SURGERY OF THE HEAD

MAJOR
BATHE RAWLING
R.A.M.C.(T.)

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SURGERY OF THE HEAD

BY

L. BATHE RAWLING

M.B., B.C. (Cantab.), F.R.C.S. (Eng.)

SURGEON AND SENIOR DEMONSTRATOR OF OPERATIVE SURGERY
ST. BARTHOLOMEW'S HOSPITAL; MAJOR R.A.M.C. (T.F.)

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CHAPTER I

CLINICAL APPLIED ANATOMY

THE SCALP. THE SKULL. THE BRAIN. THE CRANIAL NERVES. THE MEMBRANES. TOPOGRAPHY OF THE SKULL AND BRAIN.

THE **subcutaneous tissue** of the scalp is firm and fibrous, and in its meshwork ramify the various **arteries** of the scalp. It is on account of this relationship between the arteries and their supporting framework that hæmorrhage is so severe in scalp injuries, and their ligature in operations so tedious and unsatisfactory. The vessels are unable to contract and retract—as in other situations.

From the middle line in front, progressing backwards, the arteries of the scalp are as follows : frontal and supra-orbital (above the orbit), lachrymal (at the outer angle of the orbit), temporal (in front of the ear), posterior auricular (behind the ear), and occipital (half-way between the ear and the occipital protuberance). All these vessels anastomose freely, one with the other and with those of the opposite side of the head. The methods adopted for the control of bleeding during operation are enumerated in Chapter VIII.

The areas supplied by the **sensory nerves** of the scalp are depicted in the accompanying figure.

The **occipito-frontalis** possesses four small muscular bellies, two anterior arising from the supra-orbital ridge and two posterior from the superior curved line of the occipital bone, the four blending into an aponeurosis which is separated from the underlying bone by a plane of loose connective tissue—the sub-aponeurotic tissue—the aponeurosis moving freely over the bone. It is along this loose layer that the scalp is torn away in scalp injuries. The aponeurosis thins off towards the sides of the head, blending with the temporal fascia and attached to the temporal ridges. Blood or pus may spread widely throughout the subaponeurotic space, limited in front by the orbital ridges, behind by the curved line of the occipital bone and laterally by the temporal crest. In all cases, however, the effusion, whether blood or pus, will tend to gravitate towards the more dependent part of the head, usually the occiput, there leading to marked ‘ bogginess ’, with œdema and perhaps with discoloration of the skin.

The two anterior bellies of the muscle are supplied direct by the facial nerve, the two posterior by its posterior auricular branch.

The **bones** that enter into the formation of the vault of the skull (frontal, two parietal, occipital, and the two squamo-temporals) are, for the most part, composed of two tables of compact bone, separated from one another by the diploe, bone of cancellous type. This diploic tissue varies in amount in the different parts, being most developed in the frontal, parietal, and upper occipital regions, and practically

FIG. 1. DISTRIBUTION OF SENSORY NERVES TO THE HEAD AND NECK. OPHTH., Ophthalmic division of the fifth nerve; S.T., Supratrochlear branch; S.O., Supra-orbital branch; I.T., Infratrochlear branch; L., Lachrymal branch; N., External nasal branch; SUP. MAX., Superior maxillary division; T., Temporal branch; M., Malar branch; I.O., Infra-orbital branch; INF. MAX., Inferior maxillary division; A.T., Auriculo-temporal branch; B., Buccal branch; M., Mental branch; C2, 3, Branches of the second and third cervical nerves; G.O., Great occipital nerve; S.O., Small occipital nerve; G.A., Great auricular nerve; S.C., Superficial cervical nerve; C3, Least occipital nerve; 4, 5, 6, Posterior primary division of 4th, 5th, and 6th cervical nerves.

absent over the temporal and lower occipital regions where the outer and inner tables are in apposition. This diploic tissue not only fulfils the purpose of aiding the nutrition of the bone, but also acts as a buffer to blows received. Hence, there is always greater splintering of the bone in the temporal regions, with greater liability to puncture and laceration of the underlying dura mater. To compensate, however, for the greater weakness of the bone in the two situations mentioned, both receive protection from overlying muscles, the temporal muscle over the squamous portion of the temporal bone, the muscles of the neck over the occiput.

The outer table is lined with **pericranium**, a highly vascular membrane, analogous to the periosteum of long bones, but possessing less bone-forming properties and less vital to the life of the underlying bone. The pericranium is easily stripped away from the bone which it covers, except in the region of the sutures, where it dips in along the intersutural lines to become continuous with the dura mater. It is obvious, therefore, that a subpericranial hæmorrhage or purulent collection is limited in its extent. The blood or pus is confined to the bone with which it is specially related. Insomuch, also, as the occipital and temporal bones give origin by their surface to various muscles and fasciae, a typical subpericranial effusion can only take place over the parietal and frontal bones.

The dura mater acts as a kind of **internal periosteum** to the internal table of the skull, firmly adherent along sutures and the rougher projections of both vault and base, less firmly attached between these lines. The meningeal vessels, embedded in the outer part of the dural coat, minister to the vitality of the membrane and to that of the internal table of the skull.

The bones of the skull, therefore, receive blood supply from two sources, externally from the vessels of the scalp through the pericranium, internally from the dura through the medium of the meningeal arteries. Between the two supplies there are many communications through the various foramina in the bones of the vault. Between the two venous systems, however, there is a very much greater intimacy and interchange, this taking place along the various emissary veins. These emissary veins act in the manner of many safety valves, compensating for any sudden changes in intracranial pressure. At the same time they are most important pathologically—forming the line along which infection may spread, from the scalp to the meninges and in the opposite direction. For example, prolonged suppuration of scalp and skull bones is always dangerous from the possibility of spread of infection to the meninges and brain, and again, in infective thrombosis of the lateral sinus, the infection spreads readily along the mastoid emissary veins, leading to œdema and suppuration over the mastoid process.

The more important emissary veins are as follows :

(1) Parietal emissary vein—on either side of the middle line, towards the posterior part of the parietal

bone, connecting the vessels of the scalp with the superior longitudinal sinus.

2. The mastoid emissary veins, at the upper and posterior border of the mastoid process, connecting the vessels of the scalp with the lateral sinus.

3. The communications between the angular and supra-orbital veins at the inner angle of the orbit with the ophthalmic veins and so with the cavernous sinus.

The Brain

The brain practically occupies the cavity within which it is contained. It has been compared to a sponge, the main structure of which corresponds to the substance of the brain, blood and cerebro-spinal fluid filling it out in such a manner that it lies flush with its containing walls. It pulsates synchronously with the heart's beat, visibly to the eye when exposed. Respiratory changes also occur, appreciated only on mechanical investigation. Insomuch, also, as the structural framework of the brain cannot undergo compression or variation in quantity, any changes in the contents of the skull must be carried out at the expense of the fluid constituents. Thus, there may be some increase of arterial blood at the expense of cerebro-spinal fluid and venous blood after meals, after indulgence in alcohol, during periods of cerebral excitement. On the other hand, there is more venous engorgement during the 'slacker' periods of existence, after surgical shock and concussion, during the reactionary periods following great cerebral excitement and activity.

As a simple example of the relationship of the brain to the enclosing walls, it may be stated that if the brain be widely exposed in a normal individual, with free removal of bone and incision of the dura mater, there is not the slightest tendency on the part of the brain to bulge outwards through the dural and osseous openings. If, however, the patient be placed in the head-down position or if he strains violently, the brain at once bulges markedly through the aperture, through venous engorgement.

This relationship between the brain and its fluid is further exemplified by noting the sunken fontanelle of a starved and emaciated child and the change that takes place after a few days' careful feeding and treatment. The structural framework of that child's brain has not been increased—the nutrition has improved—there is more blood.

Cerebro-spinal fluid. The total quantity of cerebro-spinal fluid varies within small limits under normal conditions. This fluid is secreted actively from the choroid plexuses and lining ependyma of the lateral ventricles, passing into the third and fourth ventricles, thence escaping in two ways: (1) down the spinal cord into the neural canal and spinal subarachnoid space; and (2) through the foramina in the roof of the fourth ventricle (Majendie, Key and Retzius) into the cerebral arachnoid space. There the flow tends to pass in the upward direction, towards the lacunæ of the superior longitudinal venous sinus where the fluid is absorbed. Some also passes directly into the larger cerebral veins. The pressure of the cerebro-spinal fluid is almost equal to, slightly higher than, the intracranial venous tension. Normally, therefore, the cerebro-spinal fluid passes into the veins. If, however, the venous pressure is raised, serous fluid passes from the veins into the subarachnoid spaces,

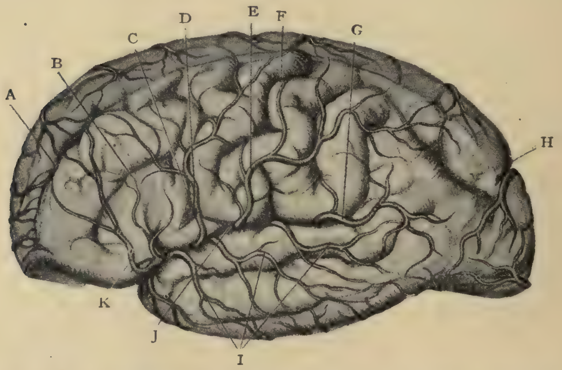


FIG. 2. SUPERO-LATERAL SURFACE OF THE CEREBRAL HEMISPHERE. (Semidiagrammatic.) A, Superior frontal sulcus; B, Inferior frontal sulcus; C, Precentral sulcus; D, Ascending frontal artery; E, Ascending parietal artery; F, Central sulcus; G, Parieto-temporal artery; H, Parieto-occipital fissure (Lateral part); I, Temporal branches; J, Posterior ramus of lateral fissure; K, Inferior lateral frontal artery.

thus accounting for the œdema (boggy brain) observed in the great majority of pathological conditions of the brain and membranes. Again, if cerebro-spinal fluid escapes freely after a fracture of the base of the skull (anterior or middle fossa), its place in the subarachnoid space is immediately taken by a serous exudation from the veins. This explains the fact that, in such cerebro-spinal discharges, it is only the first fluid collected which contains that reducing substance peculiar to cerebro-spinal fluid.

FIG. 3. VEINS OF THE SUPERO-LATERAL SURFACE OF THE HEMISPHERE. The dura mater has been removed, but the arachnoid and pia mater are *in situ*. A, Superior sagittal sinus; B, Great anastomotic vein; C, A superior cerebral vein; D, Cut edge of dura mater; E, E, Superior cerebral veins; F, An inferior cerebral vein; G, Superficial middle cerebral vein; H, An inferior cerebral vein; I, Sigmoid part of transverse sinus; J, Inferior anastomotic vein; K, Transverse sinus.

The cerebro-spinal fluid is collected towards the base of the brain to form cisternæ, water-cushions. These will be mentioned again later.

The total amount of cerebro-spinal fluid is probably, not more than a few drams.

The brain is richly supplied with **blood** from the two carotids and the two vertebrals, the four vessels communicating at the Circle of Willis, thus equalizing the cerebral circulation in general. Of the three main cerebral arteries, the **anterior**, sweeping round the genu of the corpus callosum, lies deep in the mesial longitudinal fissure of the brain, supplying in the main the mesial aspect of the cerebrum. The **middle cerebral** lies embedded in the Sylvian fissure, its branches being distributed to the frontal, parietal and temporal lobes. The **posterior cerebral** is distributed to the temporo-sphenoidal and occipital regions.

The various cortical arteries pass to their destination in the sulci of the brain, terminating finally as end arteries.

The veins of the brain lie in a similar situation but more superficial, the blood running from the Sylvian region in the upward and downward directions to the superior longitudinal and lateral sinuses. In cross section, it would be found that the venous system is far more extensive than the arterial, thus acting as a buffer to the force of the arterial flow and maintaining a more or less equal cerebral pressure. The venous return, as evidenced by the degree of venous engorgement of cerebral veins, is markedly affected by straining, coughing, defæcation, &c.

Functions of the brain. The functions of some portions of the brain are well known, proved in the first place by experimental evidence, in the second by clinical observation. The illustration appended will suffice to demonstrate the cortical areas, some definite, others surmised. The most important fissure of Rolando acts as an arbitrary line of demarcation between the motor and sensory areas. The

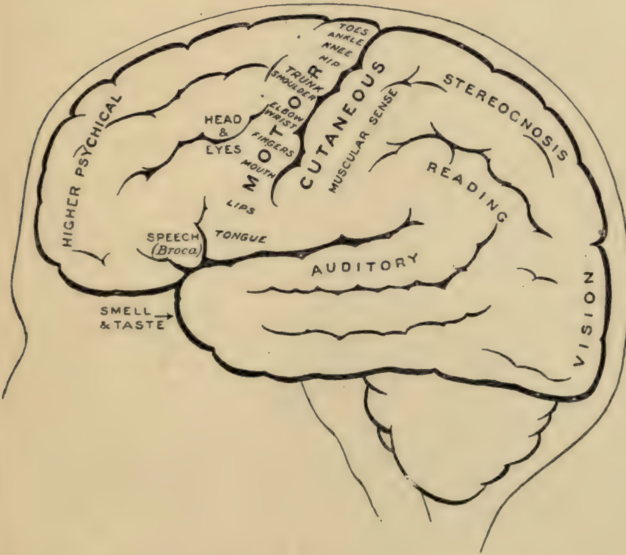


FIG. 4. THE CORTICAL MOTOR AND SENSORY AREAS.

motor strip—probably not more than three-quarters of an inch in width—lies wholly anterior to this fissure, limited behind by the fissure of Rolando and spreading in front to the precentral sulcus. In the median antero-posterior line the motor area dips over on to the mesial aspect of the brain (probably as far as the calloso-marginal fissure) and, in the downward direction, extends practically as far as the Sylvian fissure. The motor areas, as arranged in this motor strip, correspond, from above downwards, to the movements of the opposite side of the body—toes at the top and face at the bottom, the position of a person standing on his head. On the left side of the brain, at any rate in right-handed individuals, the speech centre of Broca is situated, lying in the angle between the anterior and posterior horizontal limbs of the fissure of Sylvius.

Behind the fissure of Rolando, limited in front by that fissure and behind by the post-central gyrus, the **sensory areas** are placed—another narrow cortical strip. In all probability these **sensory areas** are arranged in a manner similar to the more anterior motor areas—lower extremity at the top, face at the bottom.

Other cortical areas correspond to the regions depicted. **Vision** is dependent on the integrity of the occipital poles, more especially the mesial aspect thereof.

Speech merits special consideration. Speaking, writing, hearing, and seeing are all closely connected. The areas responsible for these several functions are probably situated according to the areas depicted (Fig. 5).

So far as the functions of the main part of the frontal and temporal lobes are concerned, but little is known. They may be highly useful, but, by reason of our want of exact knowledge, they are labelled as 'silent' areas. In all probability the frontal lobes are responsible for the higher faculties of man, reasoning, moral control, intellectuality, &c. Lesions of these lobes, however, are associated with such slight

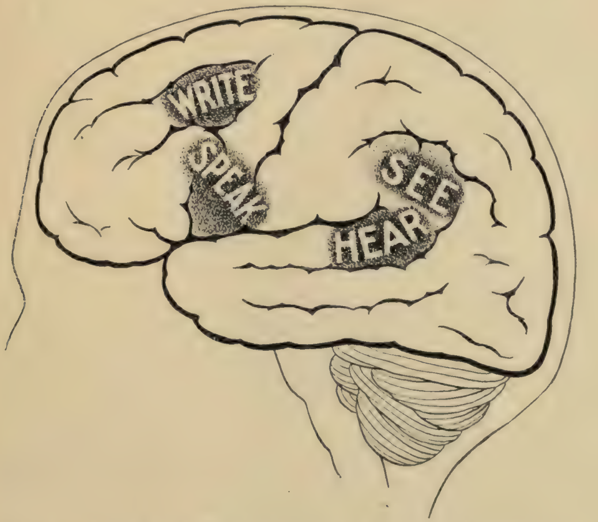


FIG. 5. THE AREAS CONCERNED IN SPEECH EXPRESSION.

disturbances that they are aptly designated 'silent'. The temporo-sphenoidal lobe, in particular, is apparently of such little importance that the **temporal region is the site of election for decompression operations**. Its protrusion, definitely aimed for and desired, appears to exercise no deleterious effect on the individual.

The Cranial Nerves

(1) **The first or olfactory nerve.** The olfactory bulb overlies the cribriform plate of the ethmoid, that part of the anterior fossa of the skull which is so liable to fracture. The various efferent olfactory nerves pass through the foramina of the cribriform plate towards their destination in the nose. Loss of smell—anosmia—is likely to result in all anterior fossa fractures. In addition, insomuch as these various olfactory nerves carry with them, in their course through the cribriform plate, prolongations of dura and arachnoid, their laceration will allow of the escape of cerebrospinal fluid, with the added danger of ascending infection from the nose to the meningeal region.

(2) **The second or optic nerve.** The optic chiasma overlies the base of the sphenoid, but is in front of the usual trans-sphenoidal line of middle fossa fracture. It may, of course, be injured as the result of bullet wound, with consequent blindness of both eyes. The optic nerves pass to the orbit through the optic foramina, in which part of their course they are especially liable to injury, either by bullet or in fractures of the anterior fossa implicating the region of the optic foramina. In addition, insomuch as the two nerves carry with them a dural coat, all intracranial subdural hæmorrhages are liable to be associated with extension of blood along the course of the nerve, between it and its dural envelope—with consequent compression of the arteria centralis retinæ and of the nerve trunk itself, with proportionate degrees of visual

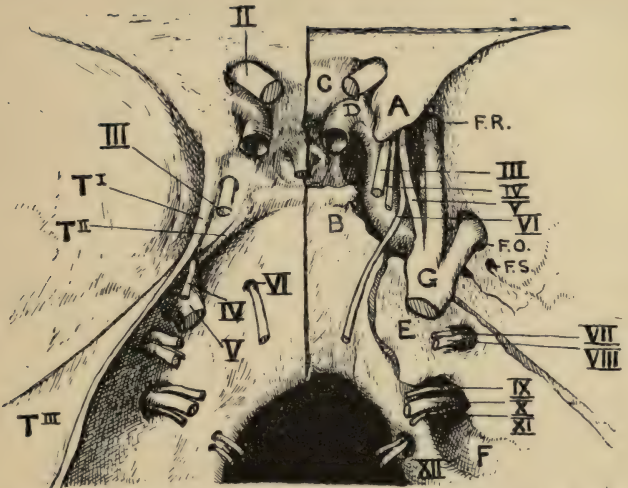


FIG. 6. DRAWING OF BASE OF SKULL. Showing: on *Left*, dura mater in position and the points where cranial nerves pierce it; on *Right*, dura removed to expose cavernous sinus (between A C B and G) and its contents. A, on *Anterior Clinoid Process* (small wing of sphenoid); B, on *Dorsum Sellae* behind *Posterior Clinoid Process* (body of sphenoid); C, on *Olivary Eminence* (body of sphenoid between optic foramina); D, on *Internal Carotid Artery*, where it turns up through roof of cavernous sinus to enter circle of Willis; traced back it is seen to lie on floor of sinus, disappearing into apex of petrous; E, on *Petrous*, between inferior petrosal sinus (to inner side), internal auditory meatus (to outer side), and jugular foramen (behind); F, on termination of *Sigmoid Sinus* behind jugular foramen; G, on *Gasserian Ganglion*, behind mandibular division passing down and out to foramen ovale (F O), maxillary division, passing forward to foramen rotundum (F R), and ophthalmic division, passing upwards along the lateral wall to the roof of cavernous sinus. Between D and F R and deep to A the 3rd, 4th, 5th, and 6th nerves enter the orbit through the sphenoidal fissure; T, *Tentorium Cerebelli* retracted at T ‴ to expose the nerves in the posterior fossa; T ″, Extension of petrous attachment to posterior clinoid process; T ′, Attachment of free edge to anterior clinoid process. Between the bands T ′ and T ″ the 3rd nerve pierces the roof of cavernous sinus. Cranial nerves shown on both sides: II, Optic; III, Oculo-motor; IV, Trochlear; V, Trigeminal; VI, Abducens; VII, Facial; VIII, Auditory; IX, Glosso-pharyngeal; X, Vagus; XI, Spinal Accessory; XII, Hypoglossal (A. Macphail, M.B., C.M.).

loss. Moreover, the experience of the war has established the fact that the great majority of head injuries with increase of intracranial pressure are associated with some degree of **papillœdema,** *not* true optic neuritis. As Mr. Jessop has written recently: 'The papillœdema is, as a rule, not characterized by much swelling of the optic disk, though in some cases there has been 3 D to 5 D. The œdema and swelling is practically limited to the optic disk and a narrow zone of effusion around. The vision is, as a rule, unaffected and the colour sense and fields are normal. The whole appearances are those of œdema due to pressure and not those of inflammation.' And again: 'In most cases, after decompression or trephining, the swelling of the disk subsided in five or six days, and in fourteen to twenty-one had disappeared.'

The visual disturbances occurring in relation to the optic nerves, optic chiasma, optic tracts and radiation are made more clear by a reference to the accompanying illustration. It will be seen that the following visual disturbances are typical of particular lesions :—

(1) **Blindness of one eye** in division of one optic nerve.

(2) **Blindness of both eyes** in transverse division of the chiasma.

(3) **Bitemporal hemianopia** in antero-posterior lesions of the chiasmic region—both nasal halves of the retina being affected, with blindness in both temporal fields.

(4) **Bilateral homonymous hemianopia** when the lesion affects the tracts posterior to the chiasma, with loss of function of the temporal half of the retina on the same side and of the nasal half on the opposite,

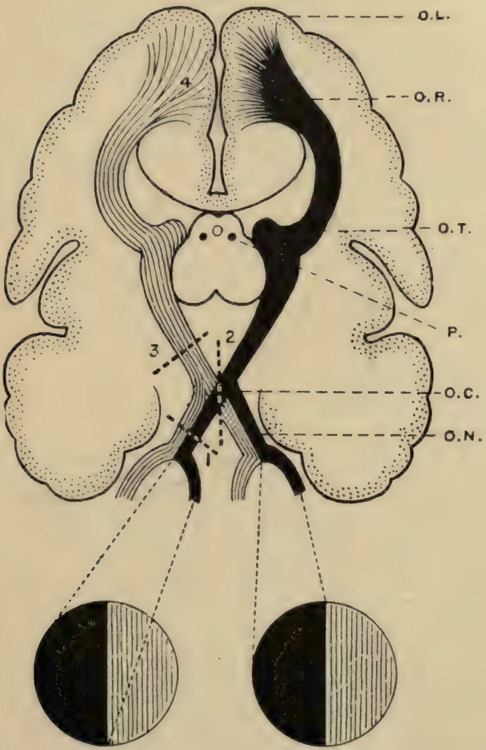


FIG. 7. THE VISUAL PATHS. O.L., Occipital lobe; O.R., Optic radiation; O.T., Optic tracts; P., Pupillary fibres from optic tract to third nerve nucleus; O.C., Optic chiasma; O.N., Optic nerve; 1, Blindness of affected eye; 2, Bitemporal hemianopia; 3, Bilateral homonymous hemianopia, with hemianopic pupillary reaction; 4, Bilateral homonymous hemianopia, pupillary reaction normal.

with corresponding blindness (see Fig. 7). The optic tracts, when traced backwards, are seen to spread out as the **optic radiation,** terminating in the occipital cortex of the brain, more especially on the mesial aspect thereof. The optic fibres are closely connected with the nucleus of the third nerve and the exact site of the lesion producing bilateral homonymous hemianopia may be determined by reference to the action of the pupil. If the optic fibres are interrupted between the retina and the third nerve nucleus, there is loss of pupillary reflex when light is thrown on the blind part of the retina. If the lesion is placed further back, pupillary reaction is unaltered (Wernicke's sign—hemianopic pupillary reaction).

The third or oculo-motor nerve. The third nerve courses along the outer wall of the cavernous sinus, passes through the sphenoidal fissure and enters the orbital cavity, there dividing into upper and lower branches. It innervates all the extrinsic ocular muscles except the superior oblique and the external rectus, and, in addition, supplies the ciliary muscle of accommodation and the circular muscles of the iris (stimulation produces contraction of the pupil and vice versa).

The fourth or trochlear nerve courses along the outer wall of the cavernous sinus, passes through the sphenoidal fissure and is distributed to the superior oblique muscle.

The fifth or trigeminal nerve. Its ganglionic enlargement, the Gasserian ganglion, is situated on the anterior aspect of the petrous portion of the temporal bone. From this ganglion the three divisions of the nerve emerge. **The first division** courses along the outer wall of the cavernous sinus, passes through

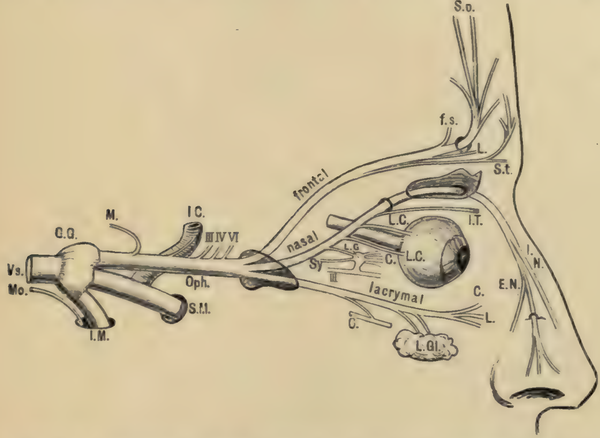


FIG. 8. SCHEME OF THE DISTRIBUTION OF THE OPHTHALMIC NERVE. VS., Trigeminal nerve, afferent root; MO., Efferent root; G.G., Gasserian ganglion; M., Meningeal branch; I.C., Branch to internal carotid artery; OPH., Ophthalmic nerve; S.M., Superior maxillary nerve; I.M., Inferior maxillary nerve; III, Communication to oculo-motor nerve; IV, To trochlear nerve; VI, To abducent nerve. Frontal nerve; F.S., Branches to frontal sinus; S.O., Supra-orbital nerve; S.T., Supra-trochlear nerve; L., Branches to upper eyelid. Nasal nerve; L.G., Long root to lenticular ganglion; SY, Root from sympathetic (on carotid artery); III, Short root from motor oculi nerve; C., Short ciliary branches; L.C., Long ciliary nerves; I.T., Infratrochlear nerve; E.N., External, and I.N., Internal nasal nerves. Lachrymal nerve; O., Orbital branch of superior maxillary nerve; L.GL., Lachrymal gland; C., Conjunctival branch; L., Branch to eyelids and face.

the sphenoidal fissure and enters the orbital cavity. It is distributed: (1) as the supra-orbital and supra-

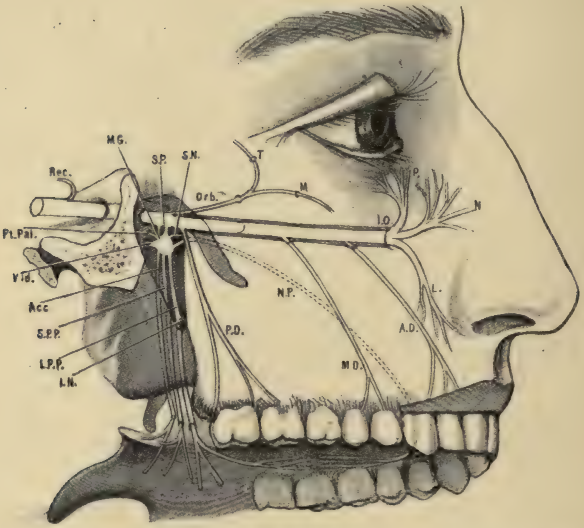


FIG. 9. SCHEME OF THE COURSE AND DISTRIBUTION OF THE SUPERIOR MAXILLARY NERVE. REC., Recurrent branch in the middle fossa of the skull; M.G., Meckel's ganglion in the spheno-maxillary fossa; S.P., Spheno-palatine nerves; S.N., Superior nasal branch; ORB., Orbital nerve; T., Temporal, and M., Malar branches; I.O., Infra-orbital nerve, appearing on the face; P., Palpebral; N., Nasal, and L., Labial branches; A.D., Anterior dental branch; M.D., Middle dental branch; N.P., Naso-palatine nerve; P.D., Posterior dental branch; I.N., Inferior nasal branch; L.P.P., Large posterior palatine nerve; S.P.P., Small posterior palatine nerve; ACC., Accessory posterior palatine nerve; VID., Vidian nerve; PT.PAL. Pterygo-palatine branch.

trochlear nerves to the skin of the forehead, (2) as the nasal nerve to the upper part of the nasal cavity and the tip of the nose externally, and (3) by other small branches to the mucous membrane of the upper lid and to the conjunctiva.

The second division passes from the skull through the foramen rotundum, traverses the spheno-maxillary fissure, courses along the infra-orbital canal, and emerges on the face at the infra-orbital foramen. On the face it breaks up into three main sensory branches, palpebral, nasal, and labial. Through other branches given off earlier in its course, sensation is supplied to the malar and anterior temporal regions (temporo-malar), and to the mucous membrane of the gums and teeth of the upper jaw (anterior, middle, and posterior dental branches).

The third division emerges from the middle fossa of the skull through the foramen ovale. It differs from the first and second divisions in that it contains **motor** fibres. These are distributed to the muscles of mastication—external and internal pterygoids, masseter, buccinator and temporal muscles, and, by means of the fine mylohyoid branch, to the mylohyoid and anterior digastric muscles. The **sensory** fibres of the nerve are distributed in the main as the lingual nerve to the anterior two-thirds of the tongue (common sensation), and as the inferior dental, which branch traverses the inferior dental canal in the lower jaw and is distributed finally to the mucous membrane and teeth of the inferior maxilla.

The sixth nerve, abducens. After grooving the

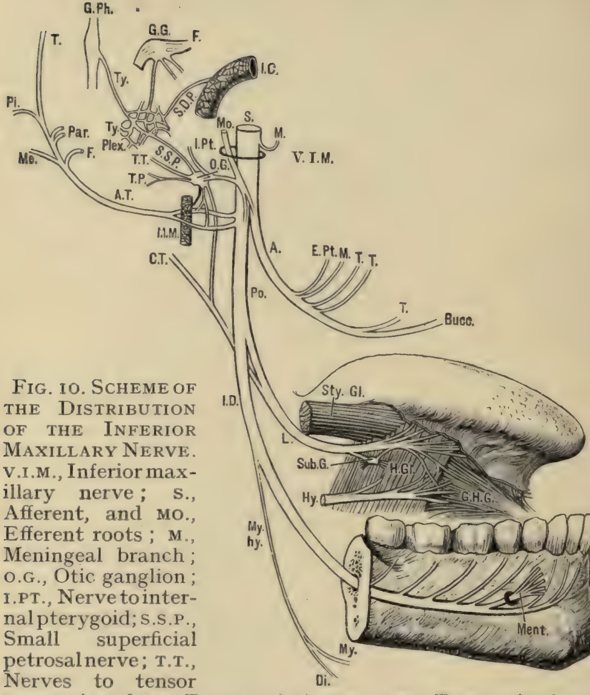


FIG. 10. SCHEME OF THE DISTRIBUTION OF THE INFERIOR MAXILLARY NERVE. V.I.M., Inferior maxillary nerve; S., Afferent, and MO., Efferent roots; M., Meningeal branch; O.G., Otic ganglion; I.PT., Nerve to internal pterygoid; S.S.P., Small superficial petrosal nerve; T.T., Nerves to tensor tympani, and T.P., Tensor palati; TY. PLEX., Tympanic plexus; I.C., Internal carotid artery; S.D.P., Small deep petrosal nerve; G.G., Geniculate ganglion; F., Facial nerve; TY., Tympanic branch; G.PH., Glosso-pharyngeal nerve; M.M., Middle meningeal artery; A.T., Auriculo-temporal nerve; F., Communication with facial nerve; PAR., Nerve to parotid gland; ME., Branch to meatus of ear; PI., Branch to pinna; T., Temporal branch; A., Anterior division of inferior maxillary nerve; E.PT., Nerves to external pterygoid; M., Masseter; T.T.T., Temporal, and BUCC., Buccinator muscles; PO., Posterior division of inferior maxillary nerve; L., Lingual nerve; C.T., Chorda tympani nerve; SUB.G., Sub-maxillary ganglion; HY., Hypoglossal nerve; I.D., Inferior dental nerve; MY.HY., Mylohyoid nerve; MY., Nerve to mylohyoid; DI., Nerve to digastric (anterior belly); MENT., Mental branch; STY.GL., Stylo-glossus; H.GL., Hyoglossus; G.H.G., Genio-hyoglossus muscles.

lateral aspect of the dorsum epiphii, immediately beneath the posterior clinoid processes (in which situation it is frequently involved in middle fossa fractures), the nerve courses along the outer wall of the cavernous sinus, passes through the sphenoidal fissure, and is distributed to the external rectus muscle.

The seventh or facial nerve. This nerve enters the petrous bone through the internal auditory meatus, in company with the eighth. It pursues a rather tortuous course through the petrous bone, comes into close approximation with the middle ear and emerges at the base of the skull through the stylo-mastoid foramen. It then turns sharply forwards, round the condyle of the jaw, and enters the substance of the parotid gland. There it divides up into many branches, the so-called pes anserinus, then being distributed to the facial muscles of expression.

Its more important branches may be summarized as follows :

Intrapetrous course, three branches :
- to the stapedius muscle,
- the chorda tympani,
- Arnold's nerve.

In the neck, three branches :
- to the stylo-hyoid muscle,
- to the posterior belly of the digastric,
- the posterior auricular nerve (posterior belly of the occipito-frontalis and the retrahens aurem muscle).

On the face, three branches to each of the two

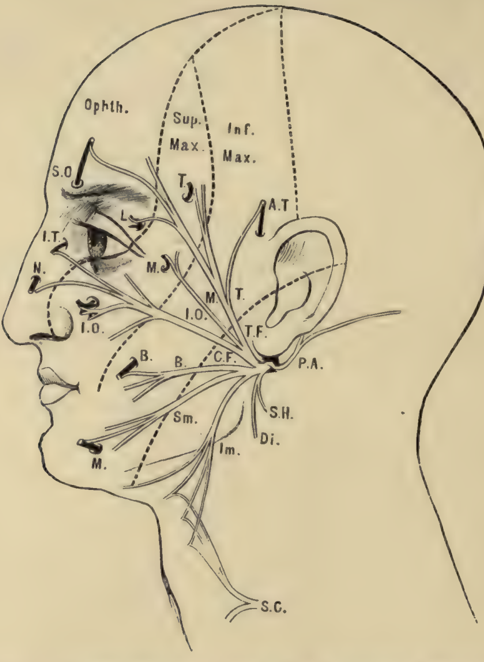


FIG. 11. DISTRIBUTION OF FACIAL NERVE OUTSIDE THE SKULL, AND COMMUNICATIONS WITH TRIGEMINAL NERVE ON THE FACE. *Facial nerve :* P.A., Posterior auricular nerve ; S.H., Nerve to stylo-hyoid ; DI., Nerve to digastric (posterior belly) ; T.F., Temporo-facial division ; T., Temporal ; M., Malar ; I.O., Infra-orbital branches ; C.F., Cervico-facial division ; B., Buccal ; SM., Supramandibular ; IM., Inframandibular branches. *Trigeminal nerve :* OPHTH., Ophthalmic division ; S.O., Supra-orbital ; I.T., Infratrochlear ; N., External nasal ; L., Lachrymal branches. SUP.MAX., Superior maxillary division ; T., Temporal ; M., Malar ; I.O., Infra-orbital branches. INF.MAX, Inferior maxillary division ; A.T., Auriculo-temporal ; B., Buccal ; M., Mental branches ; S.C., Superficial cervical nerve.

terminal divisions, temporo-facial and cervico-facial:

temporo-facial into temporal, malar, and infra-orbital.

cervico-facial into buccal, supra-, and infra-mandibular.

Paralysis of the facial nerve is divided into two main groups, according to whether the lesion is central or peripheral to the nucleus of the nerve in the floor of the fourth ventricle, the so-called **supranuclear or incomplete** type of facial paralysis and the **infranuclear or complete** type. The two types differ from one another in their effects. In the supranuclear palsies the upper face muscles escape, the patient being still able to frown and close the eye more or less completely. In other words, the following muscles are exempt from paralysis, anterior belly of occipito-frontalis, pyramidalis nasi, and orbicularis palpebrarum. The explanation offered for this fact is as follows: the facial nucleus receives fibres from both hemispheres, and interference with the one side fails to cut off the impulses still derived from the other. Consequently, in cortical and capsular lesions the patient is still capable of frowning and closing the eye more or less completely.

Paralysis due to lesions of the nucleus itself may be excluded, as it is impossible for the seventh nerve nucleus to be picked out apart from other nuclei in the immediate neighbourhood.

In both nuclear and infranuclear palsies all the distal regions are paralysed. Thus, in lesions of the petrous bone, all the face muscles are involved,

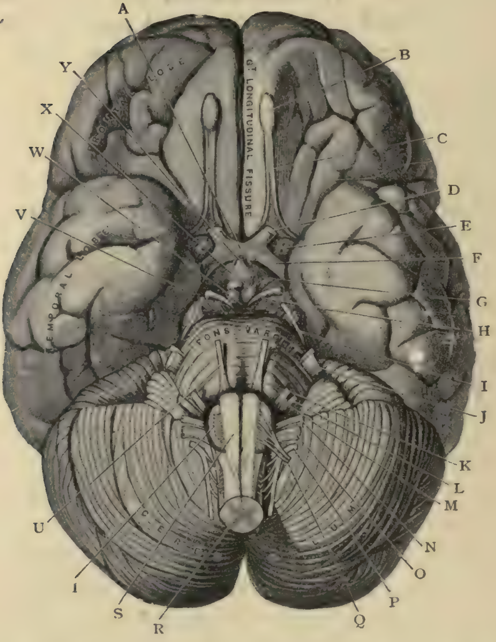


FIG. 12. THE BASE OF THE BRAIN WITH THE CEREBRAL NERVES ATTACHED. A, Optic chiasma ; B, Olfactory bulb ; C, Olfactory tract ; D, Optic nerve ; E, Substantia perforata anterior ; F, Optic tract ; G, Tuber cinereum ; H, Oculomotor nerve ; I, Trochlear nerve ; J, Trigeminal nerve ; K, Motor root of facial nerve ; L, Acoustic nerve ; M, Sensory root of facial nerve ; N, Glosso-pharyngeal nerve ; O, Vagus nerve ; P, Accessory nerve ; Q, Hypoglossal nerve ; R, Spinal medulla (cut) ; S, Pyramid ; T, Hypoglossal nerve ; U, Abducent nerve ; V, Pedunculus cerebri ; W, Substantia perforata posterior ; X, Corpora mammillaria ; Y, Infundibulum.

Fig. 13. Dissection of the Interior of the Cranium after the Removal of the Brain and the Tentorium Cerebelli. A, Infundibulum; B, Diaphragma sellæ; C, Optic nerve; D, Oculo-motor nerve; E, Abducent nerve; F, Trochlear nerve; G, Trigeminal nerve; H, Facial nerve; I, Acoustic nerve; J, Glosso-pharyngeal nerve; K, Vagus nerve; L, Accessory nerve; M, Hypoglossal nerve; N, First cervical nerve; O, Spinal medulla; P, Transverse sinus; Q, Occipital sinus; R, Ligamentum denticulatum; S, Vertebral artery; T, Basilar plexus; U, Sigmoid part of transverse sinus; V, Middle meningeal artery; W, Superior petrosal sinus; X, Inferior petrosal sinus; Y, Spheno-parietal sinus; Z, Tent. cerebelli, ant. end of free border; 1, Tent. cerebelli, ant. end of attached border; 2, Internal carotid; 3, Ophthalmic artery; 4, Anterior and posterior intercavernous sinuses.

including the stapedius, chorda tympani, &c. Paralysis of the stapedius results in inability on the part of the patient to appreciate high notes and finer sounds, whilst inclusion of the chorda tympani interferes with the sensation of sweets and bitters at the tip and sides of the tongue.

In lesions involving the facial nerve in the condyloid or parotid regions, the facial muscles alone suffer, being completely paralysed.

The eighth or acoustic nerve. This nerve enters the petrous bone at the internal auditory meatus, in company with the seventh. It immediately divides into two main branches, **Vestibular** to the ampulla for equilibration, and **Cochlear** to the cochlea for hearing purposes. It may be noted—

1. That in labyrinthine lesions and in injuries of the main trunk, both divisions of the nerve are equally affected.

2. That with nerve deafness plus facial paralysis plus middle-ear disease, labyrinthine disease or injury is indicated.

3. That paralysis of the seventh and eighth nerves, with a healthy middle ear, indicates a lesion at the internal auditory meatus or of the base of the skull.

The ninth (glosso-pharyngeal), tenth (vagus), and eleventh (spinal accessory) nerves. These nerves emerge from the posterior fossa of the skull through the foramen lacerum posterium (jugular foramen). They are closely incorporated, so much so that it is exceedingly unlikely that any lesion could pick out an isolated nerve trunk—all three are likely to be involved at the same time, producing what is called vago-glossopharyngeal paralysis, the eleventh nerve being excluded because it is of lesser importance, merely supplying the sterno-mastoid and trapezius muscles, and that incompletely.

Vago-glossopharyngeal paralysis is characterized by paralysis of the swallowing or pharyngeal muscles as well as those of the larynx, together with some loss of taste over the posterior third of the tongue and loss of laryngeal sensation.

These three nerves may be injured in any posterior fossa fracture and in penetrating or perforating bullet wounds of the posterior chamber of the skull.

The twelfth or hypoglossal nerve. This nerve emerges from the posterior fossa of the skull through the anterior condyloid foramen, a region seldom involved in posterior fossa fractures. Its inclusion leads to paralysis of the main muscles of the tongue.

All these cranial nerves, as they emerge through the basic foramina, carry with them prolongations of dura, arachnoid, and pia. The dura ends on the outer aspect of the foramina, becoming continuous with the external periosteum; the other two membranes gradually blend with the perineurium of the nerve trunks. Cerebro-spinal fluid, contained in the subarachnoid space, is enabled to escape from the cranial cavity along the course of these nerves. This escape takes place under normal conditions, during the various changes of intracranial pressure.

The membranes of the brain. The thin **pia mater** is closely related to the surface of the brain, dipping into all the sulci, major and minor. Beneath it is a space, adventitious, the so-called subpial space.

More superficial is the arachnoid membrane, also fine, separated from the pia by a delicate meshwork of cellular tissue, the subarachnoid space. This space is bathed in cerebro-spinal fluid, the meshwork also acting as a support for the numerous fine vessels that

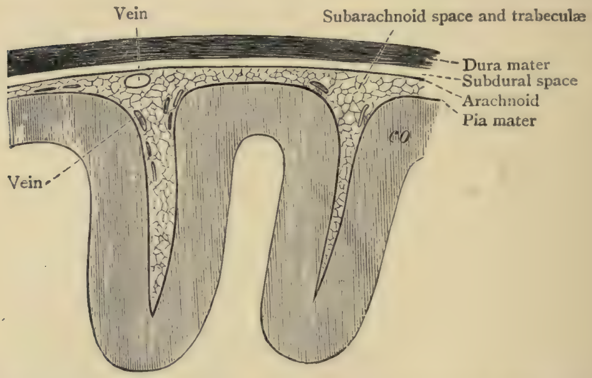


FIG. 14. DIAGRAMMATIC SECTION THROUGH THE MENINGES OF THE BRAIN. (Schwalbe.)

co, Grey matter of cerebral gyri.

ramify therein. This is the space involved in meningeal infections and in those contusions of the brain which are characterized by a thin film of blood over the surface of the convolutions. This also is the membrane which is ruptured in laceration of the brain.

The arachnoid membrane merely dips into the larger sulci, passing over the smaller and leaving, therefore, here and there, spaces in which the cerebro-spinal fluid may collect. In addition, at the base of the brain, the two membranes, pia and arachnoid, are widely separated to form the three cisternæ or so-called water-cushions of the brain, cisterna magna, cisterna pontis, and cisterna basalis.

The **dura mater** is by far the toughest of the three membranes. It consists of two layers, inner and outer, the two separating from one another for two purposes: (1) to form the **supporting membranes** of the brain—the falx cerebri between the two cerebral hemispheres, the falx cerebelli between the two halves of the cerebellum, and the tentorium cerebelli between the cerebrum and the cerebellum; and (2) to allow of the formation of the **venous sinuses** of the brain—superior longitudinal, lateral, and cavernous.

As previously stated, the meningeal arteries are embedded in the outer wall of the dura mater, and, as the dura is attached with some firmness to the inner aspect of the skull, both vault and base, it follows that hæmorrhages derived from lacerated meningeal vessels are extra-dural in position, and that some difficulty will be experienced by the blood extravasation before the hæmorrhage can attain sufficient dimensions to interfere with the cerebral circulation and produce definite symptoms of local irritation and of general increase in the intracranial pressure.

The dura mater is of such consistency that a mere removal of bone for the purpose of decompression is

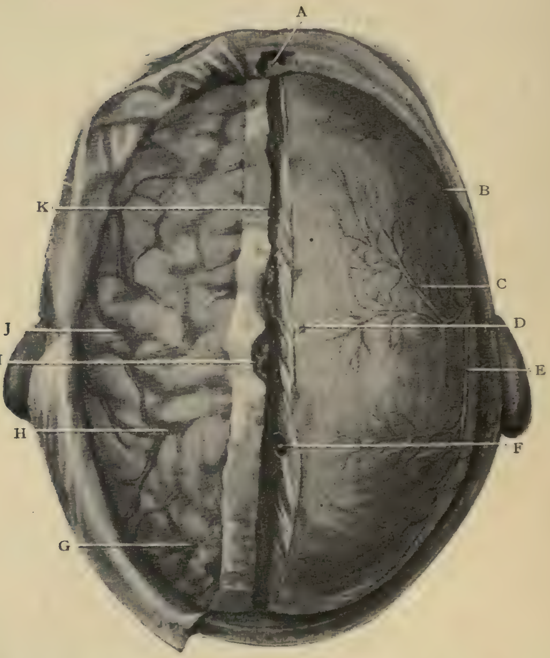


FIG. 15. SUPERIOR SAGITTAL SINUS; DURA MATER; MIDDLE MENINGEAL ARTERY AND VEIN; ARACHNOIDEA AND SUPERIOR CEREBRAL VEINS. A, Frontal air sinus; B, Dura mater; C, Anterior branch of mid. meningeal artery and accompanying vein; D, Arachnoideal granulation; E, Posterior branch of mid. meningeal artery, with vein; F, Opening of a superior cerebral vein; G, Cerebral vein; H, Arachnoidea covering cerebral vein; I, Lateral lacuna; J, Cerebral vein; K, Cut edge of superior sagittal sinus.

not likely to bring about any definite result. The dura itself must be opened, and that freely, if the desired result is to be attained. In addition, once divided, considerable difficulty will be experienced in sewing it up again. Indeed, in most cases, such a course is impossible of achievement, even if desirable, the membrane being of an elastic nature, contracting, and, in addition, the brain will bulge forcibly along the lines of dural division.

When bone is freely removed and the dura exposed over a considerable area, under normal conditions, it is seen to pulsate, synchronously with the heart's beat ; it is smooth, shiny, and sufficiently translucent to allow of the seeing of the underlying cerebral veins and brain substance itself. Under high intra-dural pressure, these pulsations cease, and the dura is firmer to the touch than under normal conditions.

CHAPTER II

INJURIES OF THE SCALP, SKULL, AND BRAIN

THE frequency with which head injuries occur in warfare, in relation to injuries of other parts of the body, varies according to the nature of the warfare. The deadliness of modern weapons, and the necessity for trench defence, bring about the necessity of the greater exposure of the head, neck, and upper parts of the body in proportion to other regions. Consequently, in this present war, the upper parts of the body suffer severely. In the South African War, of 22,461 men injured by rifle or shrapnel bullet, 2,379 were injured in the head, a proportion of rather over 10 per cent. In all probability, the present war will evidence a higher ratio of head cases as compared with the rest of the body.

In the South African War, the *mortality* resulting from head injuries was between 40 and 50 per cent. Consequently, by reason of the frequency of head injuries and the mortality associated therewith, head injuries are of special importance. Secondly, there is every reason to believe that the war will carry in its train a terrible list of mentally unfit, minor cases complaining of slight mental and physical incapacity, others of epilepsy, hemiplegia, blindness, insanity and the like. From all points of view, therefore, head-injuries demand the closest attention. Marvellous recoveries are reported from time to time, but the fact remains that no injuries of warfare are so terrible in their results, though, as a kind of compensation, it may be added that successful treatment, early and radical, may bring about such results as would have been scoffed at a few years ago.

In the consideration of bullet wounds of the skull—the term ' bullet ' including rifle and shrapnel bullet, shell wounds, and all varieties of injury occurring during warfare—the following factors require consideration :

The velocity of the bullet at the moment of impact.

The position of the bullet at the moment of impact.

The angle of impact.

(1) The velocity of the bullet at the moment of impact. The following examples may be cited. It is conceivable that a ' spent ' bullet may strike the skull at such low velocity as to injure the scalp and yet rebound. Cases of such a nature are obviously of doubtful occurrence, yet, in the South African War, they have been recorded, the soldier having received a scalp wound and, later on, found a bullet in his helmet. Similar cases have already been recorded in the present war. More authentic, perhaps, are instances where a bullet has perforated the scalp and lodged beneath it. Proceeding a little further, there are several cases recorded in which the bullet has penetrated into the frontal sinus, piercing the outer table of the skull but retaining insufficient momentum to progress further. In addition, many cases have been seen where fragments of shell have penetrated the scalp, there remaining embedded, perhaps in the surface of the bone.

Bullets of high velocity, fired at less than 500 yards range, produce most serious lesions, both to bone and brain. The penetrating power of such high velocity bullets is greatly dependent on the spin around a central axis, as imparted by the 'rifling'. A considerable proportion of the explosive and disruptive results of a bullet wound may be attributed to this rotary force, for the parts encountered by the bullet in its passage through bone and brain are thrown off, not only in the forward direction of the bullet itself but also practically at right angles to the axis of flight. (Horsley.)

The velocity of the bullet is also imparted or transmitted to all such fragments of bone as are driven into the brain, which fragments, as stated above, are driven in two directions, *forwards* in the direction of the bullet and *radially* as the result of the spin or rotary action of the bullet. In addition, the smaller and lighter fragments of bone or bullet usually progress the furthest, even further perhaps than the bullet itself. The resistance offered by the brain to such small fragments is of course less than that of the larger body, the velocity being the same. A very pretty instance of this projection of bodies of varying weight was seen in a case under Major MacAdam Eccles at No. 1 London General Hospital. The bullet entered in the left temporal region, and several fragments of bone and disintegrated bullet, traversing the temporo-sphenoidal lobe, were seen lying between the wound of entry and the cavernous sinus. The various fragments diminished in size the nearer they were situated to the sinus.

The velocity of the bullet is also transmitted to the brain in both the forward and lateral directions. These waves involve both the structural substance of the brain and its fluid contents, blood and cerebro-spinal fluid. In the immediate vicinity of the track, the brain-substance is destroyed, vessels are torn, with consequent hæmorrhage into the meningeal spaces, into the ventricles and into the substance of the brain itself. More distally are many punctate hæmorrhages, diminishing in size the further they are distant from the track of the bullet. In addition, a great wave is transmitted throughout the cerebro-spinal fluid, especially through the ventricular spaces, so rapidly and so menacingly, in some cases, that the respiratory, vaso-motor, and cardiac centres are at once paralysed. Of these centres, the respiratory is the more sensitive to such changes, almost invariably failing first. The heart usually beats for some seconds or minutes after respiration has ceased.

These punctate hæmorrhages and alterations of cerebro-spinal pressure account, in all probability, for the milder and more transitory symptoms observed in cases of shell-concussion.

The injury being received at close range, the degree of destruction to bone and brain is excessive, portions of skull and brain being blown away, sutures torn apart, and the base burst open.

(2) **The position of the bullet at the moment of impact.** The bullet may strike the skull end on, in which case the wound of entry through the skull may conform more or less to the size and shape of the bullet. On the other hand, either by reason of ricochet, 'wobbling' or 'head-over-heels' position, the degree of destruction is greatly increased. 'Wobbling' on the long axis occurs, in all probability, only in bullets possessing but low velocity, more or less 'spent' bullets. The condition has been compared to the action of a top immediately previous to cessation of spinning.

The 'head-over-heels' position, e. g. the turning over around a transverse axis in the middle of the length of the bullet, is often regarded as of common occurrence. According, however, to the most recent experiments, the bullet only turns over once, 'when the progressive velocity is greatly reduced and the advance of the bullet becomes more sensitive to obstructions which will first affect the light tip, the momentum of which is very different to that of the base' (Horsley).

On the other hand, a bullet may strike some obstacle, becoming a ricochet bullet, so altered in position and spin as to assume any position, head-over-heels or otherwise. Such a bullet may strike the skull on its long axis, producing corresponding serious damage. A bullet may also increase the degree of injury to bone and brain by alterations in shape as the result of ricochet, becoming blunted, distorted, split or stripped of its casing.

(3) **The angle of impact.** According to the angle at which the bullet strikes the skull, the fracture may be of the so-called **glancing or gutter type,** or it may **penetrate** the skull or pass completely through, **perforating.**

In all cases of fracture, however, the osseous lesion is of lesser importance than (1) **the degree of associated damage to the soft parts, and** (2) **the degree of infectivity of the wound.** Reference has already been made to the degree of associated damage to the brain according to the velocity of the bullet and the velocity imparted to fragments of bone carried in with the bullet. In addition, the danger of bullet wounds of the head depends very greatly on the part injured. Wounds of the **frontal** and **temporo-sphenoidal lobes,** the two so-called 'silent' areas of the brain, are the least dangerous, and, in general, it may be stated that the **nearer the injury to the cerebellar chamber—with its medullary centres—the more serious the prognosis.** Wounds of the occipital and cerebellar regions are always very dangerous.

Equally important is the question of **infection.** Each fragment of bone driven into the brain carries with it a certain degree of infection, more especially when the injury is situated in the region of the hairy scalp, hair or portions of head-gear being carried inwards along with the bullet. Even more important, perhaps, is the fact that the wounded man may fall on to filthy ground, previous to removal and dressing, perhaps capable of examining his wounded head with highly infected fingers. The bacteria of the soil have a heavy price to pay for the damage that they produce, in this region of the body as well in others.

Wounds of the scalp, without injury to the bone. Rifle and shrapnel bullet wounds of the scalp, without injury to the bone, must obviously be of rare occurrence. As the result of shell injury, however, they are not uncommon, fragments being embedded in or beneath the scalp immediately at the place of entry, or ploughing their way between the scalp and the bone for a variable distance. Sometimes portions of the scalp may be torn away, lacerated, ploughed up wounds. The greatest care is required in investigating the possibility of skull fracture, either of the external table only or of the whole thickness of the skull, and in many cases it is only possible to determine the exact extent of the injury with any degree of certainty after full exploration. In fact, when it is considered that practically every scalp wound is infected (1) from the hair and skin of the patient, (2) from investigations on the part of the patient as to the nature of his injury, and (3) from contact with contaminated earth, it is obvious that even slight scalp wounds are to be treated with care and circumspection. There is a definite mortality attached to scalp wounds. In the American Civil War, in 7,739 cases of scalp wound there was a mortality rate of 2 per cent. Probably amongst these so-called scalp wounds there was a certain proportion of cases in which the patient suffered in reality from a more serious lesion, yet the fact remains that cellulitis, erysipelas, and the spread of infection (through emissary and diploic veins and lymphatics) to meninges and venous sinuses does lead to the most serious complications. Consequently, rigorous treatment is required on the ground of infection only. In addition, there is always the risk that a fracture of the vault may be overlooked—a not uncommon and quite excusable error. Two or three cases of this nature have already come under my care, transferred from France to home hospitals, with a diagnosis of scalp wound only. The wound of the scalp, as produced by the metal, may be small and slit-like, easily overlooked and seldom allowing of reasonable drainage. Consequently, any suppuration that occurs has a poor chance of free escape. Most of these injuries open up the wide subaponeurotic space, and there is, in consequence, a considerable risk of the suppuration claiming the whole of the subaponeurotic space, from the supra-orbital ridges in front to the superior curved line of the occipital bone behind, and to the temporal ridges at the side. With such suppuration, the risk of spread of infection to meninges, brain, and intracranial sinuses is sufficiently apparent.

Hæmorrhage is seldom free. The edges of the scalp wound may be specially 'dirty', ragged, and ingrained with mud, blood, portions of hair, &c. From the rent escapes a variable quantity of pus, thin in the streptococcic cases, thick in cases of mixed infection.

Symptoms. Beyond a certain loss of blood and some slight immediate headache and dizziness, the patient may be none the worse. In most cases, however, either through the direct impact of shell fragment or from concussion effects, due to the proximity of the bullet, the injury may result in a short period of unconsciousness, followed perhaps by some symptoms of cerebral irritation—restlessness, excitability, severe headache, &c. Also, the bursting of a shell in the immediate neighbourhood of the patient may add considerably to the general severity of symptoms.

At the risk of repetition, therefore, it is necessary to urge that all scalp wounds, from the point of view of infectivity and from that of possible injury to the bone, demand the closest surgical attention.

Treatment of scalp wounds. Leaving out of consideration all those cases of so trivial a description as to require no special operative treatment, the same routine should be carried out—cleansing and exploration under an anæsthetic, with the provision of adequate drainage—of the fullest description. Scalp wounds should never be sealed up with sutures, collodion, &c.

This routine treatment is as follows: The patient is anæsthetized, the head completely shaved, the skin thoroughly scrubbed with soap and water, dried, and then painted with acetone and iodine. The edges of the wound itself, presumably ragged and ingrained with dirt, are painted over with pure carbolic acid, then dried and painted with iodine.

For the purpose of examining the under surface of the scalp for foreign body, shell fragment, hair, &c., the wound must be enlarged or a scalp flap turned down. Of these two courses, the latter is to be preferred. Such measures allow of the more free exposure of the bone. The scalp flap, when turned down, is painted on its under surface with iodine and any foreign body removed. Presuming that no further measures are indicated, the flap is resutured, drainage being provided at the more dependent angles of the flap, with split drainage tube. Gauze wicks are contra-indicated. They soon dry up and prevent any free discharge of pus.

The ragged edges of the wound of entry may be pared with scissors and the wound lightly plugged with gauze wrung out in normal saline solution or soaked in iodine.

In any case, frequent inspection of the wound is required, fresh dressings being applied twice in the twenty-four hours. Fomentations may aid in the general cleansing of the wound. There is a rich blood-supply to the scalp, and, with good drainage, the wounds soon show evidence of recovery.

Fractures of the Vault

In discussing fractures of the vault, it is necessary to include, not only bullet wounds of the skull, but also such varieties of fracture as are seen so commonly in civil practice. Fractures of the vault, the result of blows from rifle-butt, blunted weapons of all sorts, sword, &c., are identical in all respects with those seen in civil life. In addition, the troops employed away from the firing line are subject to such falls and injuries as occur under more ordinary conditions.

For example, we may have to deal with fissured, punctured, and comminuted fractures, simple or compound, with or without depression, with or without associated intracranial injury. Whether the fracture is caused by a bullet, or complicated by the presence of a bullet in the brain, matters little. The general signs and symptoms are closely allied. Previous to their consideration, however, it is necessary to allude to some features peculiar to **bullet wounds.**

According to their extent and character, they may be divided into (1) **Glancing wounds ;** (2) **Penetrating wounds,** the bullet being usually, though not necessarily, within the skull ; (3) **Perforating wounds,** complete traversing of the skull.

(1) Glancing wounds of the skull. The effect of the bullet on the scalp and the skull varies according to the angle of impact and the exact position of the bullet at the moment it strikes the skull—whether head-over-heels, ricochet, &c.

The **scalp** will be ploughed up along the line of the course of the bullet, leaving an oval gap in the soft parts, clean cut at the angle first struck, ragged and with everted edges at the angle of exit.

The **external table** of the skull may be gouged away, leaving a depression in the bone, exposing the diploic tissue, tapering off at both angles, deepest at its centre.

This fracture is mentioned as it is possible of occurrence. But it is excessively rare. So much so that it may be taken as a rule that every fracture of the external table is associated with a very much more severe fracture of the internal or unsupported table of the skull. These fractures of the external table alone are of such rare occurrence that they form no exception to the general rule that trephining should be carried out in the anticipation of finding a far more serious lesion of the bone, perhaps of the dura and brain in addition.

On the day on which these notes were written, I operated on a patient suffering from a shrapnel wound of the right parieto-occipital region. Local examination failed to show any depression of the bone, however slight, but the patient suffered from considerable headache, showed signs of cerebral irritation, and had a pulse rate of less than sixty to the minute, the blood pressure being raised to 160 mm. of Hg. The wound was explored and a crack was seen in the external table, without the slightest evidence of depression. Guided by the symptoms, which suggested increased intracranial pressure, and by the fact that the patient did not take his anæsthetic well, continually failing in respiration, a trephine was applied to the bone in the immediate neighbourhood of the crack, and an extensive depression of the internal table was found, extending over an area of about two inches square, the comminuted fragments of internal table being indriven and pressing markedly on the dura mater. The bone fragments were surrounded with blood clot, derived in the main from the posterior division of the middle meningeal artery. After the opening of the skull, the respiration at once became normal. The fragments were removed and the patient soon recovered.

Cases of like nature, of considerable frequency of occurrence, force one to adopt the view that but few fractures are confined to the external table, and that the merest fissuring of the external table, the result of bullet wound, is more than likely to be complicated by a much more serious lesion of the inner or unsupported table.

And secondly, that fractures of the internal table are all liable to complication by reason of injury to meningeal vessels and to the dura mater itself.

The **Internal table alone** may be splintered by reason of its being unsupported (see p. 10). The external table is strengthened, so far as blows applied to it are concerned, by the underlying internal plate, together with the intervening buffer-like diploic tissue. The internal table receives no such support, and suffers accordingly. The fragments from the internal table may lacerate the meningeal vessels, the sinuses of the brain, and may even be driven through the dura into the brain, without there being any obvious signs of bone depression. Several cases have come under my care, both at No. 1 London General and elsewhere, illustrating this most important point.

The whole thickness of the skull may be involved. This is by far the most common condition observed in ' glancing ' fractures. The tangent at which the bullet strikes the skull may be such that there is no actual penetration, but the bone suffers—extensively fractured with fragments of bone indriven, the whole thickness of the skull or internal table only. Before discussing the local conditions of this class of fracture, it is necessary to pay more attention to the relation of the fracture to the external and internal tables respectively—in skull injuries in general, and especially in bullet wounds.

It is most important to observe that the **internal table suffers far more severely than the external,** due to two reasons: (1) because the internal table lacks support whilst the external is buffered both by diploic tissue and by the internal table, and (2) because, in accordance with Teevan's law, 'the aperture of entry is caused by the penetrating body only, whilst the aperture of exit is larger, insomuch as it is made by the penetrating body plus the fragments of bone driven out of the proximal table and diplœ'. This law applies more exactly to penetrating and perforating fractures, but the general principles underlying the statement are applicable. At the risk of repetition, condoned by the importance of the occasion, it cannot be stated too urgently that **every fracture of the external table, however trivial at first sight, is associated with a much greater comminution and depression of the internal table,** with all the associated danger of damage to dura mater, meningeal vessels, and venous sinuses. In addition, it may be added that it is not possible for a bullet wound of the temporal region (where diploic tissue is absent) to be limited to the outer table. The internal table is invariably the more shattered of the two, and in this region there is the additional attendant danger of injury to the middle meningeal vessels.

So far as **complications** are concerned in these gutter fractures, &c., every attention must be paid to the fact that the fragments of internal table are driven inwards more or less at right angles to the direction of the bullet, and that their velocity and penetrating power are dependent on that of the bullet itself. In the case of a high-velocity bullet, the fragments are driven through the dura mater deeply into the cerebral substance.

(2) **Penetrating wounds.** Penetrating wounds come under a more serious category, more especially when situated in the posterior half of the skull. In fact, the nearer to the cerebellum the more grave the prognosis.

The **scalp wound** is usually quite small, sometimes slit-like, not infrequently so insignificant as to be overlooked. The bullet, being end on at the moment of perforation of the external table of the skull, the wound of entry through that table corresponds more or less to the size and shape of the bullet, not quite rounded, slightly squared at the edges, with but little evidence of fissuring, thus differing from the fractures of the skull of civil practice. When the bullet is of the ricochet type, wobbling, head-over-heels, &c., the osseous injury may be far more severe. The internal table is always far more extensively damaged, greatly comminuted. These osseous fragments have imparted to them the velocity of the bullet, being driven both inwards and also radially to the general direction of the bullet. The dura may present a slit-like tear, or it may be extensively torn, the degree varying in direct proportion to the extent of the osseous lesion. Meningeal vessels may be torn, with some extra-dural extravasation of blood—seldom of any degree of severity—and fragments of bone may

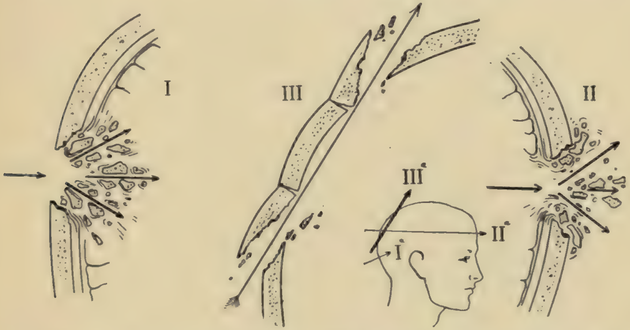


FIG. 16. TO ILLUSTRATE THE EFFECTS PRODUCED BY A BULLET ON BONE, DURA, AND BRAIN. I, A penetrating wound, or the aperture of entrance in a perforating wound; II, The aperture of exit in a perforating wound; III, A superficial perforating wound.

be driven into the superior longitudinal and lateral sinuses of the brain—a serious complication.

In addition, many fragments of bone, chiefly derived from the internal table, are driven deeply into the brain substance, to a depth of three or four inches. These fragments progress, not only in the direction of the bullet, but also radially, by reason of the spiral rotation of the bullet. All these fragments are likely to be infected.

The **bullet** itself may be anywhere, perhaps locked up amongst the various portions of depressed bone, in the superficial portion of the cortex of the brain, deep in the brain substance, or at some distance from the point of entry through the bone. In many cases, also, the bullet may have impinged against the opposite side of the skull, producing an elevated fracture or rebounding to some more distant region. In one case under my care, the bullet, entering on the right temporal region, passed through the brain, impinged against the left parietal region, there producing an elevated fracture, rebounded, and finally came to rest in the descending horn of the left lateral ventricle. In view of these facts, it is obvious that the most careful X-ray investigation is required previous to any attempt being made for the removal of the bullet itself.

(3) Perforating wounds. Such wounds are divided into two classes, **superficial** and **deep, superficial** when the entrance and exit wounds are close together, **deep** when the two wounds are situated on opposite sides of the skull.

In the **superficial type,** the scalp wound would be slit-like, the bone is extensively comminuted, fragments of bone, more especially of internal table, being driven inwards through the dura and into the brain. The dura is rent proportionately. At the site of exit of the bullet, the external table suffers the more extensively, fragments of bone lying beneath the scalp, perhaps visible on the surface, often mingled with pulped brain matter.

Between the two apertures the bone is extensively comminuted and elevated, or blown outwards. Fissures radiate in all directions, but mainly in the general line of the flight of the bullet.

The brain is extensively lacerated, in a line between the two apertures, and there is considerable effusion of blood into the subdural space.

In the **deep type,** the lesions are more or less constant, merely varying in degree according to the velocity of the bullet, &c. The internal table is driven inwards at the site of entry, the external blown outwards at that of exit, in both cases with but little fissuring of the bone. In bullets of high velocity, however, the destruction may be far more serious, **disruptive** or **explosive** fractures. In such cases the bones of the vault are comminuted, fissures radiating in all directions, sutures are torn open, and portions of bone actually blown away.

In perforating wounds the damage to the **brain** is always serious. With low-velocity bullets the injury is more or less confined to the immediate neighbourhood of the track of the bullet, pulping along the line and hæmorrhages around, diminishing in size and number the more distant from the track. With high-velocity bullets the damage is greater. Hæmorrhages are more numerous, pulping and laceration of the brain more extensive.

Signs and symptoms of fracture

In most cases the signs of a fracture of the vault are sufficiently obvious—a scalp wound leading down to comminuted bone, depressed or elevated according to whether the wound is that of entrance or exit. The probe is, of course, a useful aid to diagnosis, but the gloved finger is more sure. In the examination of the wound there is no need whatever to determine the **degree of comminution, depression, &c.** The mere fact that such conditions are present suffice. That point alone determines the question of operation. Mere superficial examinations with the finger will offer sufficient evidence as to the real nature of the case. The probe is less sure, damage may be caused to the dura mater, and sutures may be mistaken for fissured fractures, &c.

The **diagnosis** is confirmed by the presence of brain-matter in the wounds or by the escape of cerebro-spinal fluid.

In many cases, however, the scalp wound may be quite small and slit-like, and a large superficial area may be involved in an extensive subaponeurotic hæmatoma. In such cases the probe will aid materially, but a certain diagnosis can often only be accomplished after thorough exploration of the wound under anæsthesia.

The **symptoms** arising in fracture of the vault fall naturally under two headings: **General symptoms** and **localizing symptoms,** the former resulting from the effect of the injury on the general intracranial pressure, the latter due to the pressure exercised on a certain definite part of the cortex—by depressed bone, subdural clot, &c. For both general and local symptoms, see the next chapter.

CHAPTER III

FRACTURES OF THE VAULT

CONCUSSION, COMPRESSION, AND IRRITATION OF THE BRAIN. TREATMENT OF VAULT FRACTURES

THESE three conditions are so wrapped up with the physiology and pathology of the cerebral circulation, and so closely connected with one another, that a few remarks are required previous to discussing **symptomatology and treatment.**

First of all, it must be remembered that the main vital centres, vaso-motor, respiratory, and cardiac, are situated beneath the tentorium in the medullary region of the brain. Of these, the vaso-motor centre is probably the most sensitive to vascular alterations, stimulated by venous engorgement and paralysed by arterial anæmia. This centre possesses one main function, that of keeping up the blood pressure, regulating it according to the circumstances required. Stimulation of this centre raises the pressure of the blood from 125 mm. of Mercury, the normal condition, to 200 mm. or more, whilst the application of a violent blow to the skull, or the passage of a bullet through the brain, produces immediate inhibition or paralysis of the centre, in degree proportionate to the severity of the shock. The blood pressure immediately falls rapidly, perhaps to 50 mm., the splanchnic veins are engorged, the arteries of the brain are more or less emptied, with the result that a state of acute anæmia of the brain develops, affecting both cortex and medulla. The cortical anæmia is made evident by immediate loss of consciousness, loss of volition, loss of motor power, the limbs being in a state of flaccid paralysis. The bulbar effects are shown by a rapid feeble pulse of low pressure and by shallow, feeble, and irregular respiratory efforts. This is the **first or collapse state of concussion.** If, at this period, it were possible to visualize the brain, the following conditions would be found: surface veins engorged, the brain as a whole darker and of a more venous colour than normal, with everywhere excess of cerebro-spinal fluid. These conditions are accounted for in the following manner: the intracranial contents cannot be diminished as a whole; the brain structure remains the same, there is less arterial blood and consequently there is more venous blood. And, again, as the venous pressure and cerebro-spinal tension are practically equal, there is considerable transudation from the veins into the cisternæ, into the meshwork of the brain and pia-arachnoid regions with consequent excess of fluid—**œdema of the brain.**

Presuming now that the vaso-motor paralysis is of a transitory nature, and since action and reaction are equal and opposite, the centre recovers tone and works up to a pressure rather above the normal. In consequence, the blood pressure rises and both cortex and medulla are flushed with arterial blood. This produces, so far as the cortex is concerned, mental excitability, bodily irritation and headache, and, with regard to the bulbar centres, a high blood pressure, forcible beating of the arteries (e.g. throbbing of carotids), flushed face, hot skin, increase in pulse rate and volume. This is the **second or reactionary stage of concussion.**

Next, we have to consider the fact that the first or collapse stage may be prolonged for hours or days, and that the patient not infrequently dies without showing any tendency to enter on the second or reactionary stage. The question at once arises as to the cause of this prolonged and even fatal first stage. The answer is as follows : concussion, though due to an acute inhibition or paralysis of the vaso-motor centre and resulting in acute anæmia of the brain, is dependent **in its depth and duration** on the **degree of associated damage to the brain.** Thus a patient with no injury to the brain and with no intracranial hæmorrhage soon recovers, perhaps within a few minutes, from the collapse stage, passes through a transitory reactionary stage, and then completely recovers. In moderate degrees of brain injury, the patient may remain unconscious for some hours, then entering on a rather prolonged second stage, recovering in whole or in part, after a long convalescence, according to the severity of the injury and the region of brain which is damaged. In a third type, the injury to the brain being excessive, the first stage persists and the patient dies concussed.

In brief, therefore, **the longer the period of primary concussion the more serious the intracranial damage.**

Compression of the Brain

Compression is directly dependent on an increase of intracranial pressure by reason of the addition of extravasated blood, foreign body, &c. The skull can only contain a certain amount of substance (brain) and fluid (blood and cerebro-spinal fluid). The brain itself being incompressible, any addition to this space must first make room for itself by squeezing out a corresponding quantity of cerebro-spinal fluid ; but there is a limit to this, probably anything above 3 to 6 per cent of the intracranial capacity. Above this limit, the pressure exercises its effect on the general circulation of the brain, and with special effect on the delicately balanced and highly sensitive bulbar nuclei. The very first definite sign of intracranial pressure increase is shown by **slowing of the pulse, increase in blood pressure, and headache.** Too much stress cannot be laid on this point. This is the time to consider operative measures. Time after time I have acted on this and operated, never uselessly.

To continue now the effect of a compression force on the brain. Let us take, for example, a localized hæmorrhage between the dura and the bone (middle meningeal artery). To make room, some of the cerebro-spinal fluid is squeezed from the skull, passing down the spinal canal and through the various basal foramina. Next, as the pressure of the extravasation increases, the veins of the brain are compressed in the immediate vicinity of the pressure area. The local venous circulation is affected, the venous escape is impeded until a condition of actual local venous stasis is reached, evidenced clinically by headache, general excitability and restlessness, and, more especially, by localized twitchings of the parts supplied by the area affected—occasionally by general convulsions. To the naked eye, the compressed region would be highly engorged with venous blood, of a darker colour than normal, with considerable dilatation of surrounding cortical veins and œdema of the tissues.

The external pressure still increasing, the pressure rises to that of the arterial capillaries, which become compressed in their turn, the brain now assuming locally a white or bloodless appearance. Beyond this white area, however, the pressure is not quite so high, merely equal to that of the veins. The more distal regions, therefore, are now in a state of venous stasis. The locally anæmic area becomes paralysed, so far as functions are concerned. This process will go on and spread to the surrounding brain so long as the vital bulbar centres permit of life.

The changes, as described, are supratentorial and largely local in their effects, but the sensitive bulbar centres are also affected at the earliest stages. The pressure effects are then transmitted with very great rapidity. A slight degree of venous engorgement there exercises a marked effect, stimulating the vaso-motor and other centres. In the earlier stages of compression, therefore, the vaso-motor centre sends out additional impulses, raising the blood pressure and slowing the pulse rate. Respiration also becomes deep and noisy, perhaps stertorous. Medullary venous engorgement passing on to medullary anæmia, the bulbar centres gradually become paralysed, the blood pressure falls steadily, the pulse increases rapidly in rate and diminishes in volume, and respiration becomes Cheyne-Stokes in character. During the development of these local and bulbar symptoms the general increase of intracranial pressure is evidenced by progressive paralysis of both mind and body—unconsciousness and general paralysis.

Irritation of the Brain

From a clinical point of view, the condition of the patient is as follows : he lies curled up in bed, with the head half-buried under the clothes and covered by the arms, the lower extremities fully flexed. He is extremely irritable and intolerant of examination, conversation, &c., complaining of violent headache, especially referred to the frontal region. He is most intolerant of light (photophobia). The pupils are equal and contracted. The blood pressure is rather above the normal ; the pulse full, moderately rapid, but of good volume. The temperature is raised.

The pathology of this condition is definite. Surface contusion of the brain, a thin film of blood spread widely over the cortex in the meshes of the pia-arachnoid or a more extensive hæmorrhage in the subdural space, a few surface lacerations and perhaps some punctate hæmorrhages in the subcortical tissues. These surface lesions exercise just sufficient pressure to bring about that degree of venous congestion, even venous stasis, of the cortical vessels which results in increased excitability of the cortex. This accounts for the general attitude of irritability. The general increase of intracranial pressure accompanying the lesion accounts for the headache. If the surface hæmorrhage is rather more excessive, more especially when diffused in the subdural space, there may be some slight rigidity, even twitchings, of the extremities and face on the contralateral side of the body, with corresponding exaggeration of reflexes.

The more important **symptoms** observed in **concussion, irritation,** and **compression** are arranged in a tabular form, for the sake of simplicity (see p. 66).

These are the general symptoms observed in head injuries. In the surgery of war, however, it would appear that **pure concussion and pure compression are seldom observed in their complete typical picture. Concussion symptoms are paramount, but blended with those of cerebral Irritation.** Thus the patient shows most of the typical symptoms of concussion, but presents at the same time some irritative symptoms —restlessness, twitchings, convulsions. The patient may be quite unconscious, with equal and contracted pupils, with flaccid paralysis of the greater part of the body, *but* showing periods of restlessness and with twitchings of the unparalysed parts, sometimes even with occasional general convulsions.

Under suitable conditions, the **shock symptoms** may abate, and, after a few hours, the surgeon will be able to appreciate more fully what remains and what new factors develop. In other words, he will be able

SYMPTOMS, GENERAL

	Concussion (depression stage).	*Irritation.*	*Compression (developed stage).*
Position, &c.	Lies unconscious, in a state of general flaccid paralysis.	Lies curled up, in a position of general flexion. Conscious but irritable.	Lies unconscious, in a state of general flaccid paralysis, *or* with rigidity of certain extremities.
General appearance	Pale skin, moist.	Flushed and hot.	Flushed, turgid face, hot.
Temperature	Markedly subnormal.	Raised to 101°–102°.	Raised and steadily rising in fatal cases to 104°–106°.
Pulse	Accelerated in rate and small in volume.	Accelerated and full.	Slow (40–60) and full.
Blood pressure	Low (50–100 mm.).	Raised (130–160).	Raised (150–250).
Respiration	Shallow.	More or less normal.	Slowed, noisy, stertorous.
Pupils	Equal, contracted in mild cases, dilated in serious.	Equal and contracted.	Equal and contracted or unequal.
Reflexes	Absent.	Present, slightly exaggerated.	Absent.
Micturition	Passes urine involuntarily.	Normal.	Retention common.

to see (1) whether concussion symptoms remain predominant (severe brain injury and bad prognosis); (2) whether irritative symptoms become marked (brain laceration, &c.); (3) whether compression develops (intracranial hæmorrhage).

The **symptoms aiding in the localization of the brain lesion** vary according to the part involved. **Frontal region.** All experimental investigations and clinical evidence tend to show that the frontal lobes are closely connected with all the higher faculties of man—moral and intellectual. According also to some investigations, these faculties are more dependent on the integrity of the left frontal lobe. From previous experience, this was my opinion also. However, from the various cases of frontal lesion that have come under my observation, I have become more sceptical with respect to the functions of the frontal lobes. Cases have come under my care in which fragments of bone have been driven deeply into the left frontal lobe, all highly infective, and removed with some destruction of the brain substance. At the present time none of these cases has shown any mental deterioration. What the after-effects may be remains to be seen. In any case, injuries of this region are amongst the most favourable of all brain lesions. The most remarkable recoveries may take place. Laceration of the inferior aspect will probably destroy the olfactory bulb and its connexions, with consequent loss of the power of smell (anosmia).

Temporo-sphenoidal lobe. This region of the brain possesses no important recognized functions, and considerable lesions may take place without the patient suffering any harmful effects.

Precentral or Rolandic areas. This is the motor area of the brain. **Destruction** of this region produces paralysis with loss of reflexes, whilst **irritation** from pressure results in twitchings or convulsions, on the contralateral side of the body, of the parts supplied by the area involved, perhaps in the development of fits of the Jacksonian type. These **Jacksonian fits** differ from the ordinary epileptiform variety (1) in that they commence by twitchings of the parts supplied by the motor area which is most directly related to the compression force; (2) that the fits spread to other regions but *only* in direct accordance with the general arrangement of the cortical centres. Thus, a fit arising from irritation of the left cortical face centre and producing fits of the right side of the face must, if spreading to other centres, next involve the left upper extremity cortical region with consequent twitchings of the right arm—it cannot jump over that area and involve any other region; (3) that the patient may not lose consciousness during the development and progress of the fit; and (4) the fit may not be followed by any paralysis of the parts primarily involved.

Paralysis, the result of laceration of the Rolandic region, is *permanent*, and followed at a later date by spasticity and rigidity of the parts supplied by the area destroyed, with corresponding exaggeration of reflexes. **Time alone will determine, however, the degree of paralysis that will ultimately persist,** for the lacerated area is surrounded by a region of venous engorgement and œdema, and, in the event of the patient's recovery, the region first paralysed may diminish sensibly in degree.

The Speech areas. The four areas concerned with the power of speech are situated as shown in Fig. 5, two motor (speaking and writing) and two sensory (hearing and seeing), all situated on the left side of the brain in normal right-handed individuals. Of these areas the most important is the motor 'speech' area of Broca. Any of these four regions may be injured by bullet, hæmorrhage, &c., with a consequent upset in the whole mechanism of speech. In the motor type of aphasia the patient knows what he wants to say but cannot put his thoughts into words or writing. In the sensory type, the opposite is the case. It is stated that loss of speech from injury to the left side of the brain may be compensated by a development of power on the opposite side of the brain. It is very doubtful, however, whether such an occurrence is possible.

Post-central or post-Rolandic area. This region of the cortex is regarded as responsible for tactile sensation, the areas presenting the same general arrangement as in the pre-Rolandic motor region—leg, arm, face from above downwards. Destruction of this region results in anæsthesia of the parts supplied. The anæsthetic areas, however, are seldom very regular and definite in their distribution, and, moreover, there is a considerable possibility of recovery.

Occipital region. From the point of view of vision, lesions of this region possess a special importance.

Extensive destruction of the occipital poles, more especially when the mesial aspect is involved, result in **homonymous hemianopia.** In addition, the close relation of this region of the brain to the medullary centres renders the prognosis exceedingly grave. The importance of this region of the brain, from the point of view of vision, is shown in the figure on p. 23.

Cerebellum. The great majority of cerebellar injuries are immediately fatal. In the event of recovery the patient will evidence the loss of cerebellar function by ataxia, inco-ordination of movement, together with ipsolateral paralysis and contralateral paresis. Injuries of the cerebellar chamber are the most fatal of all head injuries.

Treatment. Immediate: If occasion permits, the hair should be clipped around the region affected, the wound washed and painted over with iodine, then protected with first-aid dressings and bandaged. The patient is transferred to the nearest hospital where a proper investigation of the case can be carried out—not an exhaustive process, and, with the exclusion of the more scientific data of the case, sufficient facts can quickly be deduced as to whether operative measures are required or not. The nature of the wound (e.g. the obvious comminution of the bone), the general condition of the patient, the depth of unconsciousness, and other symptoms, will enable the surgeon to arrive at an immediate conclusion as to whether operation is to be conducted at once or postponed. Such a decision on the part of the surgeon will be arrived at with greater precision if he approaches the case with the preconceived idea that all head cases demand immediate operation, the general condition of the patient allowing of such treatment.

If time and conditions permit, it is of advantage that the eyes should be examined for papillœdema (such a condition indicating increased intracranial pressure), and that lumbar puncture should be carried out with the object of seeing if there is any free blood in the cerebro-spinal fluid.

Such data, however, sink into insignificance when the local conditions are such as to demand immediate rectification. The fact that the patient has a compound comminuted fracture of the skull is surely sufficient to necessitate operation, presuming again that the patient is fit for operation at all. The following points may be put forward in favour of such immediate or early treatment.

(1) Because practically all head wounds are infected and all of them must be thoroughly cleansed under an anæsthetic.

(2) Because it is quite impossible to determine the extent of the injury unless the wound is fully exposed.

(3) Because an osseous injury is the rule—lesions limited to the scalp are possible but quite exceptional.

(4) Because the skull is almost always comminuted and because the various fragments of bone are most likely driven through the dura into the brain.

(5) Because all these indriven fragments of bone are infective.

(6) Because infection of the brain and meninges is

the grave danger, against which the whole efforts of the surgeon should be conducted.

(7) Because the surgeon has to consider, not only the immediate chances of life and death, but also to weigh the various pros and cons in regard to the future prospects. The patient might recover with a bullet in his brain, but the ultimate history of such cases is not encouraging. It is not creditable to surgery if a patient lives with a fragment of bone in his frontal lobe and remains more or less a lunatic for the rest of his life. The removal of such foreign bodies is of course associated with some risk, but is worth undertaking, from all points of view.

The **time at which any operation should be conducted** is a far more difficult matter—a question on which there is some divergence of opinion. Hasty and ill-conducted operations, ill-conducted by want of proper appliances, &c., are not likely to meet with any very favourable results. Under such circumstances, in spite of obvious risk, the ultimate result may be more favourable if operation is postponed for a day or so until more favourable surroundings can be attained. In some cases, also, when no urgent symptoms supervene, when, for example, the wound is comparatively clean and there are no immediate symptoms of compression, &c., operation may be postponed, the opportunity being seized to cleanse the wound further—shaving the scalp, painting it over frequently with iodine, and applying dressings wrung out in 1 in 40 carbolic, saline solution, &c.

This rather more expectant attitude, if the symptoms permit of the same, presents another advantage in that the early concussion or shock symptoms may abate, with the secondary development of more definite and more localizing symptoms, such as may be of assistance for the conduction of planned operative measures.

Again, the question of **X-rays.** By early conduction of operation, both circumstances and time may not allow of their application, and the surgeon may be deprived of this most valuable aid. The presence of fragments of bone, their position and number, the existence of a bullet and the position of the bullet, are all of the utmost interest and importance to the surgeon. He is a wise man who will await the assistance and verdict of the X-ray colleague, if circumstances permit.

Still, with all these points in view, with all these indications against immediate operation, the final conclusion is this—the **general advantages of immediate operation outweigh all other considerations,** provided that the operation can be carried out in the most correct manner, with all suitable appliances, and that the surgeon has sufficient knowledge of these operations to know when to stop. More harm is done by doing too much than too little.

The above paragraph indicates what one may designate the ideal condition, for, even with insufficient appliances, such as are used at a fully-equipped hospital, lives may be saved by immediate operation. For example, Major Sherran operated at the field dressing station within a very *few minutes* of the infliction of the wound by trephining and washing out the extravasated blood, thus relieving the pressure and saving the patient's life. Such a course may not be often possible of application, but it shows what can be done on the spur of the moment and with simple apparatus.

The operation. The general technique for all operations on the skull is fully described in Chapter VIII. The shock resulting from a properly conducted operation is not very severe, but some advantage may be attained by the administration, half an hour previous to the anæsthetic, of a quarter-grain of morphia and one-hundredth of atropine. The patient is anæsthetized, the head completely shaved, dried and painted with acetone and iodine. The protective gauze covering is then applied and the scalp tourniquet, Makkas' clips or other appliance, to lessen, so far as is possible, the loss of blood (see Chap. VIII).

The scalp flap should always be framed so as to allow of the most free exposure of the affected region. It is not possible to foretell the extent of the injury, and every allowance must be made for the extension of the operative field in any required direction.

Previous to the formation of the scalp flap, it is advisable to pay attention to the aperture of entry of the bullet (and of that of exit if such should exist). The edges, when especially ragged, are cut away; otherwise, they are painted with pure carbolic acid and then dried.

The scalp flap is then turned down, not including the pericranium, the local conditions investigated, further procedures being carried out according to requirements.

Thus (1) **if there is a fracture of the vault without apparent depression,** and in the complete absence of any definite symptoms pointing to increased intracranial pressure, a careful search is made for a foreign body beneath the scalp, the wound thoroughly cleansed with iodine, and the flap approximated again, with the provision of the freest possible drainage, split rubber tube at the more convenient points. Direct drainage is far more satisfactory in its results than all oblique varieties. The tube, therefore, should not be too long and too oblique in direction.

Dry dressings may be applied, but the probable infectivity of the wound necessitates daily dressings, the tube being shortened each time and removed, in favourable cases, within two or three days. In the event of suppuration, whether stitch or general, fomentations should be used, wrung out in normal saline solution, applied several times during the twenty-four hours. As the wound cleans up, dry dressings can be utilized. The stitches are taken out at the end of a week or ten days.

(2) **If there is a fracture of the vault, without depression but with symptoms suggestive of intracranial pressure** (slow pulse, high blood pressure, &c.), the trephine must be applied. All evidence tends to show that the internal table of the skull is likely to be depressed and comminuted, with or without injury to dura mater and meningeal vessels, and with

consequent danger of meningeal infection. Consequently, the trephine is applied, the disk elevated, and the conditions investigated. Comminuted fragments of internal table are removed, for which purpose it is almost always necessary to cut away more of the external table. The craniectomy forceps are utilized and the nibbling process carried out, in the required directions, until the surgeon is satisfied that all depressions of internal table are rectified. The wound is then cleansed and suitable drainage supplied as before. Experience shows that, however septic the wound, any meningeal complication is unlikely so long as the drainage is efficient, and so long as the dura is uninjured.

If **fragments of bone are projecting into the dura mater,** they are seized and withdrawn with all gentleness—the dura mater should not be lacerated further. The membrane is then painted with iodine and free drainage permitted. The prognosis is more grave than in the preceding case. The brain may become infected, with the subsequent development of meningeal infection, hernia cerebri, &c.

(3) **If the dura is torn and fragments of bone driven into the brain,** the rent in the membrane is enlarged and the fragments withdrawn. In this class, X-rays are especially valuable, enabling one to determine the number of bone fragments and their exact position with regard to the wound of the vault. The extent to which the dura should be slit up (on a director) varies according to circumstances. If the fragments are large, with much indriving, and

if the compression symptoms are urgent, the incision must be free—with error on the side of freedom. The intracranial pressure is definitely raised, the brain is brought into close contact with the enclosing walls and, **with free drainage,** any meningeal infection is unlikely. On the other hand, if the brain becomes infected, the removal of the fragments will be followed by the development of a hernia of the brain, in which case a free opening in the dura will allow of the best chances of recovery (see Hernia Cerebri).

To find the various osseous fragments driven into the brain, the probe should always be used in preference to the finger. The removal of the fragments will lead to quite sufficient damage to the brain: **there is not the slightest need to add to the degree of cortical destruction by searching with the finger**—a coarse and crude method.

(4) **Fractures with depression of bone, perhaps with comminution.** If trephining is required, the pin of the trephine is applied at such a distance from the seat of depression as will obviate pressure on the depressed region. These depressed fragments are already driven into or through the dura, and further pressure will only increase the damage. In addition, the fragments may be pressing on the dura in relation to one of the sinuses of the brain, in which case further damage will add considerably to the difficulties of the case.

When no trephining is required, by reason of the general comminution, the depressed portions of bone are picked away, small portions of bone being discarded whilst those which retain some scalp or pericranial connexion are merely turned aside to be replaced at the termination of the operation. A very free exposure of the underlying dura is required, it being practically certain that the membrane has been

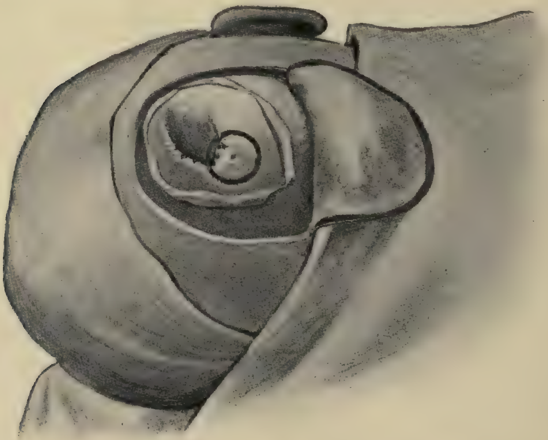


FIG. 17. THE ELEVATION OF A DEPRESSED FRACTURE. The trephine circle includes the outer portion of the depressed area.

lacerated and that portions of bone have been driven into the brain—all such fragments must be removed with the usual care.

(5) **Fractures complicated by injury to, and hæmorrhage from, the venous sinuses of the brain.** These are perhaps the most difficult cases that come under the care of the surgeon. During the process of

trephining, or more often whilst removing depressed fragments of bone, there is a sudden escape of blood, so profuse that all view of the operative field is lost. This hæmorrhage is more alarming than dangerous. If the conditions suggest that such a hæmorrhage is likely to occur, it is advisable to so enlarge the aperture in the skull, previous to attempting to remove the depressed fragments, as to expose not less than half an inch on the course of the sinus on either side of the suspected region. Whether such a course is feasible or not, if bleeding does occur, there are several methods by means of which the control may be effected. The introduction of gauze between the bone and the dura, on either side of the seat of hæmorrhage, with the object of compressing the sinus, will so reduce the blood flow that the operator is enabled to see the rent in the sinus from which the blood flows. This rent, under favourable circumstances, may be sewn up, after which the gauze plugs are withdrawn. If the tear in the sinus wall is of such a nature that it cannot be sewn up, the gauze plugs already in position between the bone and the sinus wall are left *in situ*, the rest of the wound being lightly packed. After 48 hours all plugs are removed, when the bleeding should have been arrested. If not, the wound is again lightly packed for another 24 hours. The dressing is conducted under an anæsthetic. Re-dressings are carried out daily.

If the rent in the sinus is quite small, the application of pressure, hot saline solution (temperature

115 degrees Fahrenheit), or muscle graft may suffice. In the last-named method, a small piece of tissue is snipped from the temporal or nuchal muscles, spread out on the scissors blade, squeezed lightly and then applied to the bleeding point. It may adhere and stop the bleeding.

In the more uncontrollable cases, the open mouth of the sinus must be compressed with gauze, firmly bandaged in position. The plug is allowed to remain for 48 hours.

Theoretically, these wounds of the sinuses ought to have very serious results, for the sinus receives numerous venous tributaries from the cortex, and thrombosis of the sinus ought to lead to venous congestion and œdema of the regions drained. Practically, there is so free a collateral circulation that the brain accommodates itself apparently to the new form of circulation.

(6) **Fractures complicated by the presence of a foreign body.** If occasion permits, it is obvious that the presence of depressed fragments of bone, and more especially of a foreign body, should be investigated by X-rays and the most careful localization carried out. The bullet itself may be anywhere within the skull, and fragments of shell are possible in any position. The presence of the bullet may be investigated with the aid of the telephone-probe. This instrument, however, is of no great value in these operations. If there is a foreign body within the brain, as felt by ordinary probe, it has to be removed, if possible, whether bone or bullet.

If, in a penetrating wound, the bullet is situated at some distant point, it may not be capable of removal at the first operation, in which case it may be left till the most accurate localization enables the surgeon to embark on a second operation, perhaps conducted over some entirely different region of the skull. These bullets, except under unusual circumstances, ought to be removed. They irritate the brain and tend, sooner or later, to result in abscess formation, cerebritis, &c.

CHAPTER IV

INTRACRANIAL HÆMORRHAGES

Middle meningeal hæmorrhage. The middle meningeal artery enters the middle fossa of the skull through the foramen spinosum, soon dividing into two main terminal branches, anterior and posterior, the former the larger vessel. This anterior branch runs for about two inches of its course through a canal in the bone, immediately posterior to the orbit. With this exception, the main artery and all its branches lie embedded in the outer wall of the dura mater, in such a manner that if the vessel is torn and blood extravasated, this blood occupies wholly the extra-dural space, between the dura and the bone.

The dura is firmly attached to the bone, more especially along any projections of vault and base. Consequently, in the event of laceration of the artery, the first effect of the effusion is to strip the dura from the bone, a result not accomplished in a moment. Therefore, after the receipt of the injury, whether bullet or other form of external violence, some time must elapse before the clot can have reached dimensions sufficing to produce compression of the brain, whether local or general. This period of time is known as the **lucid interval,** so called because the patient may feel comparatively well from between the time of the accident till the development of local or general compression.

This lucid interval, practically pathognomonic of an extra-dural hæmorrhage, varies in duration from a few minutes to a few hours, according to the extent of the hæmorrhage.

This **typical lucid interval** is not present in any other type of intracranial injury. Consequently, if invariably present and of any definite duration, from the point of view of diagnosis its existence would be of the utmost value. Unfortunately, any injury serious enough to damage the temporal bone, producing comminution of the bone and laceration of the artery, is usually accompanied by damage to the brain, with the blurring of all typical symptoms and with the additional advent of prolonged concussion, irritation, or compression of the brain. Still, even in such obscure cases, there may be *some* lucid interval, of however short duration—a feature of the greatest aid to the diagnosis of the condition. Careful inquiry should always be made as to its presence or absence.

Next, so far as further symptoms are concerned, the artery in its upward course between the dura and the bone overlies the pre-Rolandic or motor strip. Consequently, if the hæmorrhage is of any considerable size, it will compress the cortex, first producing a stage of surface venous congestion, stasis and œdema—with consequent irritation of the brain—and then, as the pressure increases, a state of arterial capillary anæmia with consequent paralysis of any area supplied by the part affected.

Local signs of middle meningeal hæmorrhage. (1) **Temporal wound or hæmatoma.** A wound of the temporal region will indicate the probability of a fracture of the bones entering into the formation of the temporal fossa. A temporal hæmatoma is also of frequent occurrence. The temporal fossa being fissured or comminuted, blood from the meningeal region escapes through the cracks in the bone to extravasate widely throughout the substance of the temporal muscle. The hæmatoma, therefore, is restrained by the attachments of that muscle, limited above by the temporal ridge and spreading downwards. The hæmatoma may pulsate, and pressure applied to the swelling increases the depth of unconsciousness and may induce fits on the contralateral side of the body.

(2) **Bleeding from the ear.** The temporal fracture is usually complicated by extension to the base, with some comminution of the roof of the middle ear (tegmen tympani). Such a lesion being present, a safety-valve is provided whereby blood from the meningeal region escapes into the middle ear and thence externally through the ruptured membrana tympani, and so from the external ear. The bleeding may be profuse and any attempt at its control (by plugging the external auditory meatus) adds to the degree of cerebral compression.

Symptoms. Brain effects. These are both **general** and **local,** general as the result of the general increase of intracranial pressure on the cortical and medullary centres, local by reason of the local compression.

General symptoms. First of all there is a period of **concussion,** varying in extent from a few minutes to an hour or so, seldom longer. Then a period of **apparent recovery**, sometimes so complete that the patient is enabled to walk home, and even carry out his ordinary vocations for a short time, though complaining of some headache and dizziness. During this **lucid interval,** the hæmorrhage is slowly but surely increasing in size, till it reaches such dimensions as to exercise compression symptoms, at first of a rather vague and general character, later of a more definite type. Thus, if the patient be carefully observed, it will be noticed that though he may answer questions promptly in the earlier stages, yet that his answers gradually become less ready and that his general perceptive powers slowly diminish. He becomes more heavy and drowsy, gradually but surely passing into a state of stupor and finally coma. During these **general** changes, the effect of the increasing pressure is equally marked so far as the medullary centres are concerned, the venous congestion acting as a stimulation. The vaso-motor centre sends out additional impulses raising the blood pressure, the pulse is slow and laboured, the respiration deep and noisy. Still later, the medullary engorgement gives place to capillary anæmia, with paralysis of the centres, evidenced by an increasing rapidity of the pulse rate, steady fall of blood pressure, and Cheyne-Stokes respiration.

Temperature changes are very constant. In the earlier stages the temperature rises from that of concussion (subnormal) to about 101 or 102 degrees Fahrenheit, and then rises rapidly till death ensues. These temperature changes are not proportionate to the size and extent of the blood extravasation. They result from an increasing paralysis of the heat-regulating centres.

The medullary changes may be tabulated as follows :

Early general compression.	**Late general compression.**
Practically unconscious.	Totally unconscious.
Full pulse, slow.	Feeble, rapid pulse.
High blood pressure.	Low blood pressure.
Stertorous respiration.	Cheyne-Stokes respiration.
Temperature raised.	Rapid rise.

Local symptoms. The extravasation, though external to the dura mater, exercises definite local effects. As previously stated, the artery runs upwards in direct relation to the pre-Rolandic or motor areas. Consequently, the hæmorrhage exerts special effects on that region. Again, the hæmorrhage is situated, in the great majority of cases, rather low down, and, in consequence, the lower cortical centres are first involved, producing (1) irritation by venous engorgement and (2) paralysis through capillary anæmia. The position of the clot in relation to the motor centres causes the face centre to be first involved, with twitchings, and then paralysis, of the contralateral side of the face. Then the arm centre is compressed, with twitchings and finally paralysis.

The centres for the lower extremity are not often included in the process, for the clot will have already

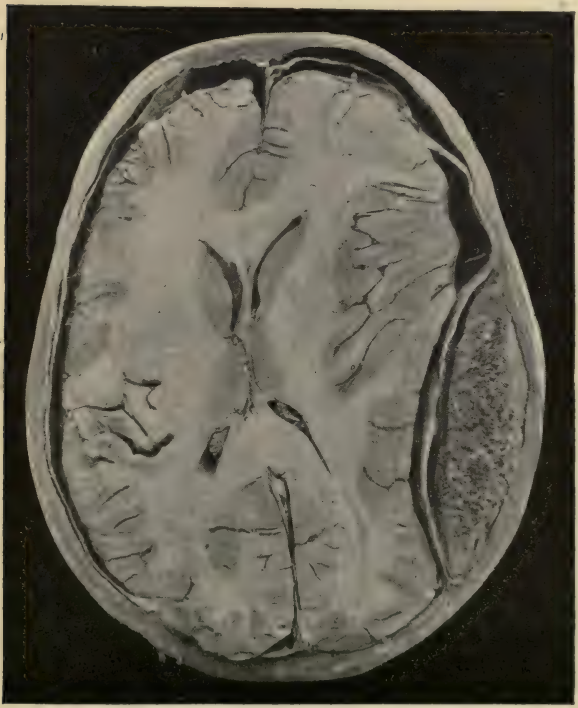


FIG. 18. TO ILLUSTRATE COMPRESSION OF THE BRAIN. As produced by an extra-dural hæmorrhage from the posterior branch of the middle meningeal artery.

attained such dimensions as to terminate the life of the patient by general compression effects.

From these facts it is obvious that a typical middle meningeal hæmorrhage gives origin to the following broad line of symptoms :

Period of unconsciousness.
Period of apparent recovery (the lucid interval).
Period of compression (local and general).
Period of collapse.

Treatment. The clot must be evacuated and the bleeding controlled. A scalp flap is framed, suited to the conditions of the case but of good size. This flap includes the temporal fascia and muscle. When turned down, it can be seen whether actual trephining is required or not. If the bone is merely fissured, the trephine is applied close to where the line of the fracture crosses the line of the artery (see Chap. I). The disk is removed. If the bone is extensively fractured, all small fragments are removed, all the larger which retain some attachment to the overlying tissues are turned aside. In no case is it advisable to immerse the fragments removed in saline solution for the purpose of replacement. The wound is almost necessarily septic and the return of the fragments is consequently contra-indicated.

This removal of bone will allow of adequate room in which to work. If trephining has been conducted, the aperture is enlarged with the craniectomy forceps in the direction in which the bleeding seems to come, probably towards the base of the skull.

The blood extravasation, partly clot but mainly fluid, is washed away with a stream of hot saline solution. This is best carried out by means of a catheter attached to the end of the irrigator, the catheter being freely introduced between the bone and the dura. The bleeding may be troublesome. For its control the following methods are available :

(1) The bleeding-points may be seized with catch-forceps and tied.

(2) The bleeding-points may be underrun with an intestinal needle on either side of the site of injury, and tied.

(3) Bleeding from the canal course of the artery may be controlled by plugging the canal with wax, wooden match, silk, wool, &c.

(4) The region from which the bleeding seems to come may be plugged with strips of gauze.

(5) The foramen spinosum may be rapidly identified, stripping away the dura, and the foramen plugged with a wooden match.

(6) The external carotid artery may be ligatured in the neck.

Of these various methods, the second is the method of choice.

The bleeding being arrested, the scalp flap is replaced, with the provision of free drainage. Tubes, in favourable cases, may be removed in forty-eight hours. Generally, however, it is advisable to shorten the tube day by day till the wound is practically healed.

Subdural hæmorrhage. Hæmorrhage occurring between the dura and the brain, in the subdural space, differs in many particulars from the extra-dural type. The blood is not confined to any limited region, but is diffused readily throughout the whole of the subdural space. For example, if originating in the right supratentorial space, it remains there most marked, but also spreads to the opposite chamber, and, more especially, tends to gravitate to the subtentorial region and base of the brain.

It is to be expected, therefore, that the injury would not be followed by any *lucid interval*, but that, instead, there might be some *latent period* during which the patient is restless, complains of headache, &c., but is not really suffering from symptoms of true cerebral irritation nor of compression. The existence of this latent period is dependent on the rapidity with which the blood is poured out. The blood is derived from torn cortical vessels (mainly veins) or from the venous sinuses of the brain. In any case, the effusion is venous in origin and of low compressing force. Consequently, in **subdural hæmorrhage from cortical veins** the latent period is likely to be present. In **hæmorrhages from the larger venous sinuses** it is of very short duration or absent.

To a large extent, also, the rapidity of bleeding is responsible for the **two groups of symptoms.** Thus, in **hæmorrhage arising from cortical veins** there is a definite latent period, not infrequently enduring two or three weeks, and during this time the patient is excitable, restless, sleeps badly, and complains of constant headache. Slight twitchings may be observed on the contralateral side of the body. The latent period terminates by the rather rapid development of symptoms pointing to both local and general brain compression. *Local* symptoms: paresis, followed by paralysis, on the contralateral side of the body. *General* symptoms: progressive loss of consciousness, slow full pulse of high pressure, and stertorous respiration.

Secondly, **when the hæmorrhage is derived from venous sinuses** (lateral, superior, longitudinal, and cavernous) the latent period is very short, even absent altogether, and the patient soon passes into a condition of general cerebral compression—quite unconscious, flaccid extremities, slow full pulse of high volume, stertorous respiration, merging later into the paralytic stage with its rapid feeble pulse, Cheyne-Stokes respiration, &c.

In both cases a rather important point in the diagnosis of such mainly unilateral hæmorrhages is the **temperature on the two sides of the body.** There is usually a very marked difference between the two, one to three degrees lower on the paralysed side than on the side at which the brain is injured or the blood clot situated. Thus, in a case recently under my care, the left side of the brain was lacerated and the patient was speechless, and hemiplegic on the right side. The temperature in the left axilla was 101° and in the right 99·4°. In another case the temperature was 99° on the lacerated side and 97° on the hemiplegic.

In both cases **lumbar puncture** is of great value, the withdrawal of blood-stained fluid at high pressure confirming the diagnosis.

Treatment. When localizing symptoms are present, the sooner the skull is opened the better. The clot is so extensive that no difficulty will be experienced in finding it. The opening should be made low down over the cortical areas or, preferably, at a slightly lower level over the temporo-sphenoidal lobe. The trephine opening is enlarged as required, and the dura inspected. If appearing plum-coloured and pulsating feebly, it is opened, and the fluid blood evacuated with the aid of a catheter attached to the nozzle of an irrigator. The dura is left open and a drainage tube inserted through the scalp flap for forty-eight hours or so.

This operative treatment may be aided by lumbar puncture, carried out daily for two or three days.

The patient is usually exceedingly irritable, for which morphia may be required.

When **compression symptoms are rapid in their development** there are two courses to pursue: (1) to rely on repeated lumbar puncture; and (2) to carry out a decompression. The latter course is advisable. The decompression is conducted in the temporal region (see subtemporal decompression, p. 101), preferably on the opposite side to that at which the blow was received—brain is lacerated more commonly by contrecoup than by direct injury. In the event of doubt as to the side injured, the decompression should be carried out on the right side of the brain, thus avoiding all question of injuring the lowly situated speech area of Broca.

All operative measures may be assisted by lumbar puncture, and in some cases free venesection seems to have done good.

CHAPTER V

FRACTURES OF THE BASE OF THE SKULL

Fractures of the base. In discussing fractures of the base, as seen in time of war, it must be understood that basic fractures as produced by bullet differ very markedly from those fractures of the base which are seen with such frequency in ordinary civil practice. In penetrating and perforating bullet wounds of the skull, aperture of entry and exit being well above the level of the base, there is no great tendency for the fracture to extend to the base. And even if it does extend in that direction, the ordinary transbasic lines pursued by the fracture are of infrequent occurrence. The fracture will cross the basic fossa quite regardless of weak lines, sutures, obstacles, &c. Also, when the bullet impinges at the level of the base or passes through the base, having entered at the eye, cheek, &c., the local destruction is so extensive that ordinary rules and ordinary symptoms are rather in abeyance.

Still, there are many injuries to the head received other than at the firing line—there are many basic fractures seen on the lines of communication, &c. Consequently an account of the average basic fracture is required.

Symptoms resulting from a fractured base.

Whether the fracture involves the anterior, middle, or posterior fossa of the skull, the following groups of symptoms require consideration :

The escape of blood from ear, nose, mouth, &c.

The escape of cerebro-spinal fluid.

The escape of brain matter.

The escape of air from the air sinuses.

The involvement of the cranial nerves at their exit from the skull.

Anterior Fossa

Escape of Blood. Beneath the conjunctiva, usually making its appearance at the outer canthus of the eye, spreading rapidly inwards, perhaps completely surrounding the cornea. In milder cases, in place of subconjunctival hæmorrhage, there may be mere œdema.

Behind the globe, in the tissues of the orbit. The eye is bulged forwards (proptosis).

Into the tissues of the lids, producing a ‘ black eye ’.

Into the retina, with dimness of vision and diminution of the visual fields.

From the nose and mouth, as a result of comminution of the cribriform plate of the ethmoid. This thin plate of bone is perforated by numerous ethmoidal arteries and is readily shattered, with the consequent escape of blood down the nose and into the posterior nares. Some blood may be swallowed and vomited later.

Escape of cerebro-spinal fluid from the nose and mouth, owing to extensive comminution of the cribriform plate, together with tearing of the dural and arachnoid coats of the various olfactory nerves that pierce the plate. This fluid may escape shortly after the injury, but more commonly after twenty-four hours or so. The discharge may be profuse. When not mixed with blood, cerebro-spinal fluid is clear, colourless, of a specific gravity of not more than 1·005. It is rich in chlorides, contains little or no albumen, and has a reducing substance. This reducing substance, however, is only found in the earlier stages of the discharge. The original quantity of cerebro-spinal fluid soon becomes exhausted, the discharge now becoming a mere serous fluid, from transudation from the veins of the brain (see Chap. I).

Escape of brain matter from the nose, the result of extensive laceration of the cribriform plate, together with tearing of the overlying membranes of the brain and severe laceration, practical pulping, of the frontal lobes. The increased intracranial pressure forces the broken-down brain substance through the ethmoid and so into the nose.

Escape of air from the frontal sinus. If the external wall of the frontal sinus be fractured, on the patient sneezing, &c., air may be forced out through the cracks. The air may remain localized, giving origin to a **pneumatocele,** a smooth, air-containing swelling situated immediately over the sinus. Sometimes the air escapes widely into the subcutaneous tissues, ' bunging up ' the eye and spreading on to the face (**surgical emphysema**).

Involvement of cranial nerves. The various ocular nerves may be involved, either actually torn or compressed by bone in the region of the sphenoidal fissure, or their functions impaired by reason of diffuse hæmorrhage into the orbital tissues. The following nerves are involved :

(1) Third nerve, with paralysis of the ocular muscles supplied, with squints, dilated and fixed pupil.

(2) Fourth nerve, with paralysis of the superior oblique.

(3) Sixth nerve, with paralysis of the external rectus.

(4) Ophthalmic division of the fifth nerve, with consequent anæsthesia or neuralgia along the course and distribution of the supraorbital and supratrochlear nerves ; also anæsthesia of cornea and conjunctiva.

Middle Fossa

Escape of blood : from the nose and mouth. This results from fracture, often extensive comminution, of the body of the sphenoid and sphenoidal sinus. The bleeding is very profuse if the cavernous sinuses are torn, these sinuses lying on either side of the sphenoidal body.

From the ear, due to the extension of the fracture along the roof of the external ear into the middle ear, with laceration of the membrana tympani. Blood may trickle in a steady stream from the external meatus.

Escape of cerebro-spinal fluid from the ear. When the membrane is torn and the petrous fracture extensive, the dural and arachnoid prolongations along the seventh nerve may be lacerated with the consequent escape of cerebro-spinal fluid through the torn tympanic membrane.

Escape of brain matter from the ear. This implies most extensive comminution of the petrous bone, laceration of the overlying dura and pulping of that part of the temporo-sphenoidal lobe which overlies the tegmen, or roof, of the middle ear.

Escape of air from the mastoid antrum. This implies a fracture extending into the antrum and the escape of air into the overlying tissues on coughing, sneezing, &c.

Involvement of nerves. Both the seventh and eighth nerves, owing to their complicated course through the petrous bone, are especially liable to injury. The degree of paralysis and deafness is proportionate to the extent of the lesion. Deafness is more likely to be permanent than facial paralysis, from which a complete recovery is frequently observed.

The sixth nerve is also often involved, its close relationship to the posterior clinoid processes rendering it liable to inclusion in all fractures involving the sphenoidal region.

The nerves passing through the sphenoidal fissure —third, fourth, ophthalmic division of fifth and sixth —may be paralysed through pressure of bone fragments, direct injury and compression of blood clot.

Posterior Fossa

Escape of blood.—There is no special orifice for the escape of blood, but there may be a considerable effusion into the scalp tissues of the occipital and cerebellar regions, leading to bogginess and subsequent ecchymosis.

There are no means of escape for either cerebro-spinal fluid or brain matter.

Escape of air. Through the involvement of the mastoid antrum, air may escape, in the manner described under middle fossa fractures.

Involvement of nerves. The seventh and eighth nerves may be included as in middle fossa fractures. Peculiar to this fossa are the glosso-pharyngeal, vagus, and spinal accessory (9, 10, and 11), these three nerves passing through the jugular foramen. Involvement of the 9th and 10th leads to dyspnœa and dysphagia, perhaps sudden death.

The hypoglossal (anterior condyloid foramen) may be injured by bullet wound with consequent paralysis of the tongue muscles.

These are the more special symptoms seen in basic fractures. With no further damage, basic fractures would not present any very high mortality. The question of life and death hinges almost entirely on the presence or absence of intracranial complication, more especially damage to the brain. Besides the special symptoms enumerated in dealing with each fossa of the base, there are usually present the more general symptoms of concussion, irritation, and compression, all referable to some intracranial lesion. These conditions are treated in Chapter III.

Treatment. Special. Of hæmorrhage from the nose. This is seldom sufficiently profuse to cause any anxiety. It ceases spontaneously unless involving any large vessel, in which case death usually results early. The nasal cavities should **not be syringed,** for fear of driving infection through the cribriform plate into the anterior fossa of the skull. The anterior nares may be *lightly* plugged if necessary.

Of hæmorrhage from the ear. Again the bleeding is not serious, and the meatus may be *lightly* plugged. Again also *no syringing* ought to be carried out for fear of infecting the meninges.

In both cases, the plugs ought to be removed and renewed not less than once every twelve hours.

Of cerebro-spinal fluid from the ear. Again the ear is lightly plugged. The discharge usually ceases spontaneously within forty-eight hours.

Of air-escape from the sinuses. When the collection is localized, no special treatment is required. If the patient abstains from sneezing, &c., the fissure in the frontal sinus will close, and the air become absorbed. If increasing, a small incision is made down to the bone so as to allow of the direct escape of air. When the air escapes widely over the eyes, face, and scalp, a similar incision must be made. Air already in the tissues soon becomes absorbed.

Of the nerves involved. Time alone will show what degree of improvement is possible. Recovery from facial paralysis will be facilitated by suitable electro-therapeutic treatment.

General treatment (for Concussion, Irritation, and Compression)

Concussion. Mild type. During the depression stage, warm blankets, hot-water bottles, &c., assist the reaction. During reaction, the body should be lightly covered and mild sedatives may be given. If restlessness is a marked feature, morphia is most useful.

Severe type. The patient remaining obstinately in the collapse stage, the prognosis is serious. The foot of the bed should be raised and stimulants given —pituitary, strychnine, &c. Rectal or intravenous infusions are often efficacious, but, in each case, they must be administered with caution, the prolonged concussion being dependent, in most cases, on serious cerebral lesion. The pulse and temperature should be taken every hour and, so soon as any sign of reaction develops, the infusions should be stopped, and the further progress of the case watched.

Irritation. The patient must be kept in a quiet room, darkened. In this condition, morphia is of the greatest use. Calomel, grs. 5 to 10, or other aperient, is administered per mouth. The bladder must not be forgotten, although retention is unusual. Headache may be relieved by aspirin, phenacetin, or the phenacetin, aspirin and caffeine mixture ($\bar{a}\bar{a}$ grs. 5), repeated every four hours.

In both concussion and irritation, the patient should be kept in hospital not less than three weeks, then being transferred to convalescent home. No work should be undertaken under a period of three months.

Compression. Earlier stages. The patient must be decompressed, either by venesection, lumbar puncture, or decompression operation. Venesection, though scoffed at by some, undoubtedly induces a favourable result in the milder cases, half to one pint of blood being withdrawn from the median cephalic or basilic veins, the exact amount being determined by reference to the pulse rate and arterial pressure of the patient. Lumbar puncture brings about good results in some cases, the process being repeated as often as occasion demands.

In the more serious cases, operative measures must be considered. Of the various methods, subtemporal decompression gives the best results. This operation is based on the following grounds: (1) it is conducted over the temporo-sphenoidal lobe of the brain, one of the so-called 'silent' areas of the brain, and a region frequently lacerated; (2) it allows of the exposure of the middle meningeal territory, a region often involved though the typical symptoms may not be existent; (3) it is conducted beneath the fibres of the temporal muscle, this muscle restraining any hernial protrusion of the temporo-sphenoidal lobe that may develop as a result of the operation. The general technique of this **subtemporal decompression** is as follows: the incision, involving skin and subcutaneous tissue, and including the superficial temporal artery, starts immediately above and behind the external angular process, on the right side of the head (for choice), curves along the temporal crest and then downwards in front of the ear to the tragus. This

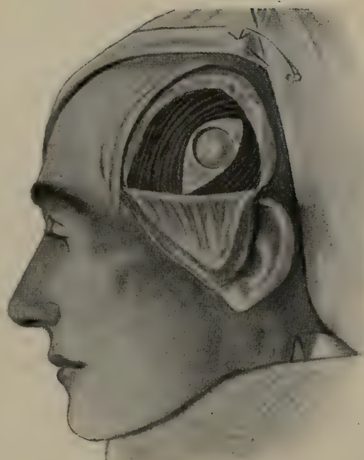


FIG. 19. INTERMUSCULO-TEMPORAL CEREBRAL DECOMPRESSION. *First stage.* The scalp and temporal fascia have been turned down as separate flaps. The temporal muscle is divided in the direction of its fibres, and the exposed bone trephined.

FIG. 20. INTERMUSCULO-TEMPORAL CEREBRAL DECOMPRESSION. *Second stage.* The temporal muscle is retracted on either side, the bone has been freely cut away, and the bulging dura mater crucially incised.

FIG. 21. INTERMUSCULO-TEMPORAL CEREBRAL DECOMPRESSION. *Third stage.* The dural flaps are turned aside, exposing the lacerated temporo-sphenoidal lobe. A rubber drainage-tube has been inserted beneath the lacerated brain, lying on the floor of the middle fossa of the skull and brought to the surface through the scalp flap.

FIG. 22. INTERMUSCULO-TEMPORAL CEREBRAL DECOMPRESSION. *Fourth stage.* The temporal muscle-fibres have been approximated, and the temporal fascia reunited in part. The drainage tube is seen to emerge through fascia and scalp.

flap is turned down, exposing the temporal fascia. This fascia is turned down also as a flap, to the level of the zygoma. The exposed temporal muscle is now split in the direction of its fibres, from top to bottom, in the middle of the field. The muscle being widely retracted on either side, the bone is trephined, and after the removal of the disk and the separation of the dura mater, the bone is freely cut away in the temporal fossa, forwards, backwards, and especially downwards towards the base of the skull. In the upward direction, one is more limited, for fear of encroaching on the lower motor areas and, on the left side, on the motor strip of Broca. The gap made should be as large as circumstances permit. The dura mater, now exposed, is freely incised, any meningeal vessels that cross the line of section being underrun and ligatured. This opening of the dura mater allows of the escape of blood and cerebro-spinal fluid and permits of the outward bulging of the temporo-sphenoidal lobe, as much as is required. The dural flaps are allowed to remain open, the temporal muscle is approximated, the fascia sewn back into position (so far as circumstances permit), and the scalp replaced.

This operation, in suitable cases, gives excellent results.

Later stages of compression. This is a very serious condition, and although decompression measures are justifiable, yet poor results are obtained both by minor measures of decompression and by decompressive operations.

The **prognosis** of fractures of the base is shown by the fact that about 50 per cent cases die. Of those that recover, probably not more than half regain their full faculties.

When the fracture of the base is associated with a fracture of the vault, more especially when that vault fracture is dependent on bullet wound, the prognosis is bad. Probably but few cases recover.

CHAPTER VI

INFECTIONS OF THE BRAIN AND MENINGES

HERNIA CEREBRI. MENINGITIS. ABSCESS OF THE BRAIN

In all head injuries, whether operative treatment has been carried out or not, the three most important complications occurring during the after-progress of the case are **hernia cerebri, meningitis,** and **abscess of the brain.** Of these, hernia cerebri is the most common, many cases of this nature having already been seen, some directly resulting from operations carried out in France, others developing later.

There are two varieties of **hernia cerebri,** the aseptic form and the septic or ordinary type.

Aseptic hernia cerebri. 'In consequence of the explosive effect of a bullet on the normal brain, if portions of the bones of a skull are carried away, then the rise of intracranial pressure will cause a certain amount of extrusion of brain substance. Owing to hæmorrhage in the brain substance produced by the explosive effect, such a hernia tends to remain just as long as there is increased intracranial pressure' (Horsley). It is argued that, in a clean wound, there may be such venous engorgement and cerebro-spinal œdema as will raise the general intracranial pressure to such an extent that brain substance, more or less normal, will protrude.

Septic hernia of the brain. When the dura mater is opened in the normal individual, there is not the slightest tendency for the brain to protrude through the membranous opening. On the other hand, if the intracranial pressure be increased, by tumour, hæmorrhage, &c., the brain will at once protrude through the opening, and will continue to do so until such an amount of brain matter has been extruded as will bring the intracranial pressure again to the normal condition. This is the result aimed at in ordinary decompressions, whether temporal, cerebellar, or in other situations. In such cases, however, the protruding brain is covered with some scalp constituents and the wound is clean. To such brain bulgings, the term **hernial protrusion** is best applied. During such operations, also, if the opening in the bone and the dura be of considerable size, the brain will not bulge too suddenly, the pia and arachnoid membranes will not be ruptured, the brain pressure is fully compensated, and, the pia and arachnoid being whole, there is but little tendency for the brain to become adherent to the scalp.

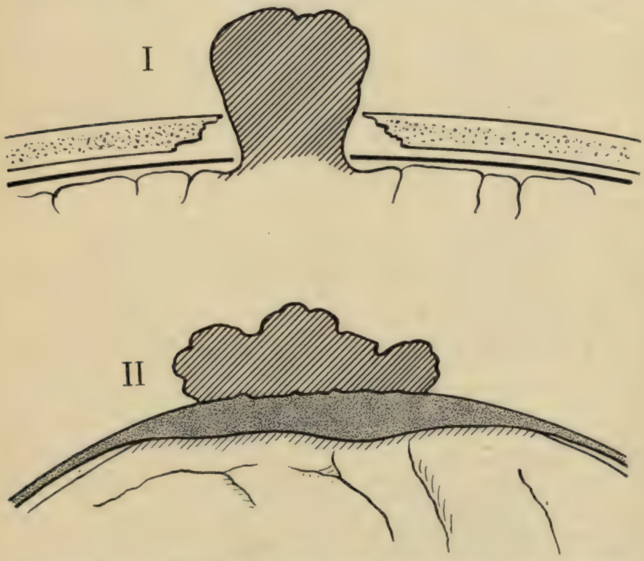
In some cases, no doubt, the pia-arachnoid ruptures and surface vessels burst, but the bulging brain can still be covered with scalp. There is some risk of formation of adhesions, but the condition is still one of hernial protrusion, not hernia cerebri.

On the other hand, if the bone be extensively destroyed (or removed by operation), if the dura be widely lacerated (or freely opened), and if the brain be under considerable pressure by reason of **contained fragments of bone, bullet, &c., especially when such foreign bodies are infective,** then the injured brain will bulge outwardly, to an extent proportionate to the increased pressure, and will appear on the surface. This is the condition known as **hernia of the brain,** (cerebri and cerebelli), the brain appearing on the surface as a red, granular mass, pulsating freely, slightly constricted at its base, and with some surface suppuration. The application of pressure leads to some diminution in size, but any more forcible attempts at such reduction in size results in headache, unconsciousness, and perhaps in the development of fits.

There is, however, a third condition to be described, **fungus** of the brain—an even more serious condition.

In such conditions the brain herniates through a *small* opening in the dura mater, the constriction at the neck of the hernia interfering with the venous return, both from the herniated mass and in the immediate neighbourhood of the neck of the hernia. In consequence, both the hernia itself and the neighbouring brain will be in a state of venous engorgement and cerebro-spinal œdema, with consequent increase in pressure. The protrusion, therefore, will tend to continue to increase in size and more and more brain matter will become extruded. A vicious circle is established, the fungus increases—perhaps to such an extent that a great mass of brain substance may be extruded on to the surface, with terrible organic disturbances.

If now there is added to this condition the existence within the brain of fragments of bone or bullet, all infective, the tendency to herniation is all the greater.



FIGS. 23 and 24. TO ILLUSTRATE THE CONDITIONS PRESENT IN 'FUNGUS CEREBRI'. (1) Showing the relation of the fungus to bone and dura. (2) Showing the relation of the fungus to dura and brain.

These facts suffice to explain the frequency with which we see hernia of the brain in this present war.

Fungus of the brain appears on the surface as a moist, cauliflower-like mass, readily bleeding and freely discharging sero-purulent fluid. Pulsation is present but not nearly so free and forcible as in hernia of the brain. The constriction at the neck of the mass acts in damping pulsation much in the same way as constriction at the neck of a hernial sac interferes with impulse on coughing. The application of pressure to the hernia has but little effect in the reduction of the mass. It should be added that the increase in size of the protrusion is always due in part to the development of granulation tissue, the growth of which is exceedingly free on the brain substance.

If, now, a section could be taken through the fungus, deep into the underlying cortex, it would be seen (1) that the narrow neck is more or less strangulated by the edges of the dural opening; (2) that the subjacent brain is softer than normal, discoloured and congested, œdematous, and without any defined margins, shading off in the rest of the brain; and (3) that the horn of the ventricular cavity of the brain which is in closest relation to the protrusion is expanded in that direction, and, in the more serious cases, that it actually passes without the limits of the skull so as to occupy the central portion of the hernia itself, even bursting at the apex of the protrusion, discharging a copious stream of cerebro-spinal fluid.

Fortunately, both in hernia and fungus of the brain, meningeal infection is of lesser frequency than might be imagined. The 'swollen' brain lies in close contact with the dura, obliterating the subdural space, and adhesions form with great rapidity between the other membranes, affording fairly efficient barrier to meningeal spread and infection.

Symptoms. If the hernia involves the 'silent' areas of the brain, frontal and temporo-sphenoidal lobes, there may be no special urgent symptoms, provided that the degree of protrusion compensates fully for the increased intracranial pressure. In fact, in many cases, the patient feels perfectly well.

If the protrusion includes the motor cortex, the results are disastrous—spastic paralysis of the contralateral side of the body, with aphasia in the event of the left side of the brain being involved, with exaggerated reflexes, Babinski, and, later on, secondary contractures.

If the occipital cortex protrudes, the patient will suffer from hemianopia, &c. (see Fig. 7).

In addition, as a general rule, hernia of the brain is associated with some mental symptoms—lethargy, headache, cerebral irritation, or actual insanity—varying in degree according to the size of the hernia and its physiological importance.

Treatment.

Class 1. Of hernia of the brain, purposely produced, fully compensative and not increasing.

Class 2. Of hernia of the brain, resulting from injury or from operation, non-compensative and tending to increase.

Class 3. Of fungus of the brain.

In class 1, the desired result has been attained, the protrusion compensating for the previous increase of intracranial pressure. All that remains to be done is to keep the exposed brain clean and dry, favouring by rest its recession and closing over. It is to be hoped that the protrusion will diminish in size, perhaps actually receding entirely, as the degree of venous congestion and cerebro-spinal œdema lessens. In the event of the more favourable result, the skin will grow in from the sides, finally covering in the protrusion, after which some form of curved metal cap will have to be worn to protect the region from the effect of accidental blows, &c. If the overgrowth of skin is slow or imperfect, the surface may be skin-grafted (after Thiersch's method).

Recession may be aided by periodic *lumbar puncture* and, in the more intractable cases, by a *contra-lateral decompression* (see p. 114).

To keep the hernia 'dry and clean', the region must be first cleansed, with washings of hydrogen peroxide and fomentations, renewed every two hours. Fomentations of saline solution give the best results. When clean, fomentations are discarded and dry dressings applied, together with some antiseptic powder, e. g. boric powder. These dressings are renewed daily, the old dressing being washed off, the hernia dried, painted over with iodine and fresh gauze applied. The brain itself is insensitive and the daily dressings are practically painless.

If the hernia is obstinate, refusing to decrease in size, it may be painted over every third day with a 40 per cent solution of formalin, the tissue necrosing and drying up. The destruction of the protruding mass does not make the condition of the patient any worse, so far as the functions of the region are concerned. These are already destroyed, and no further bad effects can develop.

In class 2, the hernia is increasing in size after apparent adequate and deliberate opening of both dura and brain. This occurrence results by reason of the infectivity of the brain or because, in addition, there are foreign bodies in the brain, keeping up the pressure and increasing the degree of infection. Thus, a bullet in the brain, even though non-infective or of low infectivity, produces such congestion and œdema as demands further protrusion, till fully compensated, though such desirable results are not easily attained. Again, a more highly infected bullet, or fragments of bone, may result in diffuse cerebritis or localized abscess, both of which conditions produce such 'swelling' of the brain as results in an increasing protrusion. In such cases, it is obvious that complete *X-ray pictures* will be of the greatest assistance, both in determining the cause and indicating the line of treatment.

First of all, it is obvious that the exciting cause must be removed if possible, bone fragments or bullet being extracted and an abscess evacuated and drained. This being done, and a considerable protrusion remaining, the measures available are as mentioned in the previous section. The hernia may be painted with a 40 per cent solution of formalin, or with alcohol, every third day, and on the two intervening days with a 2 per cent solution of iodine in spirit. By these means the protrusion may necrose and shrivel.

The hernia may be **shaved off**, though usually growing again. Unfortunately, also, the protrusion often contains in its base the expanded and dilated horn of the lateral ventricle, and the shaving off of the protrusion will uncover that region to direct infection, in addition to permitting of the free escape of cerebro-spinal fluid. Still, I have carried out this procedure on some few occasions and I have never seen any harm result, whilst in two or three instances the ultimate result obtained by the shaving process has been quite satisfactory. The mass is cut away flush with the surface of the skull, bleeding being arrested by the immediate application of dressings and firm bandage. The wound is redressed daily. The protrusion may not redevelop and healing may take place. In one instance I shaved away the hernia three times before it quieted down and scarred over. The protruding brain is quite useless so far as its functions are concerned. There is no objection to shaving away of herniæ from that point of view.

As a last resource, there is the question of conducting a **contralateral decompression**—with the object of relieving the intracranial pressure along another line and allowing of the application of pressure and recession of the hernia. The decompression should be conducted over the opposite temporo-sphenoidal lobe, for, if that lobe does bulge outwardly, there are no after ill-effects. Thus, in a right-sided hernia, the operation should be a left subtemporal decompression (for the operation, see p. 101).

In any case, the decompression opening must be free, both as regards dura and bone. After the operation, more pressure is applied to the hernia than previously. The 'window' allows protrusion in another place and assists in the recession of the hernia, after which it may scar over, or be grafted after Thiersch's method.

This operation of contralateral decompression was first carried out by me in a case at St. Bartholomew's, reported in the hospital reports in 1912. The child had a large hernia of the brain on the left side. It was shaved away three times and leaked fluid from the descending horn of the lateral ventricle, the opening being visible on the surface. All measures failed and the child appeared to be dying, when I thought of, and carried out, a compensatory subtemporal decompression on the opposite side. The result was marvellous—in three weeks the hernia had receded and was healing over. Curiously enough, also, the subtemporal protrusion receded in direct proportion.

Anyhow, this method is worth consideration in bad cases.

The ultimate result in all these cases will hinge largely on the cortical region involved. If possessing known function, that function will be permanently impaired or lost. Consequently, the more serious results are seen after herniæ of the Rolandic and occipital regions. With frontal or temporo-sphenoidal herniæ, the patient may get quite well.

In **class 3, fungus of the brain,** the protrusion is gripped at its neck and continually tends to increase in size. Such being the case, the cause must be tackled. The condition is desperate and I think the following course must be pursued—the hernia shaved away, the margins of the dural opening defined, and that membrane freely slit up. There is, of course, the danger of infecting the meninges, but so far as my experience goes such a result is of unlikely occurrence, with due precautions. After shaving the hernia away the whole region is sponged with iodine and, here and there, a director insinuated for a short distance beneath the dura, and the membrane slit up freely in several directions. The increased opening ought to relieve the strangulation. The future care and progress of the case is indicated in the preceding section.

Meningitis. Fortunately, in the surgery of war, meningitis is of less frequent occurrence than might be anticipated. This happy result is due to three causes: (1) the recognition of the fact that nearly all head injuries require immediate operative treatment, with the consequent provision of free drainage; (2) the general rise of intracranial pressure which causes the brain to swell and obliterate the meningeal spaces; and (3) the rapid development of adhesions between the membranes, preventing the spread of infection.

Symptoms. The symptoms arising in meningitis are, as a rule, rapid in their development and typical in their character. There is first of all a **period of excitation** and then a **period of depression,** a stage of acute toxæmia succeeded by one of toxic poisoning, terminating, in the great majority of cases, fatally within one to five days.

Period of excitation—(*a*) **General symptoms.** The patient is very excitable and restless, throwing himself about, sometimes maniacal and almost incapable of control. The face is flushed, perhaps cyanosed, the temperature high (often an initial rigor), the pulse full, bounding, and accelerated. Headache is intense, with considerable exacerbations. Vomiting may occur and there is well-marked vaso-motor disturbance, tache cérébrale, &c.

(*b*) **Localizing symptoms.** These vary according to whether the cortex or base of the brain is primarily involved. In the case of the *cortex*, the excitation results in twitchings, cramps, and convulsions of the regions supplied by the area involved. Often the convulsions are general and most violent, the patient crying out in agony. When the affection is *basal* in spread, the cranial nerves are involved and some of the following group of symptoms present:

Optic neuritis or acute papillœdema (optic nerve).

Myosis and squints (third, fourth, and sixth nerves).

Trismus (fifth nerve).

Facial paralysis (seventh nerve).

Deafness (eighth nerve).

Dysphagia, dyspnœa, and cardiac irregularity (ninth and tenth nerves).

Rigidity of the head and neck, retraction (upper spinal nerves).

Opisthotonos (spinal nerves).

In the second stage, stage of depression, the cortex becomes paralysed, with paralysis of the parts affected, the patient becoming unconscious, and the paralytic effects of the poison on the bulbar centres are evidenced by rapid fall in blood pressure, increasing acceleration of pulse rate, and Cheyne-Stokes respiration.

At the **very earliest suggestion of meningeal symptoms, lumbar puncture** should be carried out, and the fluid examined cytologically and bacteriologically. The fluid withdrawn will be at high pressure and with a degree of turbidity according to the extent of spinal extension.

Prognosis. This is most grave. In the earlier stages, free drainage, local and spinal, may cut the process short and a cure may be obtained. When once fully developed, it is doubtful whether a case ever recovers.

Treatment. From the point of view of prophylaxis, in addition to the provision of free drainage for every infected wound of the head, the patient may be treated with urotropin, ten grains three times a day. This drug is excreted in part by the cerebro-spinal fluid, and it possesses a decided inhibitory action on the growth of organisms.

In the treatment of meningitis itself, some benefit may be obtained in the earlier stages by repeated lumbar puncture and by the provision of adequate drainage at the seat of the wound.

The infective agent should be investigated and cultured, suitable vaccine treatment being adopted.

Adequate drainage ought to have been provided. If not, measures should be carried out at once with that object in view. The wound must be opened up freely, thoroughly cleansed, and bone cut away as required. If the dura is not obviously opened, free incisions should be made and all left open, packed with gauze soaked in iodine and dressed every two hours. The operation may reveal a localized abscess, one, however, which is commencing to leak into the meninges. In such cases, a favourable result may be obtained.

Abscess of the Brain. Abscesses of the brain are usually related to some foreign body embedded in the brain—bullet, fragments of bone, &c. Such infected bodies may lead to a localized abscess, but the leucocytic barrier is seldom sufficient to erect an enclosing wall to the infection, such as occurs in abscess formation secondary to otitis media, frontal suppuration, &c. The brain abscesses of war are more often after the nature of meningo-encephalitis (when the abscess is superficial) and encephalitis (when deeply placed). In these cases there is a small area of suppuration around the foreign body, with acute inflammation and marked leucocytosis around, fading away gradually towards normal tissues.

Abscesses are sometimes found in relation to a hernia of the brain.

The only situation in which a localized abscess is of likely occurrence, similar in type to those seen in civil practice, is in the frontal lobe, the result of prolonged sinusitis, the foreign body being locked up within the frontal antrum.

Symptoms. The symptoms closely resemble those previously mentioned under meningitis—sudden rise of temperature with rigor, violent headache, intense cerebral excitement, full bounding pulse and high blood pressure. This state of excitation is again succeeded by that of depression. Some indefinite localizing symptoms may be evident—twitchings of face or extremities on the contralateral side.

Lumbar puncture should be carried out, and repeated leucocytic counts. Examination of the eyes may show a papillœdema or optic neuritis, usually the more advanced on the affected side; X-rays also will reveal the situation of the foreign body, with perhaps around it an area of lessened density.

When diagnosed, free exposure and drainage offer the only hope. The prognosis is not so good as in abscess of the brain of civil practice, by reason of the very inefficient encapsulation.

CHAPTER VII

WOUNDS OF SPECIAL REGIONS

MASTOID PROCESS. ORBITAL REGION. JAWS.

Special injuries

1. **Wounds of the mastoid region.** The prominence of the mastoid process renders this portion of the skull unusually prone to injury, whether from blunted weapons, spent or glancing bullet, or as part and parcel of a fracture of the base of the skull. Penetrating and perforating wounds of this region are dealt with elsewhere.

However produced, the results are sufficiently distinctive :

Hæmorrhage from the ear.
Facial paralysis.
Deafness.
Surgical emphysema or pneumatocele.
Otitis media.

These special symptoms are, of course, in addition to the more general symptoms that may arise in connexion with intracranial lesions, such as laceration of the lateral sinus, contusion of the brain, &c. These more general symptoms (concussion, irritation, and compression) may be absent, or of so transient a nature as to be disregarded, attention being paid to the more special symptoms arising.

Hæmorrhage from the ear. Bleeding may be rather profuse, but, if occasion permits, it will be seen that the blood is derived from the lacerated lining of the external ear and from the middle ear, trickling through the torn membrana tympani. The ear should not be syringed, merely cleansed, with iodine if the patient is unconscious or will stand the momentary inconvenience, otherwise cleaned out with pellets of wool soaked in some antiseptic, and then lightly plugged with gauze. Wool should be applied and a firm bandage. The plugging should be renewed at least once in every twenty-four hours.

Facial paralysis. The paralysis is of the complete type, involving all the muscles of the face. As a general rule, it is permanent, being dependent on actual destruction of the nerve in its descending course through the aqueductus Fallopii. The immediate paralysis, however, is dependent in part on concussion of the nerve, and a definite prognosis cannot be made till some weeks have elapsed.

Deafness also is usually complete and permanent. It is due in part to the destruction of the membrana tympani, but more especially to concussion of the nerve and hæmorrhage into the internal ear.

Surgical emphysema and pneumatocele. The mastoid process may be injured in such a way that the antrum is included, air escaping, on coughing or sneezing, into the superficial tissues. If this air remains localized to the mastoid region, a **pneumatocele** is said to exist. This is a soft, air-containing swelling, situated over the mastoid, slightly reducible, and increasing in size when the patient strains. If the air escapes widely throughout the tissues of the side of the head and neck, the condition is one of **surgical emphysema.** Both swellings show on palpation the peculiar crepitations of air-containing tumours.

No special treatment is required so long as the air does not tend to spread widely throughout the tissues of the head and neck. In such an event, an incision carried down to the region of the fracture will allow of the direct escape of the air and the cure of the condition.

The fissure in the bone will soon close in and prevent the further escape of air.

Otitis media. In the event of the wound being septic (a probability), the infection may spread to the middle ear and mastoid antrum, otitis media resulting. This condition is treated after ordinary principles: cleansing of the wound, syringing of the ear, and, if matters do not mend, by the carrying out of the ordinary mastoid operation.

The mastoid process may be detached from the rest of the skull by the force of the blow, but seldom completely by reason of the numerous muscles obtaining attachment in this region. Operative measures may be required to secure the re-attachment of the process.

2. **Wounds of the orbital region.** Leaving out of question the effect of the injury on the globe itself (discussed in another volume), injuries of the orbital region are sufficiently serious. In the first place, all fractures of the strong orbital walls must necessarily

result in serious damage to neighbouring more delicate regions through extension of the fracture. For example, when the blow is applied to the supra-orbital region, the fracture may extend (1) to the frontal sinus, (2) to the anterior fossa of the skull—cribriform and orbital plates, (3) to the ethmo-sphenoidal region, (4) to the walls of the orbit itself, and (5) to the optic foramen, the apex of the orbital cavity.

It is clear, therefore, that the lesion may be serious and the symptoms diverse. In addition, as another source of danger, the probable infective condition of the wound and the presence of a foreign body, also infected, will open up the possibility of meningeal and brain infection—the special dangers of the region involved. Furthermore, the blow will, in all probability, result in some damage to the brain, depicted clinically by concussion, irritation, or compression of the brain.

(1) **When the fracture extends into the frontal sinus,** with or without the presence of a foreign body, the immediate results are hæmorrhage from the nose, surgical emphysema or pneumatocele. Later on, after two or three days, often much later, suppuration may take place in the sinus, with the attendant danger of spread of infection to the meninges (meningitis), to the frontal lobe (frontal abscess), and to the cavernous sinus (infective thrombosis).

(2) **When the fracture extends to the anterior fossa of the skull,** the special symptoms are hæmorrhage from the nose, discharge of cerebro-spinal fluid from

the nose (after about twelve to twenty-four hours), and the discharge of brain matter from the nose (see fractures of the base, p. 93). Here again special danger arises in connexion with the spread of infection through the cribriform plate of the ethmoid to the meninges and inferior aspect of the frontal lobe.

(3) **When the fracture extends to the ethmo-sphenoidal region,** the immediate results are hæmorrhage from the nose, and, soon afterwards, the discharge of pus, the infection having spread to the ethmo-sphenoidal cells and sinus. The patient then suffers from the troubles of chronic suppuration in that region, with the attendant dangers of necrosis of the base of the skull, prolonged suppuration, meningitis and frontal lobe abscess.

(4) **When the suppuration comminutes the walls of the orbital cavity,** the immediate effects are as follows:

Proptosis, from bleeding into the retro-ocular tissues. Squints and myosis, from paralysis of the ocular nerves. Subconjunctival hæmorrhage, from the spread of extravasated blood beneath the conjunctiva. Palpebral hæmorrhage, from the spread of blood into the tissues of both lids and surrounding tissues. Anæsthesia or neuralgia along the course and distribution of the first division of the fifth nerve.

(5) **When the fracture involves the optic foramen,** the immediate symptom is blindness of the affected eye. This may be permanent or not according to the nature of the injury. It may be due to concussion of the optic nerve, in which case a more or less complete recovery *may* take place. If due to hæmorrhage

between the nerve and its dural sheath, there is, in addition to considerable loss of vision, a high degree of papillœdema (see p. 22). This may slowly subside, leaving, however, in most cases, considerable loss of the peripheral fields of vision. If the nerve be torn or compressed by bone fragments, often the case, vision in the affected eye is permanently destroyed.

In all cases, also, there is some chance of the formation of an arterio-venous communication between the internal carotid artery and the cavernous sinus—orbital aneurysm.

In wounds of this region, these special complications sink into comparative insignificance compared with the main predominant danger of meningeal and brain infection. From the point of view of treatment, therefore, every effort must be made to cleanse and drain the wound, thus minimizing the risk. Urotropin, in ten-grain doses, may be given, from the point of view of prophylaxis.

3. Wounds of the jaws

(1) **Upper jaw.** Whether the superior maxilla be notched, perforated, or comminuted, the wounds do well on the whole. The antra are likely to be involved, often perforated, and filled with blood, but secondary suppurations (antral empyema) are not frequent. In the South African War, secondary suppuration was almost unknown. The infectivity of wounds in general, in this war, may render it necessary to give a less sanguine prognosis.

When the **alveolar border** is involved, teeth may be loosened or blown away and considerable necrosis of the jaw may take place.

When the **upper part of the maxilla** is involved, the symptoms are more marked, including paralysis of, or neuralgia along the course and distribution of, the infra-orbital nerve, hæmorrhage into the tissues of the orbit and surrounding regions, and hæmorrhage into the globe and orbital tissues, inclusive of bleeding between the optic nerve and its dural sheath.

The infra-orbital nerve is likely to be torn, with consequent anæsthesia of the parts normally supplied by the nerve—face, teeth, gums. In some cases, the injury is succeeded by persistent neuralgia—paroxysmal and tending to spread centrally, involving later the other branches of the fifth nerve—a condition simulating true trigeminal neuralgia, and demanding perhaps a similar line of treatment, alcohol injections into the trunk of the nerve at its emergence from the skull through the foramen rotundum.

Treatment is directed towards the cleansing of the wounds and of the mouth. However comminuted, the fragments should be manipulated into position, and there retained by suitable pads and bandage. Teeth, even when loosened, should always be preserved, and, if necessary, the teeth and various fragments of the jaw may be wired together. The patient should be fed on a fluid diet, and, for the first few days, nourishment may be given by means of feeder and tube. Absolute rest and avoidance of talking are necessary. The wounds generally tend to heal rapidly. Later on, some dental apparatus may be required, both for mastication and from a cosmetic point of view—false teeth, &c.

(2) **Lower jaw.** Wounds of the lower jaw are much more serious and far more disfiguring. The bone is very dense, one of the hardest bones in the body, and extensive comminution is the rule. In addition, the attachments given by this bone to the muscles of the tongue, genio-hyoid and genio-hyoglossus, may interfere seriously with the movements of the tongue, which organ may tend to fall backwards, towards the back of the mouth.

The bullet usually perforates the region, perhaps causing a fracture of the condyloid process on the one side and comminuting the body of the jaw on the other ; perhaps comminuting the vertical ramus on the one side and passing below the jaw, through the submaxillary region, on the other. In any case, fragments of bone are likely to be driven into the mouth, and teeth may be blown away. After loose fragments and teeth have been spat out, examination will show the projection into the mouth of sharp fragments of bone, with extensive laceration of the lining mucous membrane. The inferior dental nerve will almost certainly be destroyed. If merely contused or pressed on by bone fragments, intense neuralgia will be experienced.

In the most severe cases, large portions of bone and soft parts may be blown away, leaving a gaping cavity with the tongue hanging more or less loose and powerless.

Extensive suppuration is the rule. and although the lesser injuries in this region do fairly well, there is almost invariably great thickening of the tissues, together with extension of infection to the submaxillary region, with sinus formation and abscess, great limitation of movement, difficulty in talking and eating, &c.

Also the position of the fracture may give rise to great disfigurement, and swallowing will be impaired in direct proportion to the inclusion of the genial muscles.

In spite of all forms of treatment, some remote quiet necrosis of the jaw is the rule, with prolonged suppuration, sinus formation, and purulent discharge into the mouth.

These after-results are so marked that the question arises as to whether our actual **treatment** of these cases is correct. In most cases, beyond manipulating the fractured bones into position, and endeavouring to maintain them in the correct position with bandage and dental splints, no active treatment is carried out. It is suggested that the early removal of all the smaller and looser fragments of bone would bring about better results, would result in less necrosis, less thickening, and readier opening of the jaws in general. On the whole, a middle course is preferable. In any case, the free and radical removal of *all* loose portions of bone is contra-indicated. Such fragments as project into the buccal cavity, more especially those that irritate the tongue, should be removed, if small, and smoothed off and manipulated into better position, if large. Teeth may be spliced together with fine wire. Definite plating, wiring of the jaw, and cosmetic arrangements in general, may be postponed till some future date.

The extensive suppuration that occurs in most cases demands the most free drainage of the buccal cavity, and in many cases it is necessary to make a counter-incision below the jaw, in the submaxillary region, thus preventing the extension of suppuration down the neck.

Feeding is carried out with the aid of feeder and tube.

At a later date some plastic operation may be required to improve the condition of the patient.

CHAPTER VIII

CRANIO-CEREBRAL TOPOGRAPHY AND TECHNIQUE OF OPERATIONS ON THE SKULL AND BRAIN

Cranio-Cerebral Topography

For operations on the skull and brain, after complete shaving of the head, all required landmarks can be mapped out with iodine, silver nitrate, or aniline pencil. The simplest landmarks only are required.

The **falx cerebri,** the **superior longitudinal sinus,** and the **mesial fissure** between the two halves of the cerebrum are all represented by a line drawn across the vault in the antero-posterior direction from the base of the nose (nasion) to the external occipital protuberance (inion).

The **bregma,** the junction of the coronal and sagittal sutures, is situated on this line five inches distant from the nasion ; the **lambda,** the junction of the sagittal and lambdoid sutures, lies five inches posterior to the bregma ; and the **inion** is distant three inches from the lambda.

Each lateral half of the skull can be subdivided into an upper or cerebral and a lower or cerebellar chamber by the line of the **lateral sinus,** that is to say, by the line of the attachment of the **tentorium cerebelli**, the dural partition between the cerebrum and cerebellum. This **lateral sinus** corresponds to a line, presenting a slight upward convexity, from the upper and posterior border of the mastoid process of the temporal bone to the external occipital protuberance. Operations limited to the cerebellum must be conducted wholly below this line.

In the upper of these two chambers the more important landmarks are as follows :

The fissure of Rolando.
The fissure of Sylvius.
The middle meningeal artery.

The fissure of Rolando. From the point of view of topography, the fissure of Rolando is by far the most important fissure of the brain, as it separates the motor strip in front from the sensory behind. To map out this fissure, take the midpoint between nasion and inion, and a second point half an inch posterior to the midpoint, and from this second point draw a line, in the downward and forward direction, for a distance of about four and a half inches towards the centre of the zygoma. This line represents the Rolandic fissure. It is inclined to the antero-posterior median line at an angle of $67\frac{1}{2}$ degrees.

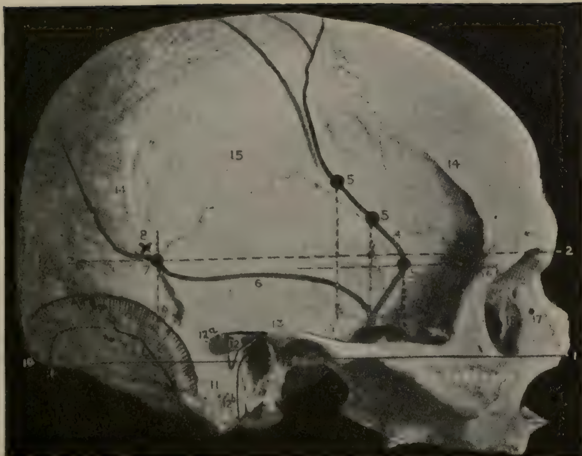
For the arrangement of the cortical motor areas, see Chap. I.

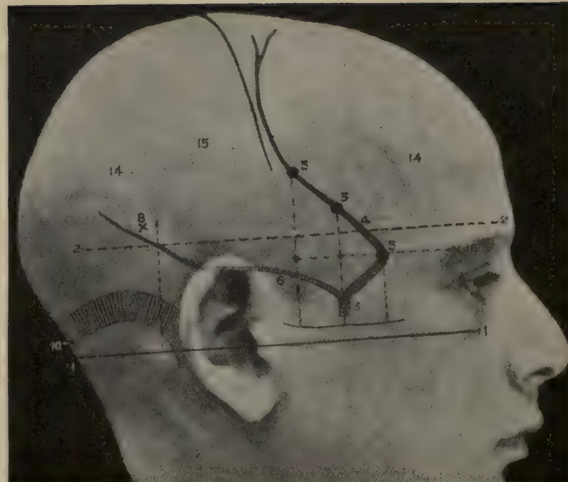
The fissure of Sylvius. This fissure separates the frontal and parietal lobes above from the temporo-sphenoidal below. To map out this fissure, first find the **Sylvian point**, the site of divergence of the three Sylvian fissures (the smaller anterior horizontal and vertical limbs and the larger posterior horizontal limb). The Sylvian point lies $1\frac{1}{4}$ inches behind the external angular frontal process, and $1\frac{1}{2}$ inches above the zygoma. From this point draw a line to a second point, three-quarters of an inch below the most prominent point of the parietal bone, the so-called 'parietal prominence'. This line represents the course and direction of the main posterior horizontal limb of the Sylvian fissure.

The small vertical limb is directed upwards from the Sylvian point for about one inch, the anterior horizontal passing directly forwards for about the same distance.

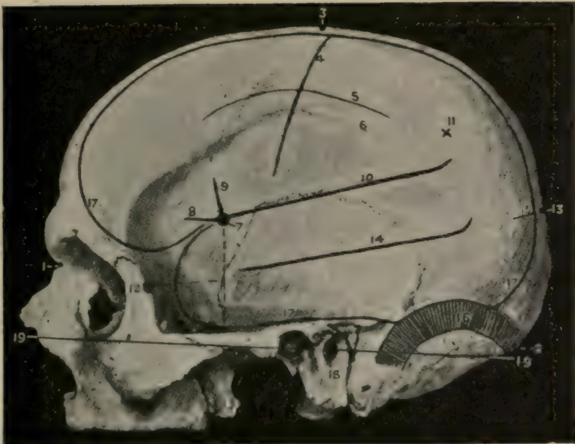
Broca's motor speech centre is situated in the angle between the two horizontal limbs. This applies to normal right-handed individuals. In left-handed people the centre usually lies on the opposite side of the brain.

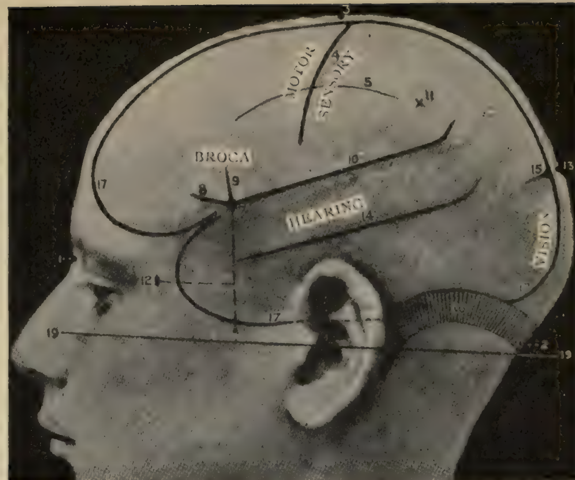
The middle meningeal artery. This vessel enters the middle fossa of the skull through the foramen spinosum, soon dividing into anterior and posterior branches. The position of the main trunk is represented by the central point of the zygoma. The larger anterior branch runs upwards towards the vertex of the skull directly over the pre-Rolandic motor strip. It may be exposed by trephining over any of the three following points: (1) 1 inch behind the external angular frontal process and 1 inch above the zygoma; (2) $1\frac{1}{2}$ inches behind and above the same points; (3) 2 inches behind and above the same points.





FIGS. 25 AND 26. CRANIO-CEREBRAL TOPOGRAPHY. 1, 1, Reid's base-line ; 2, 2, A line parallel to the above at the level of the supra-orbital margin ; 3, The middle meningeal artery ; 4, The anterior branch ; 5, 5, 5. The three sites for trephining ; 6, The posterior branch ; 7, The site for trephining ; 8, The point for trephining to reach the descending horn of the lateral ventricle ; 9, The lateral sinus ; 10, The inion ; 11, The mastoid process ; 12, Macewen's suprameatal triangle ; 12*a*, The mastoid antrum ; 12*b*, The facial nerve ; 13, The suprameatal and supramastoid crests ; 14, 14, The temporal crest ; 15, The temporal fossa ; 16, The external angular frontal process ; 17, The tendo-oculi attachment ; 18, The lachrymal groove. (*Reproduced, by the permission of Mr. H. K. Lewis, from the author's work on 'Landmarks and Surface-markings'.*)





FIGS. 27 AND 28. CRANIO-CEREBRAL TOPOGRAPHY. 1, The nasion; 2, The inion; 3, The mid-point between nasion and inion; 4, The Rolandic fissure; 5, The superior temporal crest; 6, The inferior temporal crest; 7, The Sylvian point; 8, The anterior horizontal limb of the Sylvian fissure; 9, The vertical limb of the Sylvian fissure; 10, The posterior horizontal limb of the Sylvian fissure; 11, The parietal prominence; 12, The malar tubercle; 13, The lambda; 14, The first temporo-sphenoidal sulcus; 15, The external parieto-occipital sulcus; 16, The lateral sinus; 17, 17, 17, The level of the base of the cerebrum; 18, The external auditory meatus; 19, 19, Reid's base-line. (*Reproduced, by the permission of Mr. H. K. Lewis, from the author's work on 'Landmarks and Surface-markings'.*)

The posterior branch of the artery sweeps backwards, parallel to and immediately above the zygoma.

The penetration or perforation by bullet of the side of the head makes it especially necessary to have a clear idea as to the **lower level of the brain.** In front the lower level of the brain lies flush with the supra-orbital margin, at the side of the head with the upper border of the zygoma, and behind the ear with the surface marking of the lateral sinus. The cerebellum lies wholly below the level of the lateral sinus.

The three basic fossæ. 'There is no external sign to indicate the situation of the fossæ of the brain. In general, however, it may be said that the anterior fossa extends as far back as the anterior end of the zygoma; that the middle fossa lies between this and the mastoid process, and the posterior includes all the base behind the process' (Eisendrath).

Reid's base line.—Some surgeons still work with the help of this line. It is drawn backwards from the lower border of the orbit to the middle of the external auditory meatus. When further produced, the line will be seen to fall below the level of the inion, and to lie, behind the ear, immediately below the level of the lateral sinus.

The facial nerve.—This nerve, after emerging from the stylo-mastoid foramen, curls round the condyle of the jaw and then traverses through the parotid gland. The general transparotid course of the nerve and the direction of its buccal branch may be represented by a line drawn forwards from the lobule of the ear, parallel to and below Stensen's duct. **Sten-**

sen's duct, the duct of the parotid gland, corresponds to the middle third of a line drawn from the lower border of the tragus of the ear to a point situated half-way between the ala of the nose and red line of the lip. At the anterior border of the masseter muscle the duct dips inwards, through the buccinator muscle, to open on the buccal mucous membrane, opposite the second molar tooth of the upper jaw.

The frontal air sinuses. These air sinuses occupy the space between the outer and inner tables of the skull. They are very variable in size. When well developed, they occupy the space immediately above the inner half of the supra-orbital margin.

Technique of Operations on the Skull and Brain

Position of the patient. For ordinary operations no special position is required, the patient being tilted and the head deflected to the required position. For cerebellar operations, however, the patient may have to be placed in the prone position, the shoulders supported on rests so as to allow of free inspiration.

Anæsthetic. Ether is the safer drug, administered preferably by the open method. This anæsthetic presents the disadvantage that it leads to venous congestion and consequently increases the general oozing and amount of blood lost. Chloroform, though having no such drawback, is the more dangerous, especially in operations conducted on the posterior half of the skull. A judicious combination of the two methods brings about the most satisfactory results.

It should be added that, in *cerebellar* operations, *respiratory failure* is not uncommon. Under such circumstances, it is necessary, in order to save the life of the patient, to proceed *rapidly* with the operation, making an opening in the skull. This being done, respiration usually starts spontaneously, perhaps assisted by artificial respiration.

Cleansing of the scalp. The whole head should be shaved. In operations conducted in civil practice for decompression, &c., it may be possible to limit the shaving to a certain area. In war surgery, however, such a course is inadvisable. The scalp flap in such cases must always be considerable, and the extent of the injury is unknown, necessitating perhaps formidable and extensive procedures. Hence, it is advisable to be on the safe side and to have plenty of operative room.

After shaving, the whole head is thoroughly scrubbed with soft soap and hot water, then dried, painted with acetone, and thoroughly swabbed over with a $2\frac{1}{2}$ per cent solution of iodine, care being taken not to obliterate any surface markings that may have been mapped out.

The whole head is then enveloped in '**trephining gauze**'—a large gauze sheet, about four layers thick, cut so as to allow of the envelopment of the whole head. This sheet is applied closely to the head, damped with lotion so as to adhere to the skin and, at the same time, to become sufficiently translucent to allow of the seeing of such landmarks as may have been traced.

Control of hæmorrhage from scalp vessels. The scalp is richly supplied with blood-vessels. Operations on the skull and brain usually require a large scalp flap. Consequently, unless precautions against scalp hæmorrhage are taken, the patient loses a large quantity of blood—a bad beginning to a serious operation. Also a great waste of time in clipping

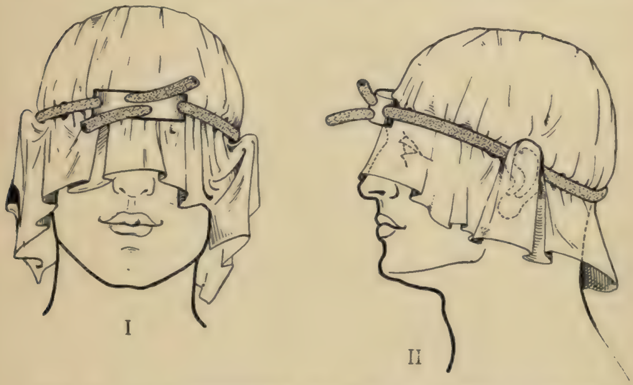


FIG. 29. TO ILLUSTRATE THE USE AND APPLICATION OF THE SCALP TOURNIQUET.

and ligaturing the vessels. The simplest and most efficacious method of preventing this bleeding is obtained by the utilization of the scalp-tourniquet. The pattern most recommended is that devised by the author. It consists of a rubber band, with a frontal metal piece through which holes are bored for the passage of the rubber. The rubber is of greater calibre than the hole through which it passes, and consequently, when tightened up, locks automatically.

The tourniquet is passed over the head, so as to lie low down over the occipital region, above the level of the ears, and low down again across the forehead. When tightened up, the following vessels are efficiently controlled: occipital, posterior auricular, temporal, frontal, and supra-orbital. When firmly and suitably adjusted, there is practically no bleeding during the formation of the scalp flap, and the surgeon can at once proceed to the more serious stages of the operation, the trephining. The advantages of this procedure are sufficiently obvious, saving of time and saving of the patient's blood—and, as shock after head operations is more or less directly proportionate to the amount of blood lost, the scalp-tourniquet should be used whenever possible. In cerebellar operations, and in subtemporal decompressions, the tourniquet cannot be utilized—it is in the way of the operative field. In such operations, and in others also, **Makkas' clamps** are of great use. These clamps are made with varied curves, suited to the various curvatures of the skull. The spring is of such strength that a special key-opener is required. A small incision is made through the scalp to the bone, and the visceral blade introduced and passed along the surface of the bone, in the subaponeurotic space, till the clamp is ' home '. The spring is then released and the clamp left *in situ*, grasping between its two blades the whole thickness of the scalp, including its vessels. As many clamps are utilized as will completely enclose the area which it is desired to expose. At the end of the operation the key-opener is applied and the clamps withdrawn. The scalp incisions should be closed with one stitch.

The scalp flap. The scalp flap is framed according to requirements, but it must always be considerable.

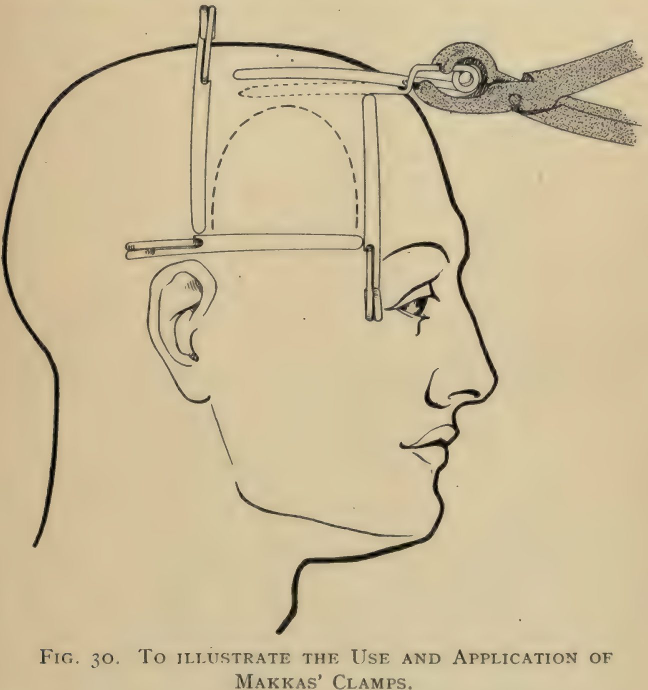


FIG. 30. TO ILLUSTRATE THE USE AND APPLICATION OF MAKKAS' CLAMPS.

The extent of the injury is unknown, and it is necessary to have a wide field of exposure. The scalp wound is almost invariably exceedingly septic. Consequently, previous to the application of gauze and scalp-tourniquet, this wound must be attended to. Foul, dirt-ingrained edges are cut away freely, and the margins of the wound lightly touched up with pure carbolic and dried ; and the whole region then painted over with iodine.

The scalp flap does not include the pericranium, this membrane being stripped aside according to requirements, according to the amount of bone it is desired to expose.

Trephining. Trephining may be conducted after many methods. Speed is gained—often at the expense of safety—by utilizing the methods conducted with the aid of burrs, electric and otherwise. Taking all in all, there is nothing that beats the ordinary hand-trephine. The method is slow, but it is *safe* and entirely under the control of the operator. In addition, it presents the great advantage of simplicity : other methods demand extensive apparatus, electric adaptations, &c. The hand-trephine is always available.

A hand-trephine, to be really efficacious, must be sharp, in general good condition, and provided with a suitable handle, after the type seen in the illustration. Trephining must always be carried out with caution, for skulls vary in density in their several parts and in individuals. A bradawl may be introduced through the scalp so as to indent the external table of the skull when the trephining is conducted over any special point and when the scalp is intact, the pin of the trephine being applied at that point after the formation of the scalp flap.

The trephine should be held at right angles to the surface of the skull until such a circle has been produced as will allow the surgeon to discard the pin and proceed without. The diploic tissue, when

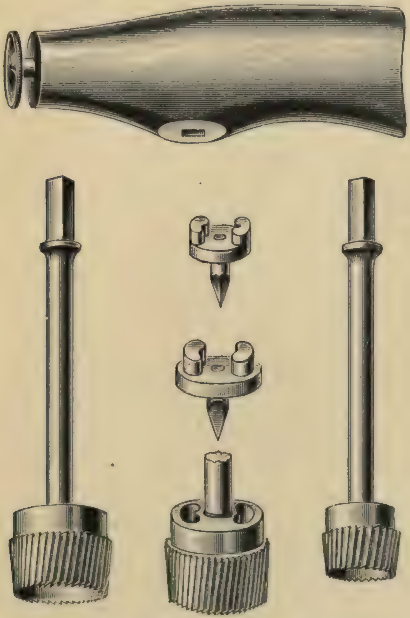


FIG. 31. THE HAND-TREPHINE.

reached and attacked, shows itself by increased bone débris and venous oozing. The internal table is appreciated by the added resistance. Care is now required. The readiness of the trephine disk for elevation and removal is demonstrated by pressing on it with the finger. When it gives to digital pressure, the special elevator may be used and the disk elevated and removed. This disk may be placed in normal saline solution, at blood temperature, for replacement, but the occasion seldom arises when such methods can be carried out.

The **dura mater** is now seen. It should be shiny, moderately tense only, and pulsatile—to the eye. It is seldom possible to determine the presence of any cause of intradural tension without further bone removal—without enlargement of the gap. This is carried out (1) by separating the dura mater from the under aspect of the surrounding bone, and (2) by cutting away the surrounding bone in all, or in the required directions, with craniectomy forceps, the so-called 'parrot-billed' type for preference. In cutting away the surrounding bone, small fragments should be 'nibbled' away, what the French call 'morcellement'. The bone is usually too strong and the forceps too weak to enable one to remove large fragments *en masse*. The surgeon should not be too greedy. A little perseverance, and some practice, will soon enable the surgeon to cut away freely and quickly.

During the processes of trephining and nibbling, some bleeding may take place from (1) a meningeal artery running through the bone, and (2) from diploic and emissary veins. In either case the hæmorrhage is readily controlled, after the removal of the disk, by plugging the various foramina with wax, wooden match (sharpened and boiled), catgut, &c.

Bleeding from the dura mater. The meningeal vessels may be injured during the process of trephining. In such an event a fine intestinal needle is passed beneath the vessel on either side of the bleeding-point, *into but not through* the dura mater, and the vessel ligatured.

Opening the dura mater. Under normal conditions the dura mater is sufficiently translucent to enable one to see the underlying cortical veins, and, in addition, the dura pulsates freely. Any underlying hæmorrhage causes the dura to assume a darker colour, slightly yellowish on the surface with the dark plum-coloured clot beneath. All definite increases of intradural pressure lead to cessation of pulsation, and cause the membrane to feel more tense than under normal conditions.

If the dura must be opened, this process should invariably be carried out with the greatest care. The brain is, in all probability, under great pressure, bulging against the dura, and with its superficial veins greatly engorged. Incautious opening will lead to damage to these vessels and troublesome bleeding. The membrane is incised lightly with the scalpel at its most prominent point, and, as soon as any fluid is seen to exude and the pia-arachnoid is visible, all further section of the membrane is carried out with blunt-pointed scissors or on a director. It should be added that all meningeal arteries that cross the line proposed for dural section should be underrun and ligatured on either side of that line. The dural incision may be crucial or flap-like, according to requirements.

Hæmorrhage from cortical vessels. If the pia-arachnoid covering the surface of the brain bursts from the effect of brain-pressure or is lacerated, bleeding takes place from surface vessels, mainly from veins. The bleeding may be serious, and is always difficult of control. Unless ceasing spontaneously, as sometimes occurs, the following measures may be taken for its control: (1) the application of pressure, (2) the use of little pads of gauze wrung out in normal saline solution at a temperature of 115° Fahrenheit, (3) underrunning the vessel on either side of the bleeding-point with an intestinal needle threaded with fine silk—a process requiring delicate manipulation, and (4) the application of a muscle-graft to the bleeding-point. This is a valuable method. The temporal or occipital muscles will probably be available for the purpose. A small piece is snipped off with the scissors, spread out on the flat of the scissors, and slightly squeezed. It is then applied directly to the bleeding-point and there held in position for a minute or two. Under favourable circumstances, it there adheres and suffices to stop the bleeding.

Closing the dura mater. The dura may be stitched up, but such a procedure is seldom advisable and often impossible. Presumably it has been opened for the removal of a foreign body or for the evacuation of blood or pus. In such cases free drainage must be supplied and the membrane left open. In addition, the increase of intradural pressure usually prohibits any attempt at sewing up the membrane.

If it is deemed wise to try and sew up, and such a process is found difficult, considerable aid may be obtained by the following methods, all of which have the object of reducing the intradural congestion: **elevation of the head, lumbar puncture,** and **puncture of the lateral ventricle.** If these methods fail, and it is still deemed wise to cover in the brain as much as possible, additional fascia may be obtained by cutting away such an extent of the fascia lata of the thigh as will enable the surgeon to sew it in position with a few sutures. Such autoplastic grafts are greatly to be preferred to all other methods, such as Cargill's membrane, &c.

Reposition of the scalp flap. At the termination of the operation the scalp flap is replaced and sewn into position with salmon-gut sutures, each suture taking up plenty of tissue on either side. The wound is then painted over with iodine, and dressings applied. The scalp tourniquet (or Makkas' clamps) is loosened and removed, pressure being applied over the dressings, after which a circular gauze bandage is wrapped round the head, much in the same position as was previously occupied by the tourniquet. The ears, if included, should be coated with vaseline, to prevent irritation. Wool is then put over all and maintained in position with bandage.

After-treatment. The patient may be given as much morphia as seems indicated. This drug lessens the degree of shock and keeps the patient quiet, a most desirable feature considering the probable condition of cerebral venous engorgement and œdema.

If the wound is clean, the head should be dressed the next day, repainted with iodine, and dressings applied, these being conveniently maintained in position by firm bandage and special head dressing. The dressings need not be touched till the seventh day, when the stitches are removed, collodion dressing applied, and the head again bandaged.

If the wound is infected, as probably is the case, re-dressing must be carried out frequently and, in the more dirty conditions of the wound, fomentations should be applied in place of dry dressings. Fomentations wrung out in normal saline solution give the best results.

Late treatment. All the more serious head cases require careful after-treatment and rest, a period devoid, as far as possible, from worries of all sorts, financial or family. The ultimate result of the case depends very largely on such factors. Undoubtedly, also, many cases, apparently cured, will require further operative procedures for the relief of headache, epilepsy, and the like. One fact stands out clearly—the after-results will be all the more disastrous unless head cases are treated in a bold and scientific manner at or soon after their inception.

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