THE REPARATION OF CRANIAL DEFECTS BY MEANS OF CARTILAGINOUS GRAFTS.

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THE problem of the reparation of cranial defects has latterly become one of extreme importance. Before the War it was, on the whole, rare to find cases in which large gaps had to be left in the skull, except where decompression was performed for increased intracranial tension, when it was obviously to the patient's advantage that the opening should remain patent. Now, we see on every hand cases of fractured skull, and they are nearly always accompanied at first by septic infection of the brain and meninges, a fact which renders free removal of bone an imperative necessity, both for purposes of drainage, and for relief of the temporarily increased cerebral tension. Hence, not only is trephining a far more common operation than formerly, but with increased experience large openings have become more and more the rule, and this in men to whom a permanent cranial defect can be no possible benefit.

There are many cases of trephining in which no reparative operation is advisable—the small trephine hole, made for a fissured fracture, and revealing an intact dura mater, has long been known to cause no trouble. But we do not very often have to deal with such cases in military surgery. Where the breach is large, as it usually is, the question of reparative operation is always to be considered.

The position of the gap also makes a difference in the symptoms caused. When it is opposite the attachment of the falx cerebri or tentorium cerebelli there are rarely any symptoms of importance, so much is the dura strengthened from within. One might indeed say (physiologically speaking) that in such cases one has to deal with two small openings rather than one large one. But the possibility of one of the great sinuses being involved in any subsequent injury to the defenceless spot must be kept in view. Wounds of the squamous temporal bone are protected by the temporal muscle and fascia, unless these are too much destroyed. But where the frontal, the parietal, or the occipital bone (above the superior curved line) is affected, it is the rule and not the exception to find symptoms of unstable intracranial equilibrium.

What then are the signs and symptoms which should lead a surgeon to advise operation in these cases? It is not always easy to know how far symptoms should be attributed to the cranial lesion, and how far to some underlying cerebral condition. It is therefore well to assure oneself that there is no foreign body lying overlooked in the brain and really causing the trouble, should such be found, its removal (if practicable) is the logical prelude to any attempt at repair of the skull.

The two most important signs—they always go together—pointing to a

seriously weakened state of the cerebral defences, are visible pulsation, and impulse on coughing. In severe cases a definite bulge may even be seen on the occasion of any quick movement. The presence of these signs may depend on the size of the hole, on its position, on the state of the underlying dura, or on all of these together. Whatever the cause, they indicate that the equilibrium of the brain is affected, that any movement jars the delicate cortical tissue against the unyielding edges of the aperture, and that a state of affairs is present which calls for remedy.

The symptoms most complained of are headache, vertigo, and sudden blurring of the vision. Though these are common symptoms of cranial and intracranial trouble, they may fairly be laid to the charge of the cranial defect when they are brought on by sudden movement. Inability to sleep, except with the head raised or tightly bandaged, and objection to noise, are also complained of. These symptoms can often be cured by a cranioplasty. We see also cases where the patient complains of pain and giddiness when the slightest pressure is applied to the affected spot; or where he is obsessed by the fear that any blow will result in sudden death, and begs for a protective apparatus. The value of such apparatus is very doubtful. It may be useful against outside injury, but it cannot protect the brain from constant traumatism against the edges of the gap, in any case the constant wearing of a tightly-fitting head covering is wearisome, and the result desired is far better obtained by an operation which secures a permanent and physiological protection.

It is doubtful whether unstable intracranial equilibrium alone is a frequent cause of Jacksonian epilepsy. But in any such case of epilepsy operation is advisable, with a view to the discovery and removal of the cause; and if at the same time the defect can be closed without any great increase of the shock and risk of the operation, there is no reason to refrain from so doing. There are cases on record where no cause for the epilepsy other than the cranial breach was found, and where the mere reparation of the skull has effected a cure.

Finally, and an important point in frontal wounds, the cosmetic result must be considered. A depressed, discoloured scar on the forehead is an unsightly thing, its removal is in itself well worth an operation—certainly many are performed for as little or less.

Contra-indications of the Operation.—These come under two headings (1) General; and (2) Local.

1. The former are those which have to be taken into account in the case of any operation of expediency. No surgeon of course would operate, except in a case of extreme urgency, on a diabetic, a consumptive, or a man with advanced heart disease or Bright's disease. But such cases rarely come into the sphere of military surgery, and it is with this branch that we are mainly concerned. Bronchitis is a contra-indication: where any cough causes a cerebral impulse, frequent coughing would tend to displace any material used to fill a gap in the skull. moreover, in the case of the operation we propose to describe, where the grafts are taken from the lower costal cartilages, coughing is painful in the extreme during the first few days after operation.

So, if any bronchitis be present, measures should be taken to cure it before proceeding to a reparation.

2. The local contra-indications are two. One should not operate while there is anything present to favour sepsis—that is to say, not until the wound has healed and the last scab dropped off. Nor should one repair the cranial gap while there is any marked bulging or any sign of increased intracranial tension. The mere size of the gap is no contra-indication, except in so far as some are too small to be worth repairing, no gap compatible with life is too large to be repaired, and the larger the gap the greater the need for repair.

Forms of Operation.—Many are suggested. Following Mauclore, we may classify them thus:—

1. *Periosteal, Osteo-periosteal, and Cutaneo-osteo-periosteal Cranioplasty.*—These operations, to be efficient, involve the removal of part of the outer table of the skull adjoining the breach. This is a matter of some difficulty, with considerable shock, and necessitates the use of expensive apparatus such as an Albee's bone set.

2. *Bone grafts.*—These may be autoplasmic, making use of the ribs (Kahle), great trochanter (Mauclore), scapula (Leclerc), or tibia (Delagenière), these are all operations of some magnitude, and involve a considerable waiting period. The use of homoplasmic grafts is limited by the difficulty of finding a suitable subject to take them from. Heterogenous grafts may be used—for example, the bone of a dog (Macewen, Ricard)—but these are open to the same objections as all heterogenous work.

3. *Sterilized decalcified bone* may be used.

4. *Prosthetic methods*, such as the use of plates of gold (Estor) or ivory (Mauclore).—These may give excellent results, but they are open to the objection urged against the introduction into the tissues of any non-absorbable foreign substance—that it may, and often does, come to act as an irritant. While this does not matter much in the case of a bone plate which can be removed when its work is done, it is a serious thing when the removal of the foreign substance would undo all the work of the operation.

5. *Cranioplasty by means of cartilaginous grafts.*—This is to our mind the best and most universally applicable of all. It is at once safe and simple, and the shock is minimal; the grafts are autoplasmic.

The operation, first described by Morestin in February, 1916, consists briefly in the filling of the gap with grafts taken from the lower costal cartilages. It was brought to our notice by M. Villandre, of Lyon, who is responsible for some notable improvements in the technique. The advantages are as follows:—

- i. The grafts are autogenous.
- ii. The shock to the patient is very small, the suffering entailed is not great, and the risk in suitable cases is practically nil.
- iii. The object is rapidly attained: most patients leave hospital with a solid skull at the end of a month or five weeks.
- iv. There is no need to wait, as in the case of bone grafts, for several months after the wound has healed before proceeding to operation, the cartilage appears to possess a power, unknown to bone grafts, of resisting

infection. Villandre reports a case where, in spite of a mild suppuration, the grafts survived and solidified. We have operated on more than one case less than a week after the last crusts had separated, and had no reason to regret it. Villandre repaired thirty-two out of his first sixty-four cases less than four months after the injury was received. This is a point of great importance in military surgery.

v. The operation is not a difficult one, and requires no special plant.

vi. In frontal cases it gives an opportunity for moulding, and readily allows of cosmetic results only obtained with difficulty by other methods.

TECHNIQUE OF THE OPERATION.

Preparation of the Patient.—The entire scalp is shaved, and the eyebrows if necessary, as are the chest and upper abdomen. The skin of the operation areas is disinfected with iodine, and surrounded with sterile towels (those over the chest should be covered with another until such time as the grafts are to be cut). A screen is absolutely necessary between the anæsthetist and surgeon, and attached to the patient's forehead, not only for asepsis, but to serve as a point of attachment for hæmostatic forceps used to retract the skin flaps.

The Anæsthetic.—The anæsthetist works under difficulties, so if possible some dosimetric apparatus should be used. Whether chloroform or ether be employed does not seem to matter. Deep anæsthesia is only necessary when cutting the grafts. In France, regional anæsthesia is often used, but though this abolishes the otherwise necessary proximity of operator and anæsthetist, it is not to be recommended, very thorough anæsthetizing of several intercostal nerves (the 5th to the 9th) is necessary. The operation offers a field for the rectal administration of ether, to which we propose to give a trial.

The Skin Incision and Resection of Fibrous Tissue.—The area of the wound is most frequently found occupied by fibrous tissue, which, if on the forehead, is very disfiguring, and in any case gives an insecure hold to stitches. The incision should therefore allow for a free resection of this, and should leave at least a sixteenth of an inch of healthy skin to be resected along with it. From the periphery of this wound cuts may be made as desired, if more room be needed. If the original wound has been sutured, and there is no cicatricial tissue to be excised, one should keep to the old line.

The classical horseshoe flap should not be used, for it is apt to leave a pocket which encourages the formation of a hæmatoma (see *Case 2*). Indeed, if the original incision has been a horseshoe one, it is best to discard it (except on the forehead, when for cosmetic reasons it must be adhered to), and make a crucial incision with the cross over the middle of the hole, giving four triangular flaps. An exception to this rule is in wounds involving the temporal muscle—the splitting of which barely gives room to work—when it is best to turn down a flap. The flaps thus marked out are carefully dissected back until the whole of the cranial gap is felt to be exposed. The plane of dissection is the sub-aponeurotic layer, if this be carefully adhered to, it is easy to bring the skin edges together later, and compensate without undue tension for quite large cicatricial areas (see *Figs. 16, 17*).

We now proceed to the excision of the island of scar tissue left in the middle. Here one must work with the greatest care, remembering that the dura has probably been injured and may only be represented by a thin layer of fibrous tissue. The plane of dissection should therefore be kept close to the surface. Should there be an escape of cerebrospinal fluid, the rent should at once be sutured, if this be impossible owing to the friability of the tissues, a muscular or fascial graft should be used.

The Cleaning of the Edges of the Gap.—The pericranium is incised with the point of the knife, keeping as close as possible to the edge of the gap. This must be done with great care, as a slip might have disastrous consequences. Bleeding is usually so free as to obscure the vision, and the work has to be done by touch. When completed, the edges of the aperture are carefully cleared with a rugine. This must be done thoroughly, right down to the dura, and the surgeon must not be satisfied until he can sweep the edge of the rugine round between the deep surface of the skull and the dura mater (*Fig. 13*).

FIG. 13.—Diagram to show the clearing of the margins of the bone opening, including the separation of the dura on the deep surface.

Should this step be inadequately carried out, a projecting spine may be missed on the deep edge of the hole, which might cause epilepsy by pressing on the brain. All roughnesses or projections are removed with a gouge forceps. Any slight cerebral hernia present now falls back, or can be gently pressed into place (the operation should not be undertaken in

the presence of more than a very slight degree of hernia).

The surgeon is now faced by a clean hole in the skull, displaying a mass of fibrous tissue with slightly raised edges. It is an easy matter to scrape this mass away with a curette, but it should not be done. To begin with, the dura may be non-existent, and such a proceeding would only open up the sub-arachnoid space. Even if this complication be avoided, there is very free oozing in two cases (*Cases 3 and 4*) we ascribe the formation of a hæmatoma to our having taken this step. Should there be too much fibrous tissue, it is better to clip it away with scissors, but even this is not necessary. The fear at first experienced of piling on too much tissue, and causing pressure, is unfounded, the real difficulty is to avoid recession of the grafts, with subsequent depression.

If the dura is to be opened, it should be done at this stage, but this is rarely necessary, and should only be done when there is some definite indication of underlying mischief. A swab wrung out of peroxide of hydrogen (to stop the oozing) is placed in the wound, the flaps are turned back over it, and the head is covered with a sterile towel. If any bleeding points are found when the wound is reopened later, they can then be dealt with by under-running.

The Cutting of the Cartilaginous Grafts.—These are taken from the 6th, 7th, and 8th costal cartilages, and should for convenience be cut from

the same side as the head wound. The usual incision is one parallel to and a little above the costal margin. After our first three cases, however, we adopted a vertical one, two finger-breadths outside the edge of the sternum. This gives equally good access, can more easily be extended if necessary; the hæmorrhage is less, and it has the great advantage of splitting instead of cutting across the upper fibres of the rectus.

The cartilages having been thus exposed, shavings are taken of about half their thickness. Care should be taken not to cut through the entire thickness of a fixed cartilage, but the whole tip of a floating one may be taken. It is well to take what seems to be considerably more than enough cartilage to fill the gap. Each graft, as cut, is dropped into warm saline solution.

To facilitate this work at the bottom of a hole, M. Villandre has devised an ingenious knife, the blade of which is set on a shank, bayonet-wise (*Fig. 14*). This enables the grafts to be cut evenly by keeping the blade of the knife flat.

FIG. 14. —Knife with shank set at an angle for cutting grafts from the costal cartilages. Designed by M. Villandre.

In operations on the occipital region, this stage must be carried out first, and the wound sutured before turning the patient to incise the head, otherwise it is best to pack the wound with gauze, and proceed at once to transfer the grafts.

Placing the Grafts.—The chief difficulty is to keep these from slipping. To this end it has been proposed to push the edge of the graft between the skull and the dura, theoretically, this might cause a rise of intracranial pressure, practically, the edge of the skull is bound to show as a ridge. It has also been suggested to groove the diploë with a chisel, and push the grafts into the groove, a step which would certainly prolong the operation and increase the shock.

A very simple and rapid method is that of Villandre. One end of a fine catgut stitch is passed through the pericranium, and tied. It is then passed through the pericranium on the other side of the gap, and taken backwards and forwards in a zigzag manner till the hole is covered in with a trellis. In the case of a very large gap it is wise to supplement this network by a second, at right angles to it, and to insinuate the grafts between the two layers. We have now a small chamber bounded by the dura, the edges of the skull, and our trellis, into which the grafts can be slipped with a forceps (*Fig. 15*). It is advised to apply the perichondral surface to the dura, in order to avoid adhesions, in any case it is easier, as the grafts curl when

cut, the perichondrium being in the concavity. They should overlap everywhere, and may well be doubled, as some slight recession always takes place, and those cases give the best final result which, at the end of the operation, show a slight boss. When the frontal or temporal regions are involved, it is well carefully to study the sound side before operating, it is then possible to restore almost exactly the symmetry of the forehead.

Suture of the Wounds.—In this step great care must be exercised to obtain as perfect a scar as possible. If hæmostatic forceps are left on till the wound is to be closed, ligature of vessels is rarely necessary. To get perfect apposition it is well to put one or two mattress sutures in each limb of the incision, supplemented by a continuous blanket stitch, or (in the case of the forehead) by interrupted sutures of horsehair on a round needle. Where the cosmetic effect is of importance, it is advisable to begin the suture at the most invisible end of the wound. We have found it well to leave a silkworm-gut drain in the posterior corner of the wound. The thoracic wound is closed in layers. Time can be saved by the assistant doing this while the surgeon sews up the head.

FIG. 15.—Diagram showing cartilaginous grafts inserted between trellis and dura mater.

After-Treatment.—A hypodermic injection of morphine and atropine is given as soon as the patient begins to recover consciousness. This may have to be repeated, as the pain in the thoracic wound is at first acute. The head is inspected on the second day, and the drain removed. The stitches may be removed at the end of the week, when the patient is generally allowed up. At the end of a fortnight the skull is usually hard, though slightly elastic, and all dressings may be discontinued.

RESULTS.

It is necessary to be quite clear as to what the surgeon intends to achieve when he performs a cranioplasty. It is not possible to remove troubles due to brain lesions, but only to protect the brain from further injury, especially from repeated slight trauma due to continual impact against the edge of the breach. He must, therefore, before operating, make up his mind what symptoms really are due to the cranial defects, so as to be able to explain to the patient how much relief he may expect. Viewed from this standpoint, the results are very satisfactory. It is usual to find that the headache is less, that the patient suffers less from noise, and can make efforts previously

impossible, not infrequently he can bend forward quickly without any vertigo. These events do not come immediately, nor even as soon as the grafts have solidified, but at the end of about six weeks considerable improvement is usually shown.

A few statistics may be helpful. Gosset, in May, 1916, reports 32 cases, with 2 deaths (from bronchopneumonia) and 30 successes, Villandre, in October, 1916, 64 cases, with 63 successes. These observers probably count their successes from the point of view of the solidification of the breach. Marie, in reporting on 21 cases in which mechanical success was achieved, notes 6 improved as regards symptoms, 12 stationary, and 3 aggravated. This is probably an unfortunate experience. Of the 7 cases operated upon in the Ulster Volunteer Hospital, 6 have shown definite improvement in the symptoms, while all 7 have solid skulls.

As regards the military fate of the patients, very few are able to go back to the front, it is found that the strain and noise bring on a return of the symptoms. Most of them, however—in fact, practically all who have not sustained some deeper injury—are, at the end of a few months, fit to do useful work in the auxiliary services.

The ultimate fate of the grafts has not yet been decided. Only time and the *x* rays can show whether they remain cartilaginous, or ossify. So far, radiograms taken at the end of some months tend to uphold the former view. Sicard was obliged, because of return of the symptoms, to remove a graft at the end of four months. He found no sign of ossification, or even of calcification. The line of demarcation between bone and cartilage was perfectly clear, the two being firmly fixed together by fibrous tissue.

NOTES OF SEVEN CASES OPERATED UPON IN THE ULSTER VOLUNTEER HOSPITAL.

Case 1.—Soldat F. G. Wounded on May 19, 1916, in the left frontal region. Operated on, May 20. Projectile removed from fracture of skull, a piece of the inner table which had been driven some 3 or 4 mm. into the brain was also removed, as were several splinters from the dura.

ON ADMISSION, June 26.—A triradiate scar in the left frontal region, depression over an area the size of a florin, pulsation and impulse on coughing marked. No motor symptoms. Headache, vertigo on bending forward.

Gradual cicatrization of wound.

OPERATION, Sept. 5.—Cartilaginous cranioplasty, with excision of the cicatrix. The gap was an irregular triangle, apex downwards, with a side of about one and a half inches.

The sequelæ were excellent. The skull was quite hard at the end of the month. He was discharged convalescent on Oct. 7. He still suffered from headache, but much less, and could bend forward without any trouble.

Case 2.—Soldat C. T. Wounded on Aug. 15, 1916. (No notes.)

ON ADMISSION, Sept. 3.—The patient presented a horseshoe scar, almost healed, on vertex. Trephine hole about $1\frac{1}{2}$ in. in diameter. No pulsation, very slight impulse on coughing, no headache or other symptoms, but any pressure on the gap causes acute pain.

OPERATION, Sept. 16.—Cranio-plasty. The old semicircular flap was again raised. He developed a small hæmatoma, which was absorbed at the end of three weeks.

When discharged on Oct. 21, the skull was quite solid and he could stand considerable pressure on the grafts.

Case 3.—Soldat A. G. Patient was wounded on Aug. 2, 1916. (No notes.) Admitted to hospital on Sept. 3.

ON ADMISSION.—There was a large depression in right parietal area, the wound was nearly healed. Marked pulsation, and impulse. Headache, giddiness, insomnia. Slight weakness in left hand.

OPERATION, Oct. 4.—Cranioplasty A crucial incision was made. The fibrous tissue covering the dura was scraped off. The hole measured about 2 in. by $2\frac{1}{4}$ in. A large hæmatoma formed and had to be evacuated.

Nearly a month after operation there was still some pulsation in the centre, but by Nov. 25 the grafts were solid, and all impulse on coughing had gone. His hand was quite strong. He still suffered from headache, giddiness, and insomnia as much as before the operation.

Case 4.—Soldat L. G. This patient was wounded on Aug. 18, 1916, and admitted on Sept. 3. (No notes.)

ON ADMISSION.—Patient presented a granulating wound at vertex. There was visible pulsation, impulse on coughing, headache, and vertigo on bending forward.

OPERATION, Oct. 11.—Cranioplasty (Dr. J. A. Small). A crucial incision was made, the fibrous tissue covering the dura was curetted away, a silkworm-gut drain was employed. The defect was about $1\frac{1}{4}$ in. in diameter.

In spite of the drain, a small hæmatoma formed. By Oct. 19, however, there was no pulsation in the head, and at the end of the month the graft was quite solid. When discharged convalescent on Nov. 11, the headache and vertigo were much less.

Case 5.—Soldat J. P. Was wounded Aug. 2, 1916, and admitted Sept. 2. The notes only say "Trephined at Front—loss of brain matter—vision of right eye diminished."

FIG. 16.—*Case 5.* Before operation.

FIG. 17.—*Case 5.* After operation.

ON ADMISSION.—There appeared a depressed granulating wound above the right outer canthus. The depression was triangular, with sides about $1\frac{1}{2}$ in. long. Visible pulsation, with impulse on coughing. Headache and vertigo.

OPERATION, Oct. 18.—Cranioplasty The scar was excised. During the operation the dura was accidentally opened, it was closed. Gap about 2 in. by 1 in., drainage.

Perfectly satisfactory healing of the wound followed, and consolidation of the graft. Patient can now (Nov 25) bend forward with hardly any vertigo, and has had no headache for some days. The vision is clearing up. (*Figs. 16, 17.*)

Case 6.—Soldat E. B. This man received his wound on Aug. 21, 1916, and was admitted Sept. 3. The notes say "Enlargement of scalp wound, depressed fracture of skull, fragment removed, dura intact."

ON ADMISSION.—There was a small depressed wound about 1 in. above and behind the right ear, with visible pulsation, pain on pressure, and headache.

OPERATION, Oct. 23.—Cranioplasty A round hole about 1 in. in diameter was found.

The wound was perfectly healed on Nov 25, and the skull quite solid. He had much less headache, and listened to an opera with pleasure.

Case 7 —Soldat F G. This man was wounded on Aug 1, 1916, and the notes say "Furrow in right frontal region, cerebral irritation, internal strabismus. Operation on Aug. 3 Removal of three splinters of skull from scalp, gutter fracture found, trephined, incision of dura, considerable subdural infection. Sustained improvement."

FIG. 18.—Case 7. Before operation.

FIG. 19.—Case 7. After operation.

ON ADMISSION.—A granulating wound about $2\frac{1}{2}$ in. by 1 in. above and external to right eye, visible pulsation, with impulse on coughing. On Sept. 4, much better, up; cannot bend forward, and sleeps badly

OPERATION, Oct. 28.—Cranioplasty Excision of the scar, irregular oval gap about $1\frac{3}{4}$ in. by 1 in.

Patient had a very slight attack of epilepsy on the next day The wound was perfectly healed by Nov 25, and the grafts are solid. He sleeps well, has no headache, and can touch his toes with very little discomfort. (*Figs. 18, 19.*)

SUMMARY.

It appears that in six out of seven cases we have improvement, and in most considerable improvement, of the symptoms complained of. Why *Case 3* remains in his former state it is hard to say ; if his condition gets any worse it will probably be necessary to remove the graft. In *Cases 1, 5, and 7* the cosmetic result alone was worth the trouble. Except where noted to the contrary, the technique employed was that described. We attribute the hæmatoma formation in *Case 2* to the use of a horseshoe flap, in *Cases 3 and 4* to our error in scraping the fibrous tissue off the dura , we have modified our technique accordingly.

To sum up While no one would maintain that every case of craniotomy should undergo a reparative operation, a very large percentage of such cases show symptoms which can be cured by cranioplasty While many methods have been suggested, Morestin's cranioplasty by means of cartilaginous grafts is one of the easiest to perform ; it can be undertaken at a comparatively early date , it gives a very high percentage of good results , the time of waiting for these results is short, and the operation is no more dangerous to the patient than is a radical cure of inguinal hernia.

No originality is claimed for this paper, which merely sets forth the work of others , but should it do anything to popularize this most useful operation among British surgeons, the writer will be amply rewarded.

The writer's best thanks are due to M. Villandre, not only for introducing the operation to his notice, but also for much valuable help in the description of the technique, which (as here described) is almost as much due to M. Villandre as to the original author.

Figs. 13 and 15 are the work of Miss D. Stronge, senior V.A.D. member of the hospital nursing staff. The photographs were taken by M. Oulmann, of Lyon.

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