

ORIGINAL ARTICLES.

PNEUMATIC TOURNQUETS: WITH ESPECIAL
 REFERENCE TO THEIR USE IN
 CRANIOTOMIES.BY HARVEY CUSHING, M.D.,
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SURGEONS and neurologists alike are familiar with the postoperative palsies of the extremities consequent upon the too energetic and prolonged application of an elastic tourniquet. Out of a considerable number of pressure paralyses, which have come under the writer's observation during the past two years, eight of them have thus originated. The greater number of these were of the brachial type, the tourniquet having been employed to render bloodless the field at the elbow usually for resections of the joint. A thin, flabby arm, especially in these cases of joint disease and in spite of all precautions, lends itself readily to such an injury as the poorly protected nerves are easily compressed against the hard shaft of the humerus. The skilful application of the old type of rubber tourniquet, varying it for the individual so that it exerts a compression just sufficient to shut off the arterial supply and yet not enough to harm the nerve trunks, is an art rarely acquired even by an adept hospital orderly, who may have had years of experience.

There remain other objections to its employment. One of these concerns the technic of the operation. The tourniquet usually occupies a position on the borderline of the aseptic field, and when once applied must remain so until the completion of the operation. If once relaxed, and in certain procedures, in amputations or plastic operations on aneurismal sacs for example this may be necessary in order to see whether there is a continuance of any arterial bleeding, it is most difficult to readjust the tourniquet again, should this be desirable, without dislocating all of the clean surroundings, towels, etc., at the wound. A still further drawback from an elastic band, when tightly applied, is the ensuing vasomotor palsy, evidenced by the flushing of the extremity peripheral to the site of application. In a major amputation this produces the "wet stump" oftentimes so annoying to an operator inasmuch as it necessitates drainage which otherwise might have been avoided.

Pain is another objection. In many operative procedures on the extremities, preferably carried out under local anesthesia, the temporary cessation of the local circulation is of great assistance. Patients, however, can endure the discomfort of an elastic tourniquet for a very brief period. It is furthermore a common surgical practice, and

one, I think, of questionable merit, to apply an elastic ligature, when necessary to control hemorrhage, in cases of traumatic lacerations of the extremities and to wait until the "shock" from the original traumatism wears away. Such a practice, from afferent impulses of pain due to the tourniquet alone, may add not a little to the already existing vascular depression.

Thus the possibility of paralysis, the difficulties of observing the best technic during the application, removal and especially of reapplication, and the pain when no general anesthetic is administered are all familiar drawbacks to the common form of elastic tourniquet. I think they may be avoided in large measure by the use of tourniquets of another sort.

The suggestion of an inflatable tourniquet doubtless originated in the use of the distensible armlet of the Riva-Rocci blood-pressure apparatus. On one or two occasions I had utilized the apparatus itself as a means of shutting off the circulation during cocaine operations on the hand, by holding the pressure slightly above that of the registered systolic arterial pressure. Objections are self-evident. Although the pressure of the armlet is relatively painless, its slow distention by shutting off the veins before the arteries, causes such an engorgement as to render a clean dissection most difficult. Consequently a similar armlet, though broader, of less distensible rubber and of such quality that it would stand boiling, was constructed, and by connecting it with a bicycle pump of sufficient size one or two quick strokes of the piston sufficed to fill it. Such an arrangement I have made use of many times for cocaine operations on the extremities with the greatest satisfaction. The tourniquet may be adjusted but not blown up until the moment of beginning the operation, and by palpating a peripheral artery one can tell easily when a sufficient degree of inflation has been reached.* When operating on minor cases without an assistant I have used a small bicycle foot-pump, the tourniquet either being adjusted well above the operative field before "cleaning up" or, having been boiled, placed around the member within the aseptic field just before operating. In similar fashion a larger and stronger form of cylinder than those which I have had constructed would answer for use on a muscular thigh or leg.

There is a further and a therapeutic use to which this form of peripheral construction could well be put though I have had little personal experience with this particular variety of tourni-

* It would be a refinement, of course, to insert a manometer in the course of the tube connecting tourniquet and pump, and, after measuring the tension necessary to obliterate the systolic pressure, to carry the pressure in the tourniquet slightly above this point. In a large operating room this could be conveniently and accurately done by having a tank of compressed air by which the tension could be instantly carried to the required number of millimeters of mercury.

quary therapy. Many observations, chiefly by Bier in Griefswald,* have been made to show the healing effect on chronic processes such as joint tuberculosis or the effect in the production of callus and new bone formation in pseudarthroses, etc., which is brought about by the hyperemia that follows a prolonged period of venous congestion ("Biersche Stauung") artificially produced by a loosely wrapped rubber bandage. It would seem that an inflatable tourniquet would in cases of this kind be much more easily applied, less uncomfortable for the patient and much more exact, since it is desirable to accurately regulate the degree of pressure at a certain point between venous and arterial tension.

It is, however, with this form of constriction as an operative rather than as a therapeutic aid that I have had most experience during the past two years; and, above all, in exploratory craniotomies has it been chiefly put to the test.

Since Wagner performed the great service for surgery and neurology of introducing osteoplastic resections of the skull, most operators, who have had frequent occasion to explore the cranial chamber by this method, have learned the value of a tourniquet placed about the fronto-occipital circumference. The bleeding from the long curved incision through the scalp, when this precaution is not taken, is not only the source of annoying delay before it can be sufficiently controlled, but also in the effort to secure the chief vessels there is considerable risk of partially stripping away from the bone the soft parts on which it depends for its subsequent viability. Later, when the bone flap has been elevated, the weight of pendant hemostatic forceps is especially liable to bring this about.

The method commonly employed of encircling the head with a piece of strong rubber tubing in order to control the vessels of the scalp is illustrated by a cut in Kocher's *Operationslehre*.† An elastic band of this sort may be stripped about the head from occipital base to supraorbital region where it can be knotted or held by a powerful clamp. It requires much practice and skill to properly apply such a tourniquet, and especially in children it is difficult to keep the band in its desired position and to prevent its rolling down over the orbits. In one of my patients, furthermore, it produced a most trying postoperative pressure neuritis of both supraorbitals and one suboccipital nerve after which I permanently abandoned its use.

Owing to the present limitations of our powers of cerebral localization the majority of cases, in which the skull is opened for exploratory purposes for which a wide osteoplastic flap is suitable, possess lesions which are situated well above the level girdled by a cranial tourniquet.‡ As

a matter of fact the entire surface of the hemisphere with the exception of the lower part of the frontal and temporal lobe may be exposed.

During the past year and since I have been using a tourniquet of this pattern, eighteen of my series of craniotomies have been in a situation suitable to its use. It may in general terms be said that a large area of resection is as easy (if not easier) to make and heals as rapidly as a small one. The majority of these cases, needless to say, call for an exposure of the pre- or post-central areas and it is far more simple with a large field of the hemisphere exposed to recognize the central fissure (Rolando) or to pick out with an electrode the motor strip anterior to it than to go through the usual more or less uncertain preliminary measurements and after determining on the scalp the probable situation of an underlying area to attempt its exposure through a small opening. The latter is the common practice. With any tourniquet the chief objection to a large incision, hemorrhage, is removed. The inflatable form, however, has proved so serviceable and personally I have become so dependent upon it that I unhesitatingly recommend it or a similar device to others.

Every surgeon has, of course, his more or less individual method of meeting the difficulties of the usual cranial resections. An osteoplastic opening may be made in the skull cap in various ways, any one of which with sufficient practice may suffice for its end. The trephine, burr, saws of one sort or another, mallet and chisel, the Sudek or the Stelwagon devices, the De Vibiss or Dahlgren forceps are but a few of them. What may serve one is awkward in the hands of another. All possess advantages and disadvantages. Personally for an osteoplastic resection I use a combined method which has proved so uniformly serviceable that I venture to describe the essential points of the technic. Others doubtless may use quite different methods and ones which are better adapted for their personal needs.

After preparing the patient's head a large square of gauze, wet with bichloride solution, is thrown well over it like a hood. Over this is slipped the tourniquet, which with its connecting tube has been boiled so that it can be handled and adjusted by the operator or assistant. It should fit the head snugly and lie flat against it (Fig. 1). In order to prevent any possible rolling of the tourniquet after inflation, should the shape of the head be poorly adapted to retaining it in place, the edge of the gauze hood may be drawn up over it, fore and aft, and pinned; or else, as I have occasionally done, a longitudinal tape may be used for this same purpose as shown in the accompanying photograph (Fig. 3). The tourniquet is sufficiently narrow (3 cm. on the flat) to lie, as stated above, well below the inferior areas of the motor zone. The tourniquet is then inflated and the shovel-shaped incision of whatever form desired made through gauze hood and scalp to the underlying bone. A momentary bleeding may ensue as the imprisoned vessels of

* August Bier, *Hyperämie als Heilmittel*. Leipzig, F. C. W. Vogel, 1903, p. 51. "Passive Hyperämie der Glieder durch eine Stauungsbinde."

† Vierte Auflage, 1902, p. 93.

‡ Those who choose to reflect a bone flap in operations on the Gasserian ganglion by the Hartley-Krause method, will, of course, find a tourniquet, inapplicable as it lies across the lower part of the temporal fossa.

the scalp empty themselves. It is only exceptionally necessary to clamp any bleeding points and then only on the concave side of the incision, where some of the veins may have diploetic communications. The convex side, which is the more important, remains dry.

Two openings (in a very large resection three

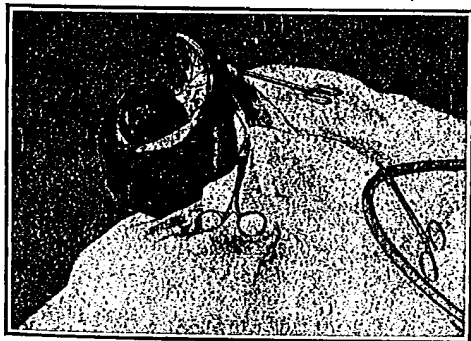
Fig. 1.



Gauze cap with tourniquet applied before inflation.

may be necessary) are then made through the skull at the angles where the superior or longitudinal portion of the incision joins the vertical sides. A small area of the skull is exposed for this purpose by retracting away the scalp on the concave edge of the incision. The openings are made preferably with a hand trephine of bevel

Fig. 2.



Bone flap elevated after inflation of tourniquet. Dura exposed, showing extradural clot.

pattern which has cutting ridges on the beveled surface. It is well to have the trephine of moderately large size (2 to 3 cm. in diameter) as any unusual amount of hemorrhage from the diploetic sinuses that may be encountered is better controlled through a large opening, or one which may be quickly enlarged if necessary by Rongeur forceps, than through the small perforations

usually made. Occasionally in long standing cases of increased intracranial tension, from tumors, etc., the diploetic sinuses may be increased to twice their normal caliber, and owing to the existing stasis their vascular tension may be greatly raised.* A very satisfactory way of controlling bleeding from these diploetic sinuses is to fill the teeth on the bevel of the trephine with bone wax, which, by the rotary motion of the instrument, becomes squeezed into the openings and thus controls the bleeding perfectly. This has been learned from experimental work on dogs, for in these animals peculiar large and symmetrically placed diploetic vessels are normally present.†

Starting from these two trephine openings the lateral edges of the bone flap are then cut in a downward direction with forceps of the De Vil-

Fig. 3.



Showing pump, connecting tube and inflated tourniquet in position; also the longitudinal tape which prevents rolling of the tourniquet after distention in those cases in which the configuration of the head is badly adapted for holding it securely in position.

biss or Dahlgren pattern which answer the purpose well since the skull becomes thinner as one approaches the base of the flap. These linear cuts in the bone should be made parallel to but slightly inside of the lateral edge of the skin incision for reasons to be explained.

A long slightly curved blunt dissector is then passed between the two trephine openings, the dura being carefully separated from the skull as the instrument advances. Alongside this as a guide is passed the end of a Gigli wire saw and the longitudinal or superior side of the bone

* It is needless to say here that for this same reason any possible pressure on the neck from position of the head, towels, etc., which can in any way press even lightly upon the jugular vessels should, in intracranial work, be studiously avoided.

† They have been described in the *Mitteilungen aus den Grenzgebieten d. Med. u. Chir.*, Bd. IX, 1902, p. 780.

quickly sawed through on a distinct bevel, the original guide meanwhile remaining in place to protect the dura by holding it away from the wire saw. The flap is then carefully elevated and broken through at its base (Fig. 2).

This entire procedure I have carried out in young adults in seven minutes. Some skulls, especially those of the negro, may require more than double this time. Speed, however, is no criterion of the desirability of a method. Those who are accustomed to follow the changes of blood pressure during critical operative procedures are well aware that rapidity, provided it is gained by the sacrifice of blood, is the least desirable of qualities.

Nothing need be said here of the means of controlling hemorrhage during the further course of an exploration save that in cases of extirpation it is well even at the expense of time to doubly ligate with delicate silk strands, passed through the brain substance with fine curved needles, all the surface vessels of any size which radiate from the area to be removed. The incision through the cortical substance made between the double ligatures thus placed, may be quite dry and what little bleeding may come from the base of the excavation is usually perfectly controlled by a few moments gentle pressure with dry sterile absorbent cotton. Dry gauze is very destructive to raw cerebral tissue. A special technic is required to prevent bleeding from the communications with the longitudinal sinus in case the exploration must pass across the median line and more particularly if it is desired to expose the leg area of the motor cortex, for it lies almost entirely under the Lacunæ laterales of the sinus into which project the Pacchionian bodies. In man there is no more difficult part of the cortex to expose than this portion of the precentral sulcus. This is, however, "another story."

On replacing the bone flap, the importance of the oblique shelf of bone made by the Gigli saw is apparent for without this the desired amount of pressure subsequently to be put upon the dressings could not be exerted without driving in the resected island of bone. Ordinarily no ligatures whatever are placed in the scalp but the edges of the incision are approximated with painstaking accuracy. For this purpose fine interrupted black silk sutures and intestinal needles are used. In this way by an exact and snug coaptation of the edges and by the slight compression of the dressing over the line of incision thus united, against the solid underlying bone, the divided vessels of the incision may be controlled. It will be remembered that the bony part of the flap is cut concentric with but a somewhat smaller diameter than the scalp incision. The local portion of the dressing over the wound is applied before the tourniquet is allowed to collapse and is removed from the head.

Though rarely, drainage may occasionally be necessary. When so, it is inadvisable to drain directly through the incision. A better practice is to lead the strip of gauze or protective or a silver

tube such as Kocher employs through a small opening made 2 or 3 cm. outside of the original incision. It is perhaps well to err on the side of drainage rather than otherwise, though in the majority of instances I find it unnecessary. Once only in a long series of cases have I regretted it for in this case the bone flap became elevated by an underlying clot and the wound had to be reopened.

In cases of exploration for cerebral tumors, provided the growth is not found or proves inaccessible, I unhesitatingly remove the bone portion of the flap extensive though it be, make no effort to close the dura over the bulging brain, and carefully unite the scalp as described above. It is in these palliative operations that the importance of an accurate approximation is most evident since with early and perfect healing a large hernia may develop without separating the skin incision. By taking these precautions I have never yet seen the lamentable sequence of a fungus cerebri develop. In one case only in my series has this occurred, and it might have been avoided had I at the time had a wider experience. The case was one in which I successfully extirpated a solitary tubercle of the cerebellum, but instead of closing the wound or of draining over the edge of bone from the outside of my original incision, I drained directly into the cavity left by the extirpation through the latter. In the course of a few days a hernia developed with a fungus cerebri, which protruded through the opening where the drain had been inserted, and in spite of all precautions infection ultimately led to the death of the patient some three months after the operation.

It is customary to make the first dressing in the ordinary run of cases on the second day after the operation, at which time the fine sutures are all removed from the line of incision. The delicate scar receives its subsequent support by placing over it long strips of gauze saturated in collodion. No further dressings are necessary, and this hard protective covering is then left untouched for two weeks or more. No cases, when handled properly, are technically so simple, nor have such an uneventful convalescence as these very cases of exploratory craniotomy—for unlike similar abdominal explorations a period of recumbency after the operation is not essential.

Not the least factor in simplifying the procedure is the use of the inflatable tourniquet, and the belief that such an apparatus has heretofore not been used is the chief reason for making this communication.