false aneurism. In such wounds, owing to the fact that they are caused by small-calibre bullets, the external wounds are small, so that there is very little external hæmorrhage. Hence pressure in the tissues exerts a hæmostatic effect. Such wounds usually occur in the larger vessels.

(3) **Incomplete Division.**—Such wounds consist of a loss of continuity of a part of the vessel wall and may be either grooves or lacerations. Grooves are caused by bullets striking the edge of the circumference of the vessel and carrying away part of the wall. Lacerations are caused by deflected or deformed bullets, by shell and grenade fragments, and by bone fragments which have been projected through the tissues and act as secondary projectiles. These injuries occur also in the larger vessels.

(4) **Complete Division.**—Injuries to the smaller blood-vessels usually result in a complete division, and this may be caused by any projectile. Complete division of larger arteries is due to shrapnel bullets, shell fragments, and also to deflected or deformed rifle bullets. On account of the tearing effect produced by such projectiles there is usually very little hæmorrhage, as the walls of the vessel constrict and occluding clots form rapidly. This effect is best seen in those cases in which, when limbs are torn off by large shell fragments, there is usually a comparatively small

amount of hæmorrhage due apparently to the crushing and constricting effects produced upon the artery.

We have described briefly the various types of lesions to blood-vessels caused by projectiles, and we shall now consider the immediate and secondary results of such injuries. These consist of:

1. Hæmorrhage.
2. Aneurisms.
3. Sequelæ.

II. Hæmorrhage

Hæmorrhage of a varying degree of severity occurs primarily in all gunshot injuries following the infliction of the wound, and later may occur as a secondary complication due to the weakening of the walls of the artery or vein by the projectile inflicting the original injury, or it may be the result of an infection in the vicinity of blood-vessels which causes an erosion through into the lumen of the vessel and thus gives rise to a hæmorrhage.

Hæmorrhage is therefore divided into:

(*a*) Primary Hæmorrhage.
(*b*) Secondary Hæmorrhage.

(*a*) **Primary Hæmorrhage.**—Bleeding which immediately follows the reception of a wound is known as primary hæmorrhage, and is either slight or severe depending upon the nature of the injury and its location. Bullet wounds of the soft parts do not ordinarily give rise to much external bleeding unless the vessels so entered are superficially situated, as in the neck. On the other hand, the large vessels of the abdomen or thorax give rise to no external signs of hæmorrhage, and we can therefore classify primary hæmorrhage as:

(i) External Primary Hæmorrhage.
(ii) Internal Primary Hæmorrhage.

(i) **External Primary Hæmorrhage.**—In this class we refer more especially to the hæmorrhage which is seen when blood-vessels which are situated externally are injured, and which may be readily ligated. Such vessels are situated in the neck or in the extremities.

External primary hæmorrhage of the more severe types has, however, never been a prominent feature in war surgery. Lagarde ([1]) states that "in the American Civil War primary hæmorrhage only came under the observation of the surgeons in 5 per cent. of all wounds received, and in the Crimean War in 3 per cent. Of the 1,400 wounded at Santiago in 1898, the large majority of the wounds being caused by the reduced-calibre Mauser bullet, no death from external primary hæmorrhage was recorded, and no vessel was tied on the field to arrest this kind of hæmorrhage."

The experience of Makins in the South African Campaign coincides with Lagarde's, and, furthermore, Makins ([2]) says "a marked distinction needs to be drawn between external and internal hæmorrhage. External hæmorrhage from the great vessels of the limbs or even of the neck proved responsible for a remarkably small proportion of deaths on the battlefield." This statement is also supported by information supplied by medical officers on duty with field companies, and is further supported by Makins' statement that "cases in which primary ligation was resorted to at the base hospitals were extremely rare, while, on the other hand, aneurisms of any one of the large trunks of the neck and limbs were comparatively common." He had only one instance of a rapidly fatal case of a hæmorrhage reported to him, and this soldier was wounded in the axillary artery and died from hæmorrhage in twenty minutes. These statements, however, are based on the figures furnished by previous wars, and whether or not they will prove the same or will need to be modified following this present war, owing to the more extensive use of high-explosive shells and grenades, one is as yet unable to say. The explanation of the small amount of external hæmorrhage or even hæmorrhage into the tissues following bullet wounds seems to be that the bullet causes only a small opening through the muscles and fascia, which opening closes quickly by muscular action and thus localises the bleeding and favours coagulation. The vessel walls also tend to constrict and thus diminish the amount of bleeding. Such wounds, however, often lead to the formation of aneurisms, and this will be discussed later.

Treatment.—The treatment of external primary hæmorrhage resolves itself into the general principles of applying compression to the wound at the front, and immobilising the injured part. At the base ligation should be done if the bleeding persists, as in the more extensive wounds, otherwise the soldier should be kept absolutely quiet and carefully watched for any further signs of hæmorrhage.

(ii) **Internal Primary Hæmorrhage.**—This is a much graver condition than is the external primary hæmorrhage, since it is caused by injuries to the vessels of the thorax and abdomen, where there is no muscular support to aid in the spontaneous control of the hæmorrhage, as there is in the case of the extremities. Furthermore, injuries to the vessels in the thorax and abdomen give rise to a greater degree of hæmorrhage than do the vessels in the extremities. Makins says that "while deaths from external primary hæmorrhage were rare, a considerable number resulted from primary internal hæmorrhage. In some of these injury to the largest trunks in the thorax or abdomen led to an immediately fatal issue, and other wounds of the large visceral arteries, as of the lungs, liver, or mesentery, were scarcely less rapid in their results." He also states that in such cases "the potential space offered by the peritoneal or pleural cavities favours the ready escape of blood from the wounded vessel, while the tendency of the blood effused into serous cavities to rapidly coagulate is notably slight."

Even before the era of the present-day high-velocity projectiles the mortality of such wounds was high, and from this type of injury the majority of men die before any surgical aid can be instituted. In the Civil War and the wars preceding it the average of deaths to the number of wounded stood as 1 to $4\frac{1}{2}$, in the Manchurian Campaign the proportion was as 1 to $3\frac{1}{2}$ (Lagarde). Exact figures in any campaign are difficult to obtain, for the reason that when the wounded are coming in rapidly to the dressing stations, the military surgeon must of necessity treat those to whom he can do the most good, and cannot therefore take the time to diagnose the lesions in those already dead or who are moribund and obviously dying.

The signs of internal hæmorrhage are too well known to need comment, but in addition to those well-known signs we have the evidence of an external wound of a varying degree of severity, and rapid blanching of the skin, especially if one of the larger vessels be involved.

(*b*) **Secondary Hæmorrhage.**—This condition may occur in any wound, but is rarely seen in simple wounds caused by bullets. More extensive wounds caused by shell fragments and wounds by bullets where there is marked destruction of the soft parts by the secondary projectiles together with trauma to the vessel walls frequently give rise to secondary hæmorrhage. Infection in a wound and in the vicinity of a blood-vessel may often cause a severe hæmorrhage due to the erosion of the vessel by the digestive ferments associated with pyogenic organisms. It may also occur owing to the sudden liberation of an occluding blood-clot, due possibly to the shaking up of the patient incident to transportation. Drainage by rubber tubes, especially in the vicinity of blood-vessels, is a factor which should not be overlooked, as it occasionally happens that a hard rubber drainage-tube pressing upon a blood-vessel, especially if infection be present, may cause an erosion which will give rise to a severe secondary hæmorrhage.

Secondary hæmorrhage, therefore, is essentially a condition which is seen in the base hospitals and may occur in from four days to two weeks, although instances have occurred where hæmorrhage has taken place as late as five weeks after injury.

Treatment.—The treatment of secondary hæmorrhage depends upon the location of the wound and the degree of severity of the hæmorrhage. It must always be borne in mind that secondary hæmorrhage nearly always occurs in wounds which are infected, and, if not absolutely controlled, the hæmorrhage may recur in constantly increasing severity. Furthermore, the patient may become progressively weaker with each succeeding hæmorrhage until he succumbs. It is therefore necessary that radical rather than temporising measures should be immediately instituted as soon as there is any evidence of secondary hæmorrhage. In smaller wounds which may be relatively aseptic a local ligature may be sufficient. When severe infection is present amputation should be done and the vessel tied. A third method which is available is by proximal ligature; the vessel should be ligated in its continuity at a point remote from the infected wound. Hæmorrhage in an infected wound should not be controlled by packing, except when no other methods are available, such as in a deep cavity where the vessel cannot be easily reached or where it is impracticable to dissect out the artery to ligate it. If it is found necessary to pack the wound, the packing will have to be left in for several days, and, if the wound be infected, this retards the free drainage and may increase the severity of the infection.

It is therefore essential that if it is found absolutely necessary to pack a wound, the elimination of the septic material should be promoted as much as possible by keeping the gauze packing well saturated with saline, and, while this tends to decrease the coagulation of the blood, nevertheless it will be much preferable to controlling both a severe infection and another hæmorrhage.

When once the hæmorrhage has been controlled the patient should be infused with subcutaneous or intravenous saline solution or by the transfusion of blood. This latter gives by far the best results, and the improvement noted in the patient is immediate. In the American Women's War Hospital this is the procedure of choice, as the operation is performed quickly and easily by means of the Kimpton transfusion tube.

These facts are illustrated by the following case, and while it is true that this man died later, nevertheless the essential points are shown.

B. H., aged twenty-nine, 6th North Staffs, was wounded at Hulluch on October 13th, 1915, by a bullet which struck

Fig. 142. Bullet wound of exit on thigh associated with severe secondary hæmorrhage and infection. Photograph shows extensive swelling and eversion of tissues about wound. Sanguinous exudate may also be seen escaping from wound. Photograph taken just before operation.

him in his right thigh. He was dressed two hours later at a dressing station and transferred to England, and admitted to the American Women's War Hospital on October 19th.

On entrance examination showed a bullet wound entering the right thigh on the anterior aspect of the lower third and a wound of exit on the posterior inner aspect of middle thigh. The wound of exit was of an explosive nature about $1\frac{1}{2}$ inches in diameter with everted edges. Femur intact. There was marked general swelling of the whole thigh with tenderness in the lower third, and there was also a considerable amount of sero-purulent discharge from the posterior wound (Fig. 142).

On October 21st there was a profuse hæmorrhage from posterior wound which was controlled by packing. Patient rather pale and worried. Pulse good.

On October 25th there was another small hæmorrhage. Wound repacked. Patient in fair condition. There were considerable pain and swelling of the whole thigh, and also numbness of the leg below the knee.

October 30th.—No further bleeding; pack removed to-day. Swelling of thigh diminished. Much less pain. Patient regaining colour and feels stronger. Temperature elevated.

November 8th.—A third and severe hæmorrhage to-day which was controlled by a pack. Pulse rate elevated. Patient seen in consultation and immediate operation advised. No pulsation or bruit over thigh.

Operation: Incision made through posterior wound. A large cavity was found in back of thigh filled with septic blood-clot. Both the femoral vein and the femoral artery were found to be lacerated by the bullet. All the adjacent tissues of the thigh were markedly septic, and there was also the characteristic odour of gas bacillus, which had not been noticed before, together with a bubbling of gas. Rapid amputation of the thigh was performed at the junction of the lower and middle thirds. At operation the blood-vessels were found to be partially occluded.

Patient's condition following operation very poor. Markedly blanched, pulse rapid—140—and very weak. Later in the day he was transfused and 28 ounces of blood were introduced into the median basillic vein. Patient began immediately to improve. Marked anæmia of mucous membranes disappeared and the pulse became less rapid and of a better quality.

On the day following operation there was a marked improvement in the patient's condition. Pulse was stronger and of lower rate. Condition remained practically the same all day, but during the night there was a sudden failure of respiration and patient died.

No autopsy was performed, but death suggested either an embolism or acute dilatation of the heart.

This case illustrates the necessity for immediate operation in all suspected cases where the condition is growing progressively worse, although in this case the improvement seemed to be so marked that operation at first was deemed unnecessary.

Hæmatoma.—The descriptions of those cases of interstitial hæmorrhage are too well known to require comment, as they are often encountered in civil practice. In such cases it may be impossible to discover the source of bleeding, and the best treatment seems to be the expectant. Later, if the condition becomes chronic, good results may be obtained by incision and evacuation of the blood-clot.

III. Aneurisms

Aneurisms as a result of trauma to arteries and veins were a comparative rarity in the days when projectiles of a large calibre and a low velocity were in use, and in those times traumatic aneurisms were seen mainly in civil hospitals as a result of accidents by stab wounds, or as a result of the operation for venesection for the bleeding of a patient.

Since the advent of the small-calibre and high-velocity projectiles which have been in use for the past few years, traumatic aneurism as a result of gunshot injuries to blood-vessels is relatively common.

In the Civil War there were 74 cases of aneurisms as a result of gunshot injuries to blood-vessels and 44 cases in the Franco-Prussian War, its appearance being one case for every 2,000 wounded in the latter. In more recent campaigns a single observer in the Boer War found 4 per cent. of his wounded suffering from some form of traumatic aneurism (Lagarde).

Aneurisms as a result of injury to the blood-vessels are divided into :

(*a*) False Aneurisms.
(*b*) Arterio-venous Aneurisms.

(*a*) **False Aneurism.**—This condition is due to injury of and constant slow hæmorrhage from an artery. This condition may be due to the complete division of an artery by a bullet or small shell fragment. It may also be the result of an erosion and contusion of the vessel with a local necrosis of the contused portion which later sloughs off and allows of bleeding into the tissues, or it may be due to a small perforation through the wall of the vessel by a small shell fragment. The injury to the vessel wall allows of a gradual effusion into the adjacent tissues and the consequent formation of a tumour mass which will be well defined. This tumour mass is in reality a hæmatoma, and if situated over one of the larger vessels may give rise to a distinct bruit as well as to a visible and palpable pulsation. Such a condition as this is also known as a "pulsating hæmatoma." If the opening in the vessel wall be small, as is the external wound, the hæmorrhage will usually cease spontaneously owing to the increased pressure exerted by the firm surrounding muscles and fascia. In such a case if the wound remains aseptic the wound in the vessel may heal and the hæmatoma be absorbed. But, on the other hand, if the external wound heals while the wound in the vessel remains open, we get a rapidly increasing tumour mass which is a source of danger to the patient. A number of these false aneurisms present signs of a secondary hæmorrhage and there is also a recurrence of a hæmorrhage through the external or original wound at different periods. Occasionally, when the blood-clot begins to organise, a definite wall will form which simulates a true aneurism.

Treatment.—If the wounds heal aseptically and the tumour mass shows signs of decreasing in size, the treatment should be expectant, but if, on the other hand, there are signs of secondary hæmorrhage and the tumour mass is increasing, an incision should be made over the tumour and the injured vessel ligated above and below and the hæmatoma evacuated. It is important that the blood-stream should be controlled by a tourniquet or by a Crile clamp in order to prevent undue hæmorrhage when the blood-clot is removed and also to ensure a dry field in order to inspect the wounded vessels. Small wounds in the arteries may occasionally be sutured without destroying the lumen of the vessel. Such cases are prone to infection, especially if the skin wound be large, and this condition is described in the case noted under Secondary Hæmorrhage.

The following case illustrates the amount of damage which may be caused by a minute shell fragment, and also the formation of a definite wall about a false aneurism [3]:

T. M., aged twenty-four, private in the 5th Sherwood Foresters, was wounded by an exploding shell on October 14th, 1915, while making an advance at Hulluch. He was admitted to the American Women's War Hospital on October 19th. Examination at that time as follows: Well-developed and nourished man, in considerable pain. General physical examination : Negative, save as follows : Right upper arm and forearm very much swollen, upper arm tender and markedly ecchymosed. Over inner edge of biceps, about 1 inch from median line and about junction of middle and upper thirds, is a small wound $\frac{3}{16}$ inch long by $\frac{1}{8}$ inch wide. No foreign body can be felt. Thumb and index finger hypersensitive ; sensation in other fingers normal. Patient cannot extend or flex fingers. X-Ray shows minute foreign body in location of wound. Circulation of forearm and hand good.

November 1st.—Arm has been baked daily and also treated with dry heat. Swelling has now disappeared, but a distinct thickening may be felt along the course of the brachial vessels, suggesting a thrombo-phlebitis. Considerable tenderness along this region. Radial pulse good, not irregular. Patient complains of marked hypersensitiveness of all fingers, also shooting pains in arm, and is unable to bear any pressure on fingers or dorsum of hand.

November 20th.—Thickening along course of artery still persists. At a point 2 inches below tendon of pectoralis major and at inner side of biceps at a point corresponding to the level of the wound is a small area ½ inch in diameter, over vein, which pulsates with a forcible and visible impulse, but no thrill can be felt. On auscultation a distinct, though faint, bruit may be heard.

November 25th.—Area on inner side of biceps the same as at last note. On inner edge of triceps at a point slightly higher, is an indurated area 1 inch in diameter, pulsating (transmitted impulse ?), and over this area can also be heard a bruit of a lower note than in the original area. No edema of arm. Pain practically the same.

December 1st.—Tumour mass distinctly larger than at last note (Fig. 143 *A*). Distinct bruit over whole area occupied by tumour mass with a distinct palpable and visible impulse. Immediate operation deemed necessary.

December 2nd.—Operation; ether: Incision made in axilla. Dissection carried down through brachial plexus and first part of axillary artery identified and freed. Crile clamp applied to control hæmorrhage. Incision was then carried down over tumour mass. Deep tissues found œdematous, and, owing to the absorption of the old hæmatoma, there was very much scar tissue which made dissection very difficult, as structures and tissues could not be easily recognised. Tumour mass dissected free. A minute piece of shell found adherent to and penetrating the wall of the brachial artery (Fig. 143 *B*). Distinct capsule found on tumour mass. This was opened and a considerable amount of organising blood-clot was evacuated. A tear of considerable size was found in the brachial artery, and the basilic vein also was torn. It was not possible to suture the tear in the artery, so both artery and vein were tied

A

B

FIG. 143. False aneurism of brachial artery. Tumour mass shows just below axilla. Just in the region of the tumour mass and slightly below it will be seen a darkened area which represents the point of entrance of the shell fragment. The actual size and shape of the shell fragment causing the injury, and which was removed at the time of operation, is shown in *B*.

above and below the wound. The artery was probably tied above the profunda branch, which could not, however, be identified. The median nerve was found bound down in scar tissue and freed. Wound closed in layers, rubber dam drainage. Good ether recovery.

December 6th.—Following operation, hand and forearm have been somewhat cyanotic, very little œdema. Pain in hand has been apparently the same until to-day, when it disappeared. To-day hand of good colour, warm and not hypersensitive. Perceptible radial pulse can be felt. Wound dressed, healing by primary union.

December 20th.—For the past two weeks patient has been making an uneventful convalescence. Wound healed by primary union. There is considerable pain, although not so severe or so frequent as formerly. Pain now localised to thumb and index finger.

January 1st.—Patient has been having daily massage and passive motions of fingers. Movements of fingers and arm are increasing. Pain has practically gone. Tips of index finger and thumb feel numb. Colour of hand and fingers good. Good radial pulse. Patient transferred to 4th London General Hospital for electrical treatment.

(*b*) **Arterio-venous Aneurism.**—This form of aneurism is due to a communication being made by the projectile between the artery and the vein (Fig. 144). Two distinct types of arterio-venous injuries are recognised :

1. Aneurismal Varix.
2. Varicose Aneurism.

1. **Aneurismal Varix.**—This type of aneurism is the result of a bullet wounding coincidently an artery and a vein which are lying close together. The vessels adhere, and there is a distinct communication between the two without an intervening sac. The arterial blood flows into and distends the vein and thus forms a pulsating tumour mass with a definite sac. Owing to the injury to the artery a similar thin-walled sac may form on the artery

itself. This condition is seen less frequently than are the varicose aneurisms.

Symptoms.—The symptoms of aneurismal varix may perhaps be best described by the report of the following case:

E. B., aged nineteen, 2nd Devons, was wounded on

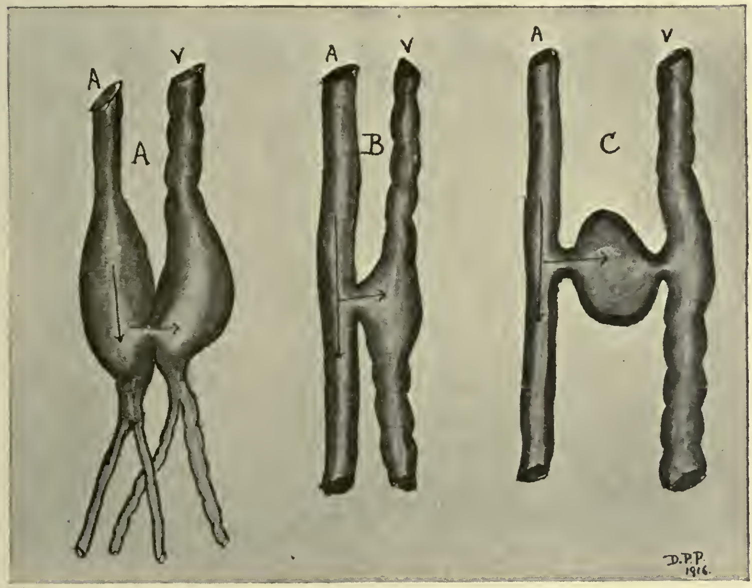


Fig. 144. Diagrammatic representation of types of arterio-venous aneurisms. *A*, diagrammatic representation of aneurismal varix, which is described later. *B*, aneurismal varix; *C*, varicose aneurism.

January 24th, 1915, by a bullet which struck him above his right knee.

Was admitted to the American Women's War Hospital on February 14th, 1915, and examination at that time was as follows: About 3½ cms. above the inner border of the right patella is a healed bullet wound of entrance and posteriorly about 1 cm. below the level of the wound of entrance, and about 1 cm. to the inner side of the mid line on the posterior surface of thigh is a healed bullet wound of exit. This wound is just in the upper limits of the popliteal space. About this wound as a centre there is a tumour mass about 3 inches in diameter and 1 inch high, pulsating and presenting a marked thrill and bruit. The knee cannot be fully flexed without considerable pain. Murmur cannot be heard over dorsalis pedis. After walking about there is a difference in colour about the popliteal space, a general duskiness which extends to the ankle. There is no difference in the colour of the feet. Change in colour involves the lower third of the thigh. The superficial veins become enlarged. Right leg larger than the left, especially about the knee.

Following admission patient was kept quiet in bed and leg was immobilised in a plaster cast. A window was cut over popliteal space and pressure was applied through this in an attempt to increase the collateral circulation. A month later the cast was removed.

Examination at that time was as follows: Tumour is most marked in the upper half of the popliteal space and the thrill here is much more intense; it is also intense just below and to the right of the wound of exit. There is no pistol shot felt in the tumour, which has no visible dilatation of veins. On auscultation over tumour no pistol shot is heard, but there is an intense machinery murmur with systolic intensification. Over the right femur just above Poupart's ligament there is a loud pistol-shot sound and the murmur is conveyed upwards. Over the left femoral the pistol shot is less intense. Heart is clear. On deep pressure over the femorals there is a striking difference. Patient was kept under observation until June 1st, and the conditions remained practically the same, although the collateral circulation was comparatively well established.

June 3rd.—Operation: A long median incision was made over the popliteal region and skin and fascia reflected. Lower portion of the femoral artery was exposed and followed down to the popliteal space, where a large aneurismal sac was found. Section was carried down below the aneurism and the popliteal artery and veins exposed. A Crile clamp was applied to the artery above the aneurism and to the veins below. The aneurismal sac was dissected free and was seen to be an aneurismal varix rather than a varicose aneurism. Artery was ligated above the aneurismal sac and an attempt was made to close the opening in the vein. Owing to the walls being extremely thin, this was not wholly successful, but it appeared at the time as though complete closure had been made. Wound closed in layers. Leg immobilised on a ham splint.

June 5th.—To-day there is a decided lividity of both foot and ankle.

June 11th.—The lividity has grown more pronounced and there is marked dry gangrene of toes. There is a sharp line of demarcation above the leg, more marked on the external surface. Wound in thigh healing by first intention.

June 18th.—There is marked dry gangrene of the whole of foot and a well-marked line of demarcation half-way up the lower leg. Amputation was decided upon.

Typical operation at point of election. Following operation there was a very marked sloughing of the skin flaps of the amputated stump and also the muscles of the lower leg, and the process finally extended up and involved the wound in popliteal space and also the ham-string tendons. Wounds were freely drained and finally healed.

September 1st.—Wounds entirely healed. Some contraction at the knee joint. Patient has absolutely no power of flexion or extension.

September 24th.—Two days ago patient noticed a throbbing in the popliteal space similar to that which he had noticed before the operation. Auscultation shows a distinct bruit similar to that which was present before the original operation and which had been absent since that time. There is also a distinct thrill on palpation. It was felt that, probably owing to the thin-walled condition which was found at the time of operation and to the difficulty of closing the opening in the vein at that time, a communication had re-established itself between the artery and the vein, and for this reason, and also on account of the condition of his knee, a thigh amputation was decided upon.

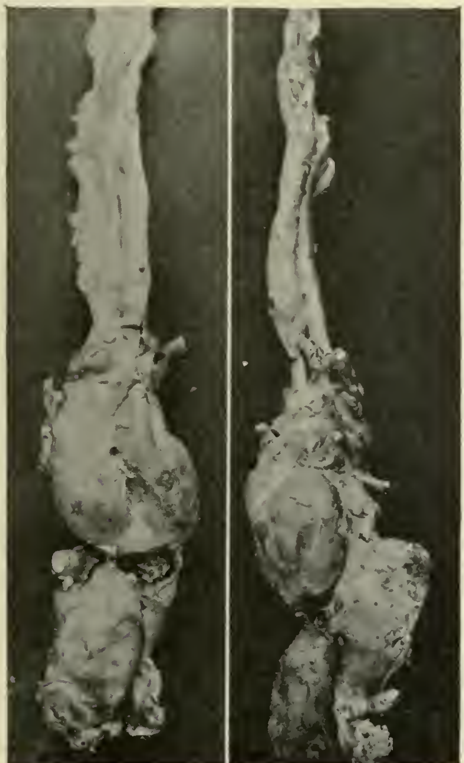
October 23rd.—Leg was amputated just above knee. Since operation patient has made an uneventful convalescence, and on November 16th was discharged for invaliding.

The aneurism was left *in situ* in the amputated portion of the leg and was injected and later dissected out, as is shown in Fig. 145. It will be seen that the walls of both artery and vein are extremely thin and very much dilated, and that there is a direct communication between the vein and the artery. Furthermore, the dilatations on the vein and the artery are adherent for a considerable distance.

Treatment.—This will be described in the treatment of varicose aneurism, as the method for the treatment of the two conditions is essentially the same.

2. **Varicose Aneurism.**—This is the more frequent form of communication between the artery and the vein. It is characterised by the formation of a sac between the two vessels and occurs where the vessels lie a short distance apart and not in close juxtaposition, as is the case when an aneurismal varix is formed. There is an extravasation of blood from the injured vessels and this becomes circumscribed and forms a sac which communicates directly with the lumen of each vessel.

Symptoms.—The symptoms are essentially those noted in the case of an aneurismal varix and consist of pulsation, a palpable thrill, and a bruit. The tumour mass may not be palpable, or it may be small or large, and this is a distinguishing feature between aneurismal varix and varicose aneurism. In the case of an aneurismal varix the tumour mass may be small or absent, while with a varicose aneurism there is more apt to be a distinct pulsating tumour mass, even though it be not large. A loud murmur—the so-called "machinery murmur" or "boiler-house roar"—is heard on auscultation over the site of injury and can also be heard at a distance along the course of the artery.



A *B*

FIG. 145. Aneurismal varix which was removed from the case already described. The aneurismal sac was very thin walled and unfortunately the sac became torn during the dissection, but the tear shows the communication between the artery and the vein. The artery is shown in *B* as the ligated blood-vessel, and the vein lies to the left and is much distended.

Prognosis.—A varicose aneurism presents a less favourable prognosis than does an aneurismal varix, as the former tends to more rapid growth with greater possibilities of spontaneous rupture. On the other hand, there may occasionally be contraction of the sac resulting in a spontaneous cure.

Treatment.—With both forms of arterio-venous aneurisms the principal requisite is absolute rest in bed, and operative procedures should not be instituted for many weeks unless there is a rapid growth of the tumour mass, or unless other complications develop, such as a partial paralysis from pressure. Further, it is important to determine whether or not the collateral circulation has become established. This may be determined in several ways, either by ascertaining the peripheral blood-pressure of the distal portions while the main trunk above the aneurism is compressed, and also by means of the change in colour in toes and feet. Some of these tests are rather difficult to apply owing to the location of certain arteries.

Matas (4) states that " in a general way it may be said that whenever the peripheral parts (digits, feet, and hands) remain cadaverically pale and cold and show no vascular flushing or active hyperemic blush upon removing an Esmarch elastic bandage while digital pressure is being maintained upon the main artery of the limb above the aneurism and if the cadaveric appearance remains as long as the finger is kept on the main trunk, it will be well to delay operative interference with the hope that the collaterals may develop. Whenever there is much œdema and tension of the peri-aneurismal tissues as in the popliteal region especially it is evident that the more quickly the sac is evacuated the more directly will the collateral circulation be relieved and improved."

The advisability of operative treatment depends upon the vessels affected and also upon the amount of disturbance which is caused by the aneurism whether or not the tumour is increasing in size or whether it is exerting pressure upon nerves.

Operation on vessels in the upper extremities offers a better prognosis than do operative procedures on the main vessels of the lower extremities. The operation both for aneurismal varix and for a varicose aneurism consists in freely exposing the tumour mass, having previously controlled the hæmorrhage from the main vessels by means of a Crile clamp, freeing the artery and ligating it above and below the aneurismal sac. Great care should be taken not to injure the vein, as otherwise gangrene may result. It may be said that the vein is the more important vessel of the two in this respect. When practicable the opening in the vein may be closed with sutures of fine silk, care being taken not to occlude the lumen of the vessel. Following the operation rest in bed and warmth to the affected region are the essentials. Proximal ligation should never be done except in cases of extreme urgency, and in such cases it is probably better to amputate.

IV. Sequelæ

Following an injury to an artery or vein or after the operation for the ligation of a vessel, either on account of the fact that the collateral circulation has not had time in which to become established or else owing to an occlusion to the afferent vessels or owing to the fact that the ligature is placed of necessity above the main collateral branches, we may get a gangrene of the infected part. This gangrene may be either moist or dry. If there is associated with the gangrene and the injury to the blood-vessel an infected gunshot wound, we must always bear strongly in mind the fact that it is in such cases that we get the most virulent types of infection from the *B. perfringens*, and amputation should be immediately performed. If the gangrene be the result of the ligature it can easily be kept dry, and in such cases we should wait for a line of demarcation, as otherwise we are apt to amputate through tissues which possibly later will become gangrenous, or else we would amputate higher than would be necessary.

The subject of gangrene is illustrated in the case referred to in the discussion of Aneurismal Varix, and the following case illustrates a condition of gangrene following the ligation of an artery for a severe secondary hæmorrhage due to the erosion of a blood-vessel by sepsis:

J. K., aged eighteen, 15th Welsh Regiment, was wounded in the thigh by a grenade while in the trenches at Givenchy on March 30th, 1916. On the day following his injury he was operated upon and wounds were incised and drained and grenade fragments removed. He was admitted to the American Women's War Hospital on April 7th, 1916.

Examination at that time showed a through-and-through wound running laterally at lower third of thigh posterior to femur and anterior to the muscles and tendons. There was a marked purulent discharge from both wounds. No hæmorrhage from wounds, no disturbance of circulation in foot. Four days after admission plaster cast was applied to overcome contraction of his knee and windows were cut in the plaster in order to afford facilities for dressing the wound.

April 18th.—There was a small slight hæmorrhage from the wound. Leg quite comfortable. Wound granulating and clean. This hæmorrhage readily stopped and seemed to come apparently from granulations.

April 20th.—There was a severe hæmorrhage about ten o'clock in the morning. Patient was pale, pulse rapid. Was taken at once to the operating room and etherised; cast removed; tourniquet applied; median incision made through popliteal space and popliteal artery exposed. On the posterior aspect of the popliteal artery was a small erosion extending into the lumen and partially occluded by a small clot. Popliteal vein intact. Artery ligated above and below the erosion. Wound packed with gauze. Following the operation patient was sent to the ward in poor condition. Was given subpectoral saline as well as rectal saline, and bed placed on shock blocks. In the evening patient was in much better condition, pulse was rapid but of fair quality. There was extreme pallor, leg was pale but warm.

April 22nd.—To-day two areas of ecchymosis over the inner aspect of leg over the course of the internal saphenous vein noticed. Temperature still high. White blood count 20,000.

April 25th.—A large bleb has appeared over upper

FIG. 146. Shows area of gangrene which has already been described.

ecchymotic area and is gradually extending downwards to ankle. Bleb contains a sero-sanguinous exudate. There is extreme tenderness of calf muscles.

April 28th.—Tissues beneath bleb have sloughed. Cut away without evident pain. There is an area of necrosis 2 inches wide along postero-internal aspect from lower margin of popliteal space to 2 inches above ankle, involving calf muscles and Achilles tendon (Fig. 146).

May 5th.—Since last note patient's general condition has improved, pulse of normal rate and of good quality. Colour of face and mucous membranes is good over the whole of the area described before and the tissues are clean and granulating. Foot remains cool and pale, and there is now some cyanosis of toes. Patient still in hospital at time of writing.

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CHAPTER XIII

ORTHOPÆDICS IN A BASE HOSPITAL

Contractures—Hallux Valgus—Hallux Rigidus—Hammer Toe—Flat Feet —Dislocation of Semilunar Cartilages.

WHILE it is true that in a base hospital the majority of the orthopædic cases should be considered under the heading of fractures and of gunshot injuries of joints, nevertheless there are certain other conditions which are constantly met with and which should be considered in this class, as they either totally incapacitate or else limit the man's usefulness as a soldier.

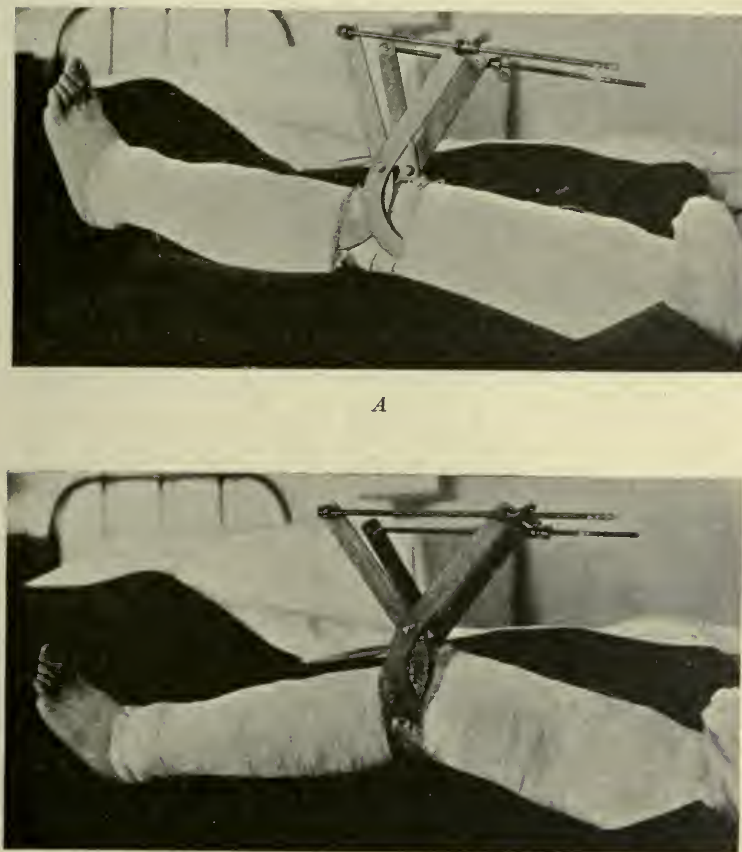
We have already discussed in detail, under the heading of joints and fractures of the long bones, much of the work which should by rights come under this heading, and we shall now consider briefly some of the more common conditions which are constantly seen apart from fractures and joint injuries.

Under this heading we shall include the contractures of tendons and muscles due to adherent scar tissue about the joints and which limit the flexion and extension of such joints, and we shall also consider some of the more common non-traumatic conditions, such as hallux valgus, hallux rigidus, hammer toe, and flat foot, as well as dislocations of semilunar cartilages. All of these conditions tend to render the man unfit for military service, for it is evident that if he is affected by any of the above he will be unable to perform properly his duties as a soldier and to withstand the rigours of a long and hard march.

We shall first of all take up the subject of contractures.

A contracture of a joint is one of the most common sequelæ following an extensive gunshot injury even of the soft parts, and may be due either to a large extensive wound in the skin which forms dense scar tissue on healing or to an injury of the periarticular tissues, not necessarily involving the joint itself. Sometimes it may also be due to contracture of the tendons following injury or to contracture of the muscles themselves. On the other hand, there may be loss of complete extension, as in the lower leg, if there are injury and loss of tissue of the quadriceps extensor muscles. The muscles become united by a band of cicatricial tissue which unites the separated ends and so does not allow of complete extension.

We shall first of all consider loss of motion due to contractures by scar tissue. In such injuries, as has already been said, the loss of motion is due to contracture of the scar in the skin or to contractures of the flexor or extensor muscles or tendons. If the scar in the external tissues be the cause of the disability and if the scar be at all extensive, good results may often be obtained by excising and freeing the scar tissue and performing a plastic operation to cover in the defect. The limb should then be placed in the desired position and immobilised. If the scar tissue is not extensive the deformity may often be corrected by means of an extension apparatus. The apparatus with which we have had the best success at this hospital has been the Turner apparatus (Fig. 147), which we have used for the knees, and also a Turner apparatus with a reversed action, which we have used in cases where there have been contractures about the elbow joint (Fig. 148). This apparatus allows of a gradual stretching, without tearing, of the tissues and has the advantage that the patient is able to use it himself and can adjust the amount of pull without causing himself any undue pain. In the case of contractures due to injuries to the muscles or to the tendons, the same apparatus may be used to stretch the muscles. If this method proves to be insufficient, an operation for the



A

B

FIG. 147. Turner apparatus for the correction of deformities caused by contractures about knee joints. *B*. Leg partially flexed. *A*. Leg in full extension. The apparatus is incorporated into plaster of Paris and great care should be taken to see that sufficient padding be applied under the metal bars and at points on the plaster where undue pressure may be exercised, as otherwise areas of skin necrosis may occur.

lengthening of the muscle or of the tendon may be performed. In cases where there has been a solution of continuity of the muscle fibres and where the ends are held together by a band of cicatricial tissue which will not allow of full extension, the scar tissue should be excised, the adherent muscles freed and the ends freshened and sutured. In such cases it is most important that an apparatus should be applied while such wounds are healing,

Fig. 148. Turner apparatus with reverse action as applied to the elbow joint. It is necessary to reverse the action in this case in order to have the metal levers coming on the flexor side of the arm so as to be less in the way.

which will overcome the deformity due to the solution of continuity of the muscles and which will approximate as closely as possible the severed ends of those muscles. Instances of this condition are seen in foot drop due to a severed tibialis anticus, or in wrist drop due to a solution of continuity of the extensor muscles of the forearm. In these instances an apparatus which will keep the hand and the foot in dorsal flexion should be applied. Later it may be necessary to apply some form of apparatus which will

A

B

Fig. 149. Permanent flexion apparatus for overcoming contractures about knee-joints. The degree of pull may be regulated by the tension of the rubber tubing. Apparatus consists of two leather cuffs which are well padded and which are connected by means of hinged steel bars.

passively and actively exercise the injured parts. The apparatus which we use for such purposes at this hospital (shown in Figs. 149 and 150) consists of two cuffs of leather which are well padded. One of these cuffs fits on the thigh, the other on the lower leg, and they are connected by a hinged brace on a level with the knee joint. A strong elastic band is fastened to the eyes on the posterior aspect of the cuffs and the tension of this is regulated just enough, so that the patient is able to counteract the flexing effect

Fig. 150. Permanent flexion apparatus for overcoming contractures about the wrist joint. The degree of pull may be regulated by the tension of the rubber tubing. Apparatus consists of two leather cuffs which are well padded and which are connected by means of a hinged steel bar which is not shown as it is on the ulnar side.

of the rubber by his extensor muscles. Massage in all these cases is an important adjunct, and this, combined with galvanism and often ionisation, is an important factor in connection with other forms of treatment.

Hallux Valgus.—This condition is seen quite frequently in some of the older soldiers, and is sometimes of a very pronounced degree, so much so that the man is absolutely incapacitated from marching. The degree of valgus may be only slight, but on the other hand it may be very extreme. The head of the first metatarsal shows a degree of enlargement which does not seem always to be proportionate to the amount of valgus observed in the toe. Such conditions are usually painful and the soldier is unable to wear boots with any degree of comfort or to march any distance. In other words, his function as a soldier is nullified by the condition existing in his foot, and it is important that if he is to perform his work efficiently this condition should at once be rectified.

The operation which we use at this hospital and with which we have obtained the best results is the Mayo operation, which consists of making a curved incision over the outer part of the enlarged head of the metatarsal. The skin is dissected free without injuring the bursa. The base of the skin flap should be towards the sole of the foot. The bursa, which will be found very much thickened in these cases, should then be freed from over the joint, and the direction of freeing should be from the metatarsal towards the phalanges. The dissection of the bursa should be started well back of the head of the metatarsal in order to leave as much bursa as possible. This leaves the joint surface exposed and the head of the metatarsal is found to be very much enlarged, often with large protuberances and exostoses on the surface. Remove the head of the metatarsal at about the level of the epiphyseal line by means of a metacarpal saw, and, as soon as the tarsal is cut through, the head will shell out very readily. It will be found that now the deformity can be easily corrected, and the next step consists in interposing the flap of the freed bursa between the articular surface of the proximal phalanx and the distal portion of the first metatarsal. The bursa should be held in place by a few catgut sutures fastened to the edge from which the bursa was freed. The extensor longus hallucis should be displaced slightly to the inner side of toe and held in place by a few catgut sutures through its sheath. Wound is then closed in layers and an alcohol dressing applied. A splint should be applied in order to keep the great toe in the proper position.

At the end of a week or ten days, after the wound has healed, patient may be allowed to walk about. By this method good functional results are obtained.

Hallux Rigidus.—This condition is occasionally seen but is not especially common, and the disability from which the soldier suffers in this case is due to the fact that there is resulting loss of motion in the metatarsal phalangeal joint. X-Ray examination in these cases shows the metatarsus and the proximal phalanx to be adherent, and there is only a thin line where the joint surface should be. Exactly what the etiology of this condition is I am not prepared to say. In such a condition it is necessary that at least an attempt should be made to restore the mobility of the great toe. It sometimes happens that in such a condition it may be possible to regain some motion by forcible correction after the patient has been etherised, and if this method fails an open operation and a procedure similar to that in the case of a hallux valgus seem advisable. Care, however, must be taken in these conditions to dissect away enough bursa, as here the bursa will be found to be not so thickened or extensive as in the case of the hallux valgus, and it may also be necessary, if the bursa be insufficient, to interpose some fat tissue or fascia from some other part of the patient.

The after treatment is the same as with hallux valgus.

Hammer Toe.—This condition is not uncommon and is caused by the fact of the soldier wearing boots or shoes which do not allow enough room for the full extension of his toes, especially when he walks. The main disability in this case, apart from the cramping of the toes, is that discomfort and often inflamed calluses develop on the dorsal surface of the first interphalangeal joints due to the toes being pressed up against the shoe. Such a condition should be corrected by operative procedure, and this is best done by making a lateral incision over the first phalangeal joint, freely exposing the joint, and excising the distal head of the first phalanx. A sufficient amount of the distal head should be removed to allow of free correction of the deformity. The wound is then closed in layers, an alcohol dressing applied, and the toes held in the proper position by means of a splint.

Flat Feet.—The subject of flat feet is too well known to require much comment, and is simply mentioned here as being one of the common ailments to which the soldier is prone. It is, moreover, an important condition to note, as soldiers suffering from flat feet are a burden on the march, and are constantly dropping out and often may require to be transported.

The treatment which we adopt here consists of absolute rest until the acute symptoms have subsided and then of strapping the foot in the position of inversion to overcome the pronation. The arch should also be supported by means of a felt pad. Later corrective exercises should be instituted in order to build up the supporting plantar muscles, and a corrective sole should be applied to the shoe to overcome any further tendency to pronation.

Dislocation of Semilunar Cartilages.—This is an important condition which is constantly seen, and in every convoy of wounded which is received one usually finds two or three cases of dislocations of semilunar cartilages. In such cases there is the history of the soldier having slipped and twisted his knee and often the history of the injury having recurred several times. Following the initial injury there is immediate pain, especially over the inner portion of the head of the tibia, associated often with a feeling as though something were loose in the joint. The soldier usually reports on the sick list on account of the resultant synovitis, although sometimes the knee may become locked in a position of semi flexion and he reports on account of this condition. When such a patient is received in the base hospital effusion in the joint may or may not be present, and often the diagnosis has to be made solely on the typical history. With all such cases, however, palpation usually reveals an area of tenderness which is usually localised over the inner side of the joint, and frequently on movements of the knee a distinct slipping of the cartilage may be found. Quite recently I had here a case of dislocation of the semilunar cartilage. The man stated that at the time of injury he felt a sharp pain in his knee, something seemed to slip, and he was then unable to extend his leg. On admission here his leg was held in a position of semi-flexion and he was unable to extend it completely. Examination revealed nothing except extreme tenderness over the internal condyle, and even under manipulation the leg could not be straightened. In a few days, however, the patient felt something slip in his knee and complete extension was immediately possible. At operation the internal semilunar cartilage was found to be free and to be curled up, and the mass thus formed was found to be lying between the articular surfaces. In such cases operation affords the best chance of a permanent cure, especially if there is a history of the state having occurred several times, as is so often the case, and, as a matter of fact, most of the men are anxious to have the operation performed on account of the extreme discomfort which they constantly suffer when the condition occurs. The operation should not be undertaken except under the strictest aseptic precautions, and several days' preparation should be given to the skin about the knee joint before any such procedures are instituted.

The operation is as follows: After the patient has been anæsthetised, an Esmarch elastic bandage is applied from the foot to above the knee, a tourniquet is then applied and the Esmarch bandage removed. Patient is drawn down on the operating table so that his leg hangs over the end and is flexed at right angles. A curved incision is made over the internal condyle of the femur about 1 inch from the edge of the patella. The skin is carefully dissected away and the synovium carefully opened. The cartilage will usually be found lying either loose or partially detached from its posterior or anterior end and can easily be removed by means of a pair of sharp-pointed scissors. Great care should be exercised not to touch the wound except with instruments and not to injure the joint surfaces. The synovium is then closed with catgut and the fascia and skin closed in layers. The leg is immobilised on a splint and patient should be kept in bed for about ten days, at the end of which time the stitches are removed and he is allowed to get up and walk about, still with the leg immobilised. At the end of two weeks the splint is removed and passive motions are begun. At the end of three weeks the patient should be walking without any discomfort and is ready to be returned to light duty.

One other condition which has been met with here in one case is cited here simply as a matter of interest. The patient gave a history of the sudden twist of his knee followed by a sharp pain. Immediately following the injury he was conscious of some hard substance in his knee joint, which substance was freely movable and which he could feel. This mass would migrate up under the patella and prevent him from flexing his leg. On admission here a definite freely movable mass the size of a Lima bean could be felt in the knee joint. This could be displaced downward and inward and then would escape from the palpating fingers and migrate up under the patella. X-Ray showed a definite cartilaginous oval mass lying free in the knee joint. This case was operated upon by the same procedure as for a semilunar cartilage and the cartilaginous mass was removed. The rounded surface of this mass was of the same structure and appeared similar to the joint surface of the femur, and the flattened surface was pitted and slightly roughened. There was a loss of substance on the inner aspect of the internal condyle of the femur and this area corresponded to the flattened surface of the foreign body which was removed. The internal lateral ligament was intact. The appearance of the foreign body and the appearance of the condyle of the femur suggested a pathological separation of part of the internal condyle, a separation which must have been nearly complete at the time the patient wrenched his knee. The degree of injury at that time was so slight that it was followed by no effusion in the joint.

These few conditions which have been described here illustrate some of the many orthopædic conditions which are met with in military surgery apart from the lesions of joints and fractures, and they are of interest as they determine to a great extent the ability of the man to discharge his duties as a soldier.

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CHAPTER XIV

SHELL SHOCK, GAS POISONING, TRENCH FOOT

I. Shell Shock

In modern warfare, with its many phases, numerous conditions attributable to a disturbance of the central nervous system are constantly seen. While it is true that many of the men so affected are of a highly nervous temperament, nevertheless some of the manifestations occur in men who are apparently of a phlegmatic nature. These disturbances are of a functional rather than of an organic nature. Such manifestations are termed "traumatic neuroses," and are apparently due to a cumulative effect from exposure to concussion from modern high-explosive shells, and also from the strain and nervous excitement preceding and during an attack.

The condition manifests itself in numerous ways, and cases have been reported where there is a marked paraplegia or a total loss of memory, and oftentimes the organs of special sense alone are affected, and we find either blindness, deafness, or even aphonia. Sometimes these various conditions are combined.

In this hospital we have been particularly fortunate in having had several of these neuroses, and, while it is true that with the first cases which were admitted we were at a loss as regards the proper treatment, we now have a method of treatment by means of which the symptoms immediately disappear.

Among the first cases which were seen at the American Women's War Hospital we had one case in which there was a total loss of memory, although this man had rare intervals during which his memory returned in so far that he was able to recall his name and where he lived. We had also a case of mutism, in which the soldier recovered his speech spontaneously four days after entrance.

At first the treatment by suggestion was tried with rather indifferent results, and later we tried anæsthetising such patients and the results were surprising. Since we started this method, other writers have reported cases treated in the same way, and apparently the same beneficial results have been obtained.

We have had no case of blindness due to shell shock on which to try this method of treatment, but there is no reason to believe that it would fail in the case of functional blindness any more than in those cases of mutism and deafness which are not organic.

The following cases rather strikingly illustrate the results obtained by anæsthesia, and, in the first case, it will be seen that in addition to the deafness and mutism there were other marked disturbances.

Case 1 ([1]).—L. H., aged twenty-five, private in the Durham Light Infantry, was admitted to the American Women's War Hospital, July 30th, 1915, suffering from marked emotional shock. At the time of admission he was unable to talk, but could write answers to any questions which were asked him and gave the following history:

On active duty at Ypres and had been in the trenches for about four days; he and some other men were on watch on July 1st and some of the party were sitting down in the trenches when two shells from the German lines came over the trench, the first of which fell and exploded just near his feet, killing six men and leaving only himself and a sergeant, and the second burst close to his head. Strange as it may seem, he was not wounded by either shell. Patient states that the noise was terrific, and following the explosion of the shells everything became dark and he apparently lost consciousness, and he knew nothing further till he found himself in No. 8 General Hospital, Rouen. When he regained consciousness he was deaf, dumb, and blind. A few days later, however, he regained his sight, and, shortly after that, he was able to hear in one ear, still remaining somewhat deaf in the other.

Patient is a well-developed and nourished man, rather confused, vague, and nervous. On his first night in the hospital, he is said to have answered one question which was asked him by the nurse relative to the trouble, his answer being " concussion." Except on that occasion he did not speak, and when asked to speak or make any sound he could, he made expiratory efforts but no sound ; when asked to whistle he did the same, even after repeated trials. He was still apparently somewhat deaf, for if he was simply spoken to he paid no attention, but on clapping the hands near his ear or attracting his attention he would seem to understand what was said ; he also stated that he could hear a little bit better with the left ear than with the right. His co-ordination, sensation, and motions were apparently normal. There was no tremor of the hands, but a somewhat marked tremor of the tongue. He walked with a slow, deliberate, careful gait, eyes on the ground, toes flexed and held rigidly—a typical " tight rope " gait. With the eyes closed he nearly fell and could not stand on one leg. Knee reflexes moderate. On plantar reflex test he pulled the whole leg away and went into a general body tremor. The toes were spastically extended and later flexed. There was marked photophobia when the eyes were tested with a small electric light.

From admission to the hospital to September 22nd the patient made no vocal sounds, although he made many attempts. On the latter date he could apparently hear well, the gait in walking had become normal, and all tremors and uncertainty had disappeared ; the reflexes also were practically normal.

October 1st it was decided to give the patient primary ether to see if by any possible chance the relaxation would cause him to regain his speech. This was done, and during the etherisation he reviewed in a loud tone of voice the whole scene which occurred at the time he lost his speech, and on recovery from the ether he was able to talk perfectly well. He also stated that he could hear much better than at any time since he had been in the hospital.

Case 2.—F. W., aged eighteen, 2nd South Wales Borderers.

History: During a severe bombardment on April 11th, 1916, he became unconscious, although he was not wounded. On regaining consciousness in a dressing station he found that he had lost the power of speech.

Was admitted to the American Women's War Hospital on April 21st, 1916. His physical examination at that time was absolutely negative, save for the fact that he was unable to speak, and could hear nothing in either ear.

On April 30th he was given a primary ether anæsthesia, and as soon as the cone was removed he began to talk. There was no stage of excitement as in the previous case, and on regaining consciousness he stated that he could hear perfectly well with his right ear.

He was discharged to duty on May 9th, 1916.

Case 3.—G. T., aged twenty-four, 1st Bucks.

History: Was in the first line of trenches on April 9th, 1916, when a shell exploded about 20 yards away. He was not wounded, but was rendered unconscious, in which state he remained for about six hours. When he regained consciousness he was unable to write for about four hours, and since that time he has been unable to speak. Was deaf for one day and then his hearing returned.

Admitted to the American Women's War Hospital on April 21st, 1916, and examination at that time was negative save for the loss of speech.

On April 29th, 1916, he was given a light ether anæsthesia. There was no stage of excitement, but on regaining consciousness he sat up on the table and began to laugh, and then remarked, " Well, I can talk all right now."

He was returned for duty on May 5th, 1916.

These cases illustrate well some of the more common functional disturbances incident to the nervous strain of warfare together with the trauma inflicted on the nervous system by the concussion from shell fire.

II. Gas Poisoning

In this present war with the belligerent forces entrenched so close together, and also owing to the fact that it is what might be termed a stationary warfare in that there is very little marching and manœuvring, many new and hitherto unheard-of methods of inflicting injury to the opposing force have been devised. Of these devices the one which is best known is the poison gas, which is used to overcome large bodies of men before an attack is commenced on an opposing trench.

Two different forms of gas are being used, as well as two different methods of propelling the gas. These two gases are known according to their method of propulsion as :

(1) Shell Gas.
(2) Drift Gas.

(1) **Shell Gas.**—This form of gas is contained in shells which are projected and burst over the trenches. An irritant and asphyxiating gas is immediately liberated, which gas has a marked irritative effect on the eyes as well as causing symptoms similar to those experienced from the drift gas. Other symptoms such as nausea and vomiting are also noted. The exact nature of the gas is not known, but somewhat resembles chlorine or bromine in its effects.

The effects are well, if not grammatically, noted in the following brief descriptions by patients who were admitted here after having been " gassed " by shell gas.

Private R. L. (1st Canadians) writes : " As well as I can tell you as to the effect of my eyes by the German fumes, well, we were about 2,000 yards from their guns, and if a shell burst within 60 or 80 yards from us the Lyddite fumes would affect our eyes then, so that was the first time my eyes were affected. So when I got closer to the fumes my eyes became worse, and then I could feel a pain in my head, and when I touched my eyes they would smart very much, and then they would start running, only Sir, you must understand that I was once affected with my eyes before, but they was all right before I got these fumes, and I can tell you this, that those fumes affected my eyes, so I guess this is the only way I can describe the effect ; and also affects my breathing and stomach, in fact, it makes you dizzy and senseless and pains in head." (May 3rd, 1915.)

Private D. S. (16th Canadian Scottish), injured by gas near Ypres between 9 and 10 p.m. on Thursday, April 22nd, 1915, writes : " My eyes were injured by gas which came from a shell. When it burst, light green and yellow smoke came down mixed with the black, smelling of ether or methylated spirits. I first felt it smarting in my eyes and then going down my throat and smarting the same way. It made me cough. I rubbed my eyes with my handkerchief to get it out and did not know till afterwards that the gas was in my handkerchief and was making them worse. The gas got into our clothes and has made the leather straps on my kilt curl up and go brittle. It kills grass. I did not go straight to hospital, but went to the reserve trenches and then to a stable where we were billeted, but was all in when I got there. I still rubbed my eyes with my handkerchief because they were burning so, and the gas came off the handkerchief and got into my eyes. On Sunday I was taken away from the billet in the stable to Vlameringhe Hospital and felt my sight going. My eyes were getting hotter. We were shelled out of that hospital, and I was put into the ambulance blind. I was blind two days after the shell burst. I still feel the taste of the gas when I cough (Tuesday, May 4th). I did not get it down into my lungs, as I kept my mouth closed as much as possible."

(2) **Drift Gas.**—It is with this gas that we are the most concerned, as the majority of the cases seen have been "gassed" by this means.

Drift gas is discharged under pressure from large metal cylinders placed in the trenches. Tubes lead up over the edge of the trench and the gas is allowed to escape from these. The gas, which is heavier than air, contains chlorine as a chief constituent, and when it is liberated it drifts along over the ground towards the opposing trenches, and when it reaches these it flows over the edge and fills both the trenches and the dug-outs. It is essential that there be a slight breeze blowing towards the opposing forces, as otherwise the gas may be blown back into the trenches from which it is being liberated. The gas drifts slowly along as a dense bank lying close to the ground and rising to a height of several feet.

Symptoms.—The immediate effects from the drift gas consist of marked irritation of the eyes and throat, followed by an inability to breathe and a sensation of choking. There is also associated with this a severe burning pain in the chest.

In a short time the soldier begins to vomit up a greenish-yellow fluid, and he then passes into what is known as the toxic stage when he is unable to stand and so falls to the ground. This increases the danger, as the gas is in the greatest concentration close to the earth. In addition to a feeling of lassitude, there is marked dyspnœa associated with a sensation of constriction in the chest and also a severe headache. The skin is of a peculiar greenish-yellow colour, and this is especially noted in those who have died on the field. In the base hospitals one is unable to judge of the immediate effects of the poison gas, as such cases are only seen in the bronchitic stage, which persists for a considerable length of time after the acute symptoms have subsided.

The appearance of the gas and the symptoms to which it gives rise are noted in the following statement:

"Being on look out on the morning of April 24th, as near as I remember, I saw great clouds of smoke coming over the land between the trenches that were about 85 yards apart. I called the boys to man their posts, the cloud kept coming very slow as there was very little wind; it hung tight to the ground and seemed to rise about 7 to 8 feet in the air. At first it hurt my eyes and throat and then got down into my lungs, my chest started to tighten up, and it was impossible to get breath, some of the boys who were near me fell down gasping and tearing at their neck with their hands. I do not know how they came through, as what was left of us had to retire till we got out of the thickest of the smoke. We lined up again, those who could, but most of them were down and out with gas, vomiting and almost blind. I being the same, but having worked in mines and knowing a little of gas, tied my field dressing around my mouth early in the game, and it did not hurt me as much as others; as I went back over the ground we had retired over a half-hour or so before, I saw a lot of our boys lying unconscious and two I am sure were quite dead as I took cover in the hole where they were and saw for myself. Another thing I noticed were that the big healthy fellows seem to get it worse, those who were dead were a greeny yellow. The effect on the eyes was very bad, I also for five days kept coughing up green slime off my chest, and eyes were very dim for the same period about; also all food or water or anything I eat or drank tasted the same; the smoke hung to our clothes and left a kind of colour like our khaki. I also say those I saw dead were the same" (Private J. B., 15th Canadians, May, 1915).

The primary effects and the treatment are well noted in a report of a series of 685 cases which were observed by Lieutenants Black, Glenny, and McNee (2) at a Casualty Clearing Station, and their observations are here quoted :

" The following notes are founded on observations on 685 cases of gas poisoning which came under treatment in a casualty clearing station between May 2nd and May 7th, 1915. The patients were brought in by motor ambulance convoys from the field ambulances—a journey of about ten miles. Some arrived only six hours after being 'gassed,' while in other cases a much longer period had elapsed before they were brought in. They were detained in the casualty clearing station only until they were deemed fit to evacuate to the base. The slighter cases were sent down at the earliest possible moment, the majority being evacuated within forty-eight hours, while a number of severe cases were kept for several days while their condition remained critical. The total number of cases admitted during this period was 685. They were suffering from all degrees of asphyxia, but no good reason could be given why some cases were much worse than others from the same trench. It was, however, observed that the older men were almost all severe cases.

" Extreme pressure of work made it impossible to make notes on each case, but the following general features have been observed with care, and it is hoped may be of interest and assistance to others.

" The whole series could be roughly divided into two groups :

" (*a*) Those who seemed in imminent danger of death from asphyxiation—about 120 in number.

" (*b*) The remainder who, although suffering from the effect of gas, did not appear in immediate danger.

" Of the first group 33 died, giving a death-rate in the total number of cases observed of just under 5 per cent. It must be added here that many other cases died either on the field or at the field ambulances.

" Of the 33 deaths :

" 16 died on the day of admission.
" 13 died on the day following admission.
" 2 died on the second day following admission.
" 1 died on the third day following admission.
" 1 died on the fourth day after admission.

" It will be seen that 29 of the 33 deaths took place within thirty-six hours after admission, only four dying at a later period.

" **Condition of Cases on Admission.**—The first intimation that the urgent problem of asphyxia would have to be faced on a large scale was the arrival of the convoy, and it is difficult to convey the mental impression produced when the first batch was unloaded. It was 1.30 a.m. when they reached the casualty clearing station, the gas having been used against them about 7.30 p.m. on the previous evening. One man was dead before he could be removed from the ambulance. Most of the others were in a choking condition, making agonising efforts to breathe, clutching at their throats, and tearing open their clothes. At one moment they propped themselves up to gasp, at another they fell back exhausted by their struggles. There was marked cyanosis, especially of the lips and ears, and in a few cases a light yellowish frothy discharge was escaping from the mouth and nose. Some, especially the older men, were in a condition of collapse ; their faces and hands were of a leaden hue, their heads fallen forward on their chest. The majority of these cases did not rally. In addition to the asphyxiating effects of the gas, most of the men, although young and robust, were greatly exhausted by continuous fighting against the poison.

" All, except those moribund or collapsed, were fully conscious, and fighting desperately for life.

" Fourteen men died out of the first batch of seventeen admitted.

"Among the hundreds of cases subsequently observed all degrees of asphyxia were evident, and it is difficult to convey a composite clinical picture of all of these. Certain common features, however, stood out so prominently that our purpose will be served by calling attention to them. Certain of these have been alluded to already.

"The typical case was on admission cold, with a subnormal temperature, conscious but restless, the pulse slow and full (except in the collapsed cases). The face was cyanosed, intensely so in many cases, and the expression was strained and anxious. The posture varied. In some cases the patient sat propped up, with the head thrown back, gasping for breath ; in others he lay on his side with his head over the edge of the stretcher in an attempt to aid expectoration. The respirations were jerky and hurried, often numbering forty a minute, and were associated with a choking cough, accompanied by a varying amount of frothy expectoration.

"With each inspiration the chest expanded to its fullest, all the auxiliary muscles being brought into play just as in an asthmatical paroxysm.

"The percussion note over the chest was somewhat impaired without being actually dull. Auscultation revealed the presence of moist sounds of different qualities all over the chest.

"**Progress of the Cases.**—It was noticed that the patients who lived tended to pass three more or less definite stages while under our observation :

"1. The asphyxial stage.
"2. The quiescent or intermediate stage.
"3. The bronchitic stage.

"Nearly all the cases on admission were in the first or asphyxial stage, which has just been described. This condition demanded immediate and energetic treatment, and was that which chiefly occupied us at the casualty clearing station. Grave symptoms appeared with startling suddenness, but if patients could be safely brought through this stage, recovery was the rule.

" The first stage gradually passed off after some thirty-six hours, and the patient fell into a sleep from which he woke feeling much better. He continued in this state for perhaps half a day, and during this period every effort was made to evacuate him safely to the base.

" After these few hours of comparative quiet, symptoms of bronchitis began to manifest themselves. In the majority of cases, as far as our experience went, these were not severe. In the cases, however, which had been kept alive with difficulty there was a very short quiescent stage followed by intense bronchitis. Four of the most severe cases died in this bronchitic stage. Their symptoms, as compared with the first stage, were as follows : The frothing secretion gave way to thick greenish muco-purulent expectoration, consciousness was replaced by delirium, temperature rose from subnormal up to 104° F., and the pulse became of small volume, while its rate increased to perhaps 160. Respirations were less choking, but more shallow, and numbered up to 70 per minute before death.

" *Treatment.*—As post-mortem examination showed that the patients died of acute congestion and edema of the lungs, the aim of our treatment was :

" 1. To expel the excessive secretion from the lungs by emetics and stimulating expectorants.

" 2. To diminish the secretion.

" 3. To support the failing heart and reoxygenate the blood.

" *General Treatment.*—On arrival the patients were placed in the open air, and, as they were very cold, extra blankets, hot-water bottles, and hot drinks were provided.

" A little later on, as the weather was unsettled and to facilitate nursing, the worst cases were placed in a large lofty room with open windows on opposite sides, giving a through draught. Here about 120 out of the 685 cases were treated, the maximum number in the ward at one time being 30.

"*Special Treatment.*—1. **Emetics.**—As a routine measure, the first 80 cases admitted were treated with emetics. Later on their use was confined to those cases which were obviously choked with secretion, and had not already been sick. The most successful emetic was salt and water, administered in 10-ounce doses, followed by large draughts of lukewarm water; vomiting was *immediately* induced by tickling the back of the throat with a soft brush, or by the patient using his own finger. In all cases marked relief was experienced, the patients bringing up quantities of yellowish frothy fluid. In fact, so pronounced was the relief, that many tried to make themselves sick again. Vinum ipecacuanhæ and apomorphine hydrochloride were also tried, but were discarded, neither being so certain in their action as salt and water. There was no difficulty in getting the men to take the latter remedy, even in the most acute cases.

"2. **Artificial Respiration.**—The action of the emetics was furthered in selected cases by the application of Schäfer's method of artificial respiration. The results at times were strikingly successful, notably in the case of one man, almost moribund, who was treated in this way on four successive occasions, and who ultimately recovered.

"3. **Stimulating Expectorants.**—Every case was given ammonium carbonate gr. x every three hours as a stimulant and expectorant. Later this dose was increased to gr. xv and vinum ipecacuanhæ m. xv added. This mixture, although containing a somewhat large dose of ammonium carbonate, frequently given, gave very good results, producing copious expectoration followed by improvement in colour and general relief. In the 80 cases treated with emetics the expectorant followed.

"4. **Posture.**—The action of emetics and expectorants was sometimes aided by altering the position of the patient from sitting up to lying on the side with the head low down to aid expectoration.

"**To Diminish Secretion.**—In the hope of being able to check the excessive secretion in the lungs, atropine was administered to several severe cases, in doses of gr. $\frac{1}{50}$. We cannot say we found any beneficial result from this treatment; doubtless its administration was too late, but it might have been of use if given earlier—that is, in the field ambulance.

"**To Support the Failing Heart.—Venesection.**—In view of the cyanosis and marked dyspnœa, venesection was attempted, 10 to 15 ounces being removed on each occasion. This proved very difficult to carry out satisfactorily as the blood clotted rapidly, and the relief given was very transient. It occurred to us that a more gradual and protracted depletion of the right heart would give better results. Accordingly, leeches were procured. Sufficient suitable cases did not then remain, however, to enable an opinion to be formed as to their value.

"**Pituitary Extract.**—Whenever the pulse showed signs of weakening—which was rarely seen except in cases approaching a fatal termination—1 c.cm. of pituitary extract was given, with marked benefit, the pulse becoming fuller and slower.

"**Oxygen.**—As most cases presented marked cyanosis and dyspnœa, oxygen was given freely by inhalation; there was no doubt that temporary benefit resulted, the restlessness decreasing and the colour improving. Continuous inhalations appeared to give no more benefit than intermittent ones. In one or two cases oxygen was given by subcutaneous injection in the pectoral region, the amount being sufficient to cause a lump in each side of the chest about the size of a small football. This was absorbed very slowly, and no relief was apparent.

"**Benzoin Inhalations.**—In milder cases, when the alveolar and bronchial secretion was not so marked as the irritation of the larynx and trachea, inhalations of steam impregnated with compound tincture of benzoin, in a closed tent, were tried with some relief.

"**Opium.**—There was a type of case in which the mental strain was a more marked symptom than the pulmonary distress. This type was characterised by extreme restlessness rather than by dyspnœa, and in these cases tincture of opium m. v administered every half-hour until m. xv had been given gave certain relief, the patients quietening down and falling into a peaceful sleep.

"**Other Remedies.**—Other remedies, such as inhalation of chloroform and amyl nitrite, were tried, but without success.

"**Routine Treatment evolved from Experience.**—The routine treatment evolved from the experience gained was :

"1. Abundant supply of air and warmth.

"2. An emetic of salt and water if the patient was very cyanosed and had not already vomited, followed by the

"3. Administration of ammonium carbonate gr. xv and vinum ipecacuanhæ m. xv three-hourly.

"4. Oxygen inhalation in cases of marked cyanosis and dyspnœa.

"5. Opium m. v to m. xv in restless cases to allay the mental strain.

"6. Pituitary extract (1 c.cm.) and brandy when the heart threatened to fail."

The cases which we have seen at the American Women's War Hospital have been well along the road to convalescence, although some have been admitted within a few days of being "gassed." Some of them showed a slight degree of cyanosis, a feeling of tightness across the chest, and some dyspnœa. Associated with this was a profuse yellowish sputum. On auscultation there were many fine and coarse râles scattered throughout both chests.

Treatment.—This consisted of giving inhalations of oxygen when there was any cyanosis, a chest swathe to relieve the dyspnœa, and also opium and ammonium carbonate or ammonium chloride as an expectorant.

Such cases usually cleared up in three to four weeks, at which time the dyspnœa had disappeared, as well as the purulent expectoration and the râles.

Fig. 151. Mask for use when a gas attack is being made. Mask is saturated with hyposulphite of soda and glycerine, which counteracts the effects of the gas.

Prophylaxis.—Since the advent of the gas masks (Fig. 151) which the men must carry with them all the time, and which they put on when there is an alarm, the dangers from gas poisoning have been much decreased.

III. Trench Foot

This term has been applied to those conditions in which the soldier develops painful and swollen feet due to long immersion in the cold water which is prevalent in the trenches during the winter. By many writers it has been called " frost-bite," but strictly speaking it is not a true frost-bite, but is rather a " water-bite."

Frost-bite is essentially a condition of stasis of the circulation due to extreme cold and occurs in the more exposed parts of the body, such as the face, nose, or ear. It also affects the extremities—hands and feet—if these are not properly protected, or if they are in any way constricted so as to interfere with the free circulation of the blood. This condition usually attacks the toes or the heel and is rapidly progressive, ending in gangrene.

Three classes of frost-bite are recognised, depending upon the severity and the extent of the freezing. The first stage is one of erythema, the second stage shows the formation of blebs and bullæ, and the third and final stage results in the death of the part frozen. The convalescence of such cases is protracted, even in the erythematous form, and is associated with great pain and edema. The treatment of such cases will not be considered, as they are well known, especially among those who live in cold climates, but the essential facts are mentioned as a matter of comparison to the symptoms seen in trench foot.

The condition known as trench foot is due more particularly to the inertia of the muscles and a resultant slowing of the circulation. Men who are exercising vigorously, and whose feet are in constant motion, are not so apt to suffer from the effects of the cold water as are men who are standing still. This condition too differs from true frost-bite in that the symptoms are usually more transitory than are the symptoms in frost-bite. The conditions seen in a typical trench foot consist of pain or hyperæsthesia over the dorsal and plantar aspects of the foot which comes on usually after the initial numbness, due to the immersion in the cold water, wears off. The foot may be slightly cyanosed or may show a faint erythema, and with this there may be a slight edema. Oftentimes, however, the foot is absolutely normal in appearance, and the only symptoms which are present are subjective.

In addition to the erythema and œdema, we occasionally see cases in which there is some vesiculation of the skin, and occasionally a small area of superficial necrosis.

We may, therefore, say that the majority of the lesions caused by " water-bite " are, on the whole, less severe than those caused by frost-bite, although occasionally we see instances where gangrene of the toes or of various areas of the skin surface occurs.

A condition similar to the trench foot is occasionally seen in the hands.

Treatment.—The treatment of this condition is largely symptomatic, especially in the early stages, and should consist of rest in bed and the application of some evaporating lotion such as alcohol. Lead-and-opium wash often gives a great degree of relief if the hyperæsthesia is at all marked. Later, exposure to the air and gentle massage with olive oil or with camphorated oil tend towards an abatement of the symptoms. We have also been treating such cases with a weak faradic bath, which apparently affords them a great deal of comfort.

Prophylaxis.—The prophylactic measures in such instances are perhaps best shown by the instructions which have been issued in the " Memorandum on the Treatment of Injuries in War " (3), by the War Office, which are as follows :

" 1. Boots should not fit tightly, but should be at least a size too large. When boots are large enough it is well to wear two pairs of socks ; but this is dangerous if the boots are small, as it leads to further pressure on the feet. Puttees should never be applied tightly.

" 2. The general circulation can be kept up by keeping the body warm and dry. A mackintosh sheet worn over the great-coat is of assistance where no waterproof is available.

" 3. A dry pair of socks should be carried in the pockets when available.

" 4. Boots and puttees should be taken off at least once in twenty-four hours, the feet rubbed and dried and a dry pair of socks put on.

" 5. Boots should be well greased or dubbined.

" Officers should see that dry standing is provided in the trenches whenever possible, by means of drainage, raising of the foot level by fascines of brushwood or straw with boards on top, or by the use of pumps where these are available."

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