OF HARVEY CUSHING'S many contributions to neurological surgery, perhaps the most important was his development and standardization of neurosurgical operating technique. Dr. Cushing himself summarized this succinctly when he was questioned about his contributions. His reply was, "Tell them that I closed the galea."6

Aside from the development of many important surgical instruments, Dr. Cushing advanced neurosurgical operating technique by the introduction and adaptation of several basic principles.1–4 Foremost among these were the principles of careful hemostasis, gentle manipulation of tissues, and meticulous attention to details, which had been taught to Cushing by the man who was chiefly responsible for his surgical training, Dr. William S. Halsted.

In an address to the St. Louis Surgical Society on December 16, 1907, parts of which are reproduced below, Cushing outlined his procedure for performing osteoplastic resection of the skull. It is an unwritten tribute that most of the steps in this procedure are still followed today.


TECHNICAL METHODS OF PERFORMING CERTAIN CRANIAL OPERATIONS* 3

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... On this particular occasion... I purpose to limit my remarks largely to a description of such technical methods as have come to be more or less habitual, in Dr. Halsted's clinic with which I am associated, in the routine performance of the simpler operations of craniotomy and craniectomy...

From a purely technical point of view we are more indebted to the method of temporary osteoplastic resection, first attempted by Wagner in 1889, than to any other factor for the satisfactoriness of most of our present-day operations on the cerebral hemispheres. These trap-doors may be cut from the cranium with a variety of tools; the simplest armamentarium is a mallet and chisel, the most elaborate, a motor, with its trephines, burrs and saws, driven by electricity...

Simplicity is a desirable quality in operative technique, but the blows of a mallet, even though transmitted in a glancing direction, are undesirable; and speed, the chief advantage of the motor-driven rotary tools, is invariably a source of danger, even in accustomed hands. It really matters little, except in saving time for the surgeon, whether an osteoplastic flap can be elevated by one method in seven minutes, or whether another requires twenty; and an operator who persists in taking dangerous corners at high speed will be the cause of a serious or fatal accident some day, whether he is driving an automobile or opening a skull...

STEPS OF AN OSTEOPLASTIC RESECTION

Since this procedure may be taken as representative of any major operation on the skull, I shall, at the risk of being tedious, describe the general plan of preparation and performance to which I adhere...

General preparation. It is, I believe, a fairly universal custom to have the patient's head shaved and treated antisepically in the ward on the day before the operation—some even advocate a double preparation of this kind. This I consider an unnecessary precaution, if not positively unwise; for the patient is apt to pass an un-
comfortable night and, even with the most expert shaving, the scalp is likely to be a little "sore" the morning of operation. In something over 350 craniotomies I have never seen an infection, even a superficial stitch abscess, and have ceased to regard the chance of sepsis as a possible complication of these operations.

It is our custom, without previous ward preparation, to have the hair clipped and shaved just before the operation. . . . After a double shaving, once with and then against the direction of emergence of the hairs, there may be a preliminary cleansing of the scalp with green soap and a soft brush, the head then being wrapped in a towel wrung out of warm bichloride solution. The final preparation is deferred until after the anaesthetic.

**Position on the table.** It is a great advantage, though it does not appear to be a common practice, to place the patient on the table in the position most favorable for the operation before administering the anaesthetic. . . .

Many operators have a particular form of head-rest for all cranial operations, table extensions for this purpose having been described by Horsley, Frazier, Morestin and others. For the usual operations on the vault, however, small, flat, solid pillows or sand-bags seem to be all that are necessary to turn and hold the head in the desired position: on the other hand, I regard a head-extension with shoulder supports as essential for occipital work, chiefly to insure free respiration. Thus do surgeons' views differ. Whatever form of table be used, however, it is desirable to have the head-end capable of being raised or lowered at will.

**The anaesthetic.** Regardless of the drug to be employed, it is essential that it be administered by an expert—preferably by one who makes this his specialty. . . . Cerebral surgery is no place for a "Guck in die Luft" anaesthetist. ¹

In all serious or questionable cases the patient's pulse and blood-pressure, their usual rate and level having been previously taken under normal ward conditions, should be followed throughout the entire procedure, and the observations recorded on a plotted chart. Only in this way can we gain any idea of physiological disturbances—whether given manipulations are leading to shock, whether there is a fall of blood-pressure from loss of blood, whether the slowed pulse is due to compression, and so on. A further safeguard is an artificial respiration apparatus, to be immediately put into use in case there is failure of an already burdened respiratory centre, either from the anaesthetic, from loss of blood, or from additional medullary pressure due to cerebral manipulation. . . .

In this country, where chloroform is doubtless administered less well than ether, the latter is the anaesthetic of choice at most hands, the primary stage usually being induced with ethyl chloride. . . .

The question of the anaesthetic in a two-stage operation is an especially serious one. In, and under these circumstances, the dangers from chloroform would possibly be less than those of a repeated etherization. Some years ago, however, having had a fatality from chloroform, I employ it far less frequently in cranial operations than ether, restricting its use largely to children.

Local anaesthetics may at times suffice, especially for such simple measures as ventricular puncture, though infiltration of the scalp is difficult. I have learned, furthermore, that in favorable cases no anaesthetic need be required in a second-stage operation limited to manipulations of dura and brain after re-reflecting an original bone-flap.

**Preparation of the operative field.** With the patient anaesthetized and in proper position on the table the final cleansing is done; for this, alcohol and 1 to 1000 bichloride solution are sufficient.

It is my practice at this stage, before the landmarks are obscured by the covering of operative sheets and towels, to outline the proposed incision on the scalp by a superficial scratch with the scalpel.

An operating neurologist should acquire the power of visualizing the brain, its main fissures, the insula, the ventricles, etc., through the intact skull; and those who have, by long practice, familiarized themselves with the rules of cranio-cerebral topography, learn to judge the position of the main fissures with no greater margin of error than when measurements are employed. . . .

With the proposed flap thus outlined and the head raised by an attendant's hand placed under the back of the neck, a broad square of wet bichloride gauze is thrown over the entire head; over this, in turn, is placed a tourniquet.

For the control of hemorrhage from the scalp numerous forms of tourniquet have been advocated. Many use a simple rubber tube, or Esmark bandage, both of which are difficult to apply and to fasten without slips in the aseptic technique. Crile has employed a rubber dam which, being stretched over the entire scalp, renders it bloodless. I formerly used a pneumatic tourniquet, but have finally come to a form of rubber ring in which is inserted a buckle . . . so that the tube can be made into a ring of any size and can be easily removed at the end of the operation. Practice enables one, with a given quality of tubing, to estimate the size of the ring, necessary in a given case, to shut off arterial supply from the scalp without causing undue pressure. The ring, furthermore, is provided with a median tape . . . whose length—measured after the head is shaved—should equal the distance from glabella to inion, and the object of which is to prevent the ring from rolling over the orbits, as it is likely to do, especially if there is a prominent forehead. Having been boiled, the ring is applied by the operator and an assistant . . . being snapped over the head from occipital to frontal regions (Fig. 4).

In the majority of cases all bleeding from the scalp is thus controlled, though in certain patients with tumor, in whom there is marked intracranial stasis, some of the veins on the concave side of the incision which receive blood through emissary vessels from within the skull may have to be clamped. . . .

Around and just above the tourniquet a small towel,
Fig. 4. Cranial tourniquet in position over gauze cap.

folded lengthwise and wet in bichloride, is tightly pinned, and to this is securely fastened the large towel which covers the etherizer like a tent and leaves exposed little more than the area outlined by the preliminary incision. If there is any likelihood of the slipping of these surrounding sheets, they may even be pinned directly into the scalp.

The osteoplastic flap. With the operative field thus prepared, the incision is carried down to the skull, through gauze and soft parts, in the line previously scratched on the scalp. When the bone has been exposed it can be opened in a number of different ways.

The "combined method," to be described, makes use of the following general principles: 1. Division of the bone between two or more primary openings (Toison). 2. Incision by an advancing instrument from a simple opening. 3. The making of all cuts from within outward. 4. The leaving of a beveled flap.

A primary opening through the thickest part of the exposed cranium, usually near the parietal eminence, is made with a hand-trephine. which should be of generous size, with a crown fully 2 cm. in diameter. Bleeding from dilatior vesicles, in certain cases of tumor, may be severe. It may be controlled by the proper use of Horsley's wax, with which the beveled teeth of the trephine may be filled.

One or more secondary openings at the upper edge of the incision are made with a Doyen perforator and burr. Then, with a long-handled blunt dissector or dural separator, introduced through the large trephine opening, the dura between these openings is freed from its bony attachments. On withdrawing the dissector the cerebral pressure, in most cases, suffices to hold dura against bone again, and thus serves to control such bleeding as may have been occasioned.

From these two primary trephine openings the lateral edges of the flap are then cut downward toward the base in a line concentric with the skin incision. The first half-inch of these lateral cuts is made with Montenovesi forceps, which leave a 2.5 mm. incision, followed by the weaker Dahlgren forceps, as the thinner bone near the temporal region is approached.

A Gigli wire saw is then passed on a guide, of which there are numerous forms, between the two openings and the mesial edge of the flap is cut on a broad bevel (this is an important detail, for it enables the subsequent solid replacement of the flap without danger of its being driven inward by a snug pressure-bandage). The flap is then forced back by the insertion of blunt instruments around the edges, and is broken across at its base.

Provided the flap includes the region of the pterion, the meningeal artery may be torn owing to its having channeled the broken bone. The vessel should be ligated at its lowest point of exposure by making at a distance a small opening in the dura, through which a grooved director can be inserted; on this the curved needle may be passed without danger of injuring even a tense cortex. Bleeding from the expansions of the lateral sinus, in case they have been exposed by a high flap, is best controlled by the pressure of sterile absorbant cotton, pledges of which I find to be as valuable, as a hemostatic agent for the intracranial part of the work, as is wax for the bone itself.

The intracranial procedures. At this stage, if there has been a fall of arterial tension from loss of blood, the further progress of the operation, especially in tumor cases, may well be postponed for a second session. If there is no contra-indication on this score, the dura is opened in a line concentric with the bone incision, leaving plenty of margin for subsequent suture. The membrane should be incised on a grooved director, especially if there is increased tension, for it is very important to avoid any possible injury to the pia-arachnoid. In case the tension is so great as to threaten this, a lumbar puncture should be performed at this stage of the operation.

The dural incision should not be made too near the median line, lest the edge of the parasigmoidal expansions, or the veins entering them, be injured. If the mesial edge of the hemisphere is to be exposed it is best to open the dura in this direction by a separate radial cut, and if necessary to reneur away some of the bone toward the median line.

If the expected lesion is not disclosed and if the topography is not perfectly clear, the fissura centralis may have to be determined by faradization of the cortex.

If an incision of the cortex is necessary, whether for exploration, for extirpation of a given area in cases of focal epilepsy, or for the removal of a neoplasm, such cortical vessels as will evidently have to be divided must first be ligated on each side of the proposed incision, which should, if possible, be confined to the exposed surface of a convolution, and should not cross a sulcus. The finest strands of split silk, preferably black, should be used for these ligatures, and they should be passed around the vessels with delicate curved French needles, which are introduced and emerge in non-vascular areas. Subsequent dissections are carried out with blunt instruments, and the momentary pressure of cotton pledges will usually check the oozing.

A brain which tends to protrude may sometimes be "dropped back" by elevation of the head and trunk, or by evacuating cerebrospinal fluid. This can at times be accomplished by prickng the exposed arachnoid spaces and by milking out the fluid; at other times a lumbar puncture may be necessary, and the removal of fluid in this way during the course of an operation is of the greatest possible help under many circumstances, being in large measure free from the dangers which attend a similar proceeding in the presence of great cerebral pressure when the skull is closed.

Closure. Unless there is reason for permanent decompression, in which case the dura somewhere should remain open, an accurate approximation of the membrane in its two layers should painstakingly be carried out, to prevent the formation of adhesions, or their reforma-
tion if they have been found and divided as the presumed source of irritative symptoms. If a large cerebral defect remains after the removal of a growth, or if the brain has receded from its normal level owing to evacuation of cerebrospinal fluid, the space should be filled with warm isotonic salt solution before closing the dura.

The bone flap is solidly replaced and the scalp is, in turn, accurately approximated in a broad surface. It is well to draw together the galea aponeurotica by a few buried sutures before closing the outer layer. For the latter many use a continuous suture which has the advantage of speed. Inasmuch as the closure, in many cases, is completed before the tourniquet is removed, I feel the need of a more accurate and solid approximation; this is accomplished by rapidly placing about the incision a series of straight, round-pointed cambric needles which serve to keep the edges everted as each suture is tied, and thus to assure a ridge of tissue with a flat apposition, which prevents subsequent bleeding from the vessels of the scalp (Fig. 18). An approximation of the divided epithelial edges which is beyond reproach may be secured in this way.

Drainage is occasionally advisable—perhaps in 80 per cent of the cases—but it should be avoided if possible. . . . I prefer to take advantage of the trephine openings made in this method of resection at the upper angles of the flap. The drains, of cigarette form, covered with protective so that they may be easily withdrawn, are led out, not through the original incision, but through puncture wounds made in the scalp about 2 cm. to its outer side; this insures for the drain an oblique passage which can be occluded by pressure, in case there should be a tendency for cerebrospinal fluid to escape after their withdrawal. . . .

The wound, covered with silver foil, is partly dressed and some pressure exerted before the tourniquet is removed, after which an abundant dressing with an outer starched bandage is applied. The ears should be carefully protected with cotton to prevent discomfort from pressure.

The first dressing is made in forty-eight hours, when the drains, if used, and all the sutures are removed. The silver foil and its thin inter-leaved paper, wet with alcohol, dries into a crisp protection which is particularly ideal for a head dressing. . . . It may be said, in passing, that I have never seen a bone flap lose its vitality, and indeed in one case reported with Dr. Thomas the flap was for one reason or another elevated on six occasions and a tumor finally removed at the last sitting.

My own experience does not accord with Frazier's, in that removal of bone alone, without opening the dura, will suffice for decompressive purposes in cases of tumor, and believing that a dural opening is always necessary I have come to make this opening in a situation where the protrusion will be protected—under the temporal muscle in cerebral, and under the occipital muscle in suspected cerebellar lesions. . . .

It is not always necessary to leave a beveled flap; indeed, it is not always possible. For example, in the thin skulls of infants, more especially in the new-born, it is not practicable, owing to the thinness of the bone; hence in these patients the flap is usually made through-out by a biting tool. . . .

(To be concluded)