Decompressive hemicraniectomy. A review
Hemicraniectomía decompresiva. Una revisión

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Abstract

Even though Decompressive Hemicraniectomy has been utilized already for a few decades, currently no consensus about its indications or the clinical conditions in which it should be done has been reached. An attempt has been made here to bring the knowledge on these issues up to date together with a description of its surgical technique.

Key words: Craniectomy, intracranial pressure, brain edema, outcome.

Resumen

Si bien es cierto que la hemicraniectomía descompresiva se ha venido utilizando ya por algunas décadas, en la actualidad aún no se ha llegado a un acuerdo sobre sus indicaciones ni en qué condiciones clínicas este procedimiento debiera llevarse a cabo. Aquí se ha intentado exponer el estado actual del conocimiento en ese ámbito y se ha descrito su técnica quirúrgica.

Palabras clave: Craniectomia, presión intracraneana, edema cerebral, estado funcional.

Introduction

Different types of cerebral insults, be it traumatic, hemorrhagic or ischemic, may cause brain edema, which, depending on its intensity, can lead to an increase in intracranial pressure (ICP) with a concomitant decrease in the cerebral perfusion pressure (CPP). If this goes beyond certain limits, it may result in secondary brain damage. Decompressive hemicraniectomy´s rationale is to maintain ICP below 20 mm Hg to prevent that secondary damage.

Part I: Indications and timing for the procedure

Decompressive Hemicraniectomy (DHC) can be used as a prophylactic measure to control anexpected rise in ICP[2] or as part of a protocol to reduce elevated ICP not responding to intensive medical management[6]. It is indicated when, regardless of the actual type of insult causing the ICP elevation, the resulting brain edema affects mostly one side of the brain and consequently can cause midline shift leading to transtentorial herniation and death.

While it has become clear through a number of controlled randomized studies[7,17,22,27] that in traumatic brain injury DHC can bring about a significant decrease in ICP with a resultant reduction in mortality, its effect on the neurological function of the surviving patients has not been so far clearly established but it would appear to result in an increase in the number of patients with a poor functional outcome[7,18]. However, when DHC is done in cases of middle cerebral artery infarction[14,21,28] the results are so far encouraging, showing a decrease in mortality without an increase in the number of severely disabled patients.

A third potential indication for DHC presents itself in patients with a high grade aneurysmal subarachnoid hemorrhage and intractable elevated ICP. In these cases a persistent elevation of ICP beyond 20 mmHg may occur early after the ictus or later, due to the development of hematoma, acute hydrocephalus or ischemia with brain edema secondary to vasospasm[10,12,19]. The time span between the actual elevation of ICP and the performance of DHC, particularly in patients without a radiologically demonstrable infarction, appears to be important for the out-

come of these
patients[5,12,25] and early DHC done immediately after aneurysm coiling or simultaneously with aneurysm clipping, seems to improve the eventual results[19,20]. In spite of these impressions, the actual benefit of DHC in this setting awaits the result of a prospective randomized controlled trial[22].
A relevant topic to consider here is the clinical condition in which DHC should be carried out, all the while there is no consensus regarding this issue. While a poor neurological condition should not preclude the performance of DHC and an acceptable outcome is still possible, in patients with fixed and dilated pupils and/or other signs of severe brainstem dysfunction, the possibility of a good outcome is slim because the reversibility of that condition is unlikely. The only exception to that rule relates to pediatric cases, where remarkable and unexpected recoveries may occur[1,13].

Part II: Preoperative care and surgical technique

Preoperative care
The coagulation status should be checked and any abnormality should be corrected as much as possible. Blood typing and cross matching for at least one unit of blood should also be done. If not already in place, an ICP monitor should be placed in the side opposite to the planned DHC and ICP should be controlled to prevent rises either prior to or during the patient´s transfer to the operating room. Prophylactic wide-spectrum antibiotic coverage should be started with induction of anesthesia, as well as the placement of TEDs or any other thromboembolic preventive measure.
A Foley catheter, if not already in place, should be set to ensure free bladder decompression in the eventual use of Mannitol or hypertonic saline prior to, during or after the procedure.
In trauma cases, cervical spine clearance is indispensable to allow freedom in the patient´s positioning in the operating table. If this is not feasible, mobilizing the cervical spine should be kept to a minimum and the head´s adequate position should be attained by placing the patient in the proper oblique position in the operating table, taping him securely to it and fixing the head with a Mayfield pin head-holder (Codman Inc. Rayham, MA). Additional final adjustments can then be gotten by tilting the operating table[15].

Surgical technique
Once in position, the scalp is shaved and routine Betadine scalp preparation is done. After appropriate draping, the incision begins at a point slightly below the upper edge of the zygomatic arch and about one cm anterior to the tragus. Care should be taken here to identify and protect the superficial temporal vessels to ensure, as much as possible, the blood supply to the planned extensive scalp flap[26]. The incision then curves around the anterior and superior aspect of the pinna and extends then backwards to the posterior temporal region for a length of about 10-12 cm. Hemostasis of the scalp edges is progressively secured with Raney clips. The incision is then turned upward toward the parietal area to a point about 3 cm from the midline where it turns again, this time forward, following a course parallel to the midline but staying about two cm from it until reaching the frontal area, where it stops behind the hairline. There it makes a short curve towards the midline where it ends, thus completing a question mark design.
The scalp flap is raised by progressive dissection along the subgaleal space, separating it from the periost and temporal fascia either manually with a surgical sponge or by sharp dissection following the same plane. Then it is reflected forward down to the eyebrow line, paying attention to place under it a rolled-up surgical sponge at the forehead to prevent undue angulation of the scalp flap, which could interfere with its blood supply during the procedure.
The exposed periost is then incised as a flap, following the same pattern of the scalp incision leaving at its base the temporal muscle. The periost is then elevated from the skull together with the temporalis muscle down to the zygomatic arch. This periosteal-muscular flap is reflected laterally and it is covered with wet towels to prevent its shrinkage. A burr hole is placed just superior to the root of the zygomatic arch at the “key hole” position and then, with a round 5 mm burr, small burr holes are made following the contour of the planned skull flap, separated from each other by about 5 cm and keeping a distance of about two cm from the sagittal suture to prevent injury to the sagittal sinus and/or the bridging veins. At each one of these small burr holes the dura is carefully separated from the undersurface of the skull and then, starting at the key hole, a craniotome is used to connect each one of these small burr holes, having avoided, as much as possible, a dural tear. This step becomes particularly important when dealing with older patients, because in them, the dura, which is the periosteum of the inner table of the skull, becomes progressively more adherent to it[9]. Once this step is completed, the skull flap is carefully elevated and removed from the field. Excess bone at the temporal squama is removed with a Leksell rongeur to ensure adequate temporal decompression.
The removed skull flap is then thoroughly rinsed with antibiotic solution (Neomycine), packed with sterile towels, wrapped in plastic, clearly identified, dated and stored in a deep freezer at -80ºC until the time of the cranioplasty[11].
Because the dura is pushed against the undersurface of the skull by the underlying swollen brain, there is a need for only few tacking dural sutures along the bone edge of the craniectomy. The exposed dura is incised in a semicircular fashion[22,26,27] with its base toward the sagittal sinus but staying about two cm from the bony edge at each end.
Ideally a piece of periost of adequate dimensions is harvested from the periosteal flap already elevated and it is placed to cover the now exposed cortex. It is tucked under the dural edge all around the dural opening and fixed to it without tension with a running or interrupted suture of 4-0 Neurolon (Ethicon US, Somerville, NJ, USA) to complete a watertight duroplasty. The purpose of this duroplasty is twofold. Firstly it is to prevent the swollen brain tissue from herniating through the dural opening risking its strangulation and, secondly to enlarge that area of the dural sac, so as to accommodate the swollen brain, thus controlling the ICP. If the quality of the periosteal tissue is not adequate for that purpose, any other available dural substitute material can be used instead [3] but the newest *absorbable* dural substitutes like Cerafix^{R} (Acera Surgical St.Louis, MO, USA), Ethisorb^{R} (Codman, Raynham, MA, USA) or Seamdura^{R} (Gunze Ltd, Kyoto, Japan) should be avoided because, since a second surgical procedure i.e. the cranioplas-

ty, is planned in the near future, the absorptive/in growth process, innate to these materials, may not have been completed at that time and it could result in a reoccurrence of a dural defect at that second procedure.

When the duroplasty has been completed and hemostasis achieved, three or four parallel incisions are made along the length of the undersurface of the scalp flap involving only the galea, and separated from each other by about two cm. The purpose of these incisions is to increase the suppleness of the scalp flap so that, when it is laid over the exposed bulging dura it does not exert undue pressure over the underlying swollen brain when it is repaired. At this stage it is advisable to place a sterile sheet of Silicone Elastometer (Bendec Medical Inc. USA)[23] or Polytetrafluoroethylene (Preclude^{R} dural substitute. WL Gore & Associates Inc. USA)[29] to cover the exposed dura. This material is covered in turn by the remaining periost and the temporal muscle. Over them the scalp flap is reflected back in position and repaired in two layers with inverted interrupted sutures of Vycril 3-0 for the galea and a running suture of Neurolon 4-0 for the skin. The silicone elastomer or the polytetrafluoroethylene are an important addition to this procedure and its purpose is to prevent the formation of adhesions between the galea, the temporal muscle and the dura, adhesions that, when present, cause a significant difficulty at the time of the cranioplasty because their dissection poses the risk of dural lacerations further increasing the operating time and the blood loss[4,23,29].

Like any other surgical procedure, where postoperative complications can occur, DHC is no exception but it can also be affected by a number of *specific* complications both in the early as well as in the late postoperative period. Firstly, if the size of the achieved decompression is not sufficient, the swollen brain may bulge through the craniectomy causing undue pressure upon itself and upon the veins at the bony edge, which could result in a venous infarction and further increase in the ICP, thus closing a vicious cycle. Furthermore, in the presence of a coagulopathy or poor hemostasis, hematomata can develop in the temporalis muscle or in the subgaleal or epidural spaces, while ischemic brain tissue can also undergo hemorrhagic transformation. All these potential complications can impact on ICP and demand intensive clinical as well as ICP monitoring together with a "quick on the trigger" approach to detect them early with CT scanning, enabling their timely correction.

Complications that occur after the acute post-operative period are mostly related to the altered intracranial physiology caused by the change effected on the skull by the craniectomy, which turns an unyielding structure into a yielding one, thus exposing its content to the atmospheric pressure. This may cause changes in the CSF dynamics with the development of subdural hygromas, hydrocephalus or other ill-defined clinical conditions such as the "syndrome of the trephined" or the "syndrome of the sinking scalp flap" which seem to be related to the protracted presence of a large skull defect[16]. These complications could be prevented, at least in part, by not delaying unnecessarily the performance of the cranioplasty[8,24,30].

Part III: Cranioplasty

Once the patient has recovered from the DHC, a cranioplasty should be done to restore the skull to its compliant condition and reestablish the normal intracranial physiology and cerebrospinal fluid dynamics. This can be accomplished by using the preserved autologous skull flap[11], or by the use of titanium or other synthetic material with or without a 3D reconstruction based on a postoperative CT scan[27].

While the need of skull reconstruction in such a large skull defect is obvious, the best timing for it´s performance is still a matter of debate. While some neurosurgeons advocate one month after the DHC as the appropriate time to do it[29], others suggest longer periods of time, up to eleven months[23], adducing an increase chance for infection when the cranioplasty is done too close to the DHC.

In my experience a period of three to six weeks after the DHC has proven sufficient to enable the complete healing of the scalp wound, resolution of the brain bulge through the skull defect as visualized by CT scan while also allowing for the complete healing of the duroplasty. Moreover, this period of time is short enough to avert (in the absence of Silicone elastomer or polytetrafluoroethylene) the development of too severe dural adhesions and, more importantly, enable an early restoration of the normal intracranial physiology and CSF dynamics, thus diminishing the possible occurrence of delayed complications[8,24]. I have experienced so far no infections using that time frame.

On the morning of the planned cranioplasty and when the skull flap has been deep-freeze preserved, the frozen skull flap is taken out of the deep-freezer and brought to the operating room within its sterile package. Once thawed, it is again rinsed with antibiotic solution in preparation for its re-implantation.

After prophylactic wide-spectrum antibiotics are given and general anesthesia is induced, the previous incision is reopened and the scalp flap is easily separated and elevated from the exposed dura by removing the sheet of silicone elastometer or the polytetrafluoroethylene. After thorough clearance of scar tissue along the bony edge of the craniectomy defect, the thawed skull flap is placed in its anatomical position and pairs of corresponding drill-holes are made both along the edge of the craniectomy as well as along the edge of the skull flap.

A layer of Gelfoam is then placed over the exposed dura and the autologous deep-freeze preserved skull flap is replaced in its anatomical position. Sutures of 3-0 silk are passed through the previously drilled corresponding holes and tied in succession to establish good fixation and contiguity between the skull defect edge and the skull flap edge to facilitate its later revitalization.

This fixation method, in my experience, has showed no untoward effects, it is generally available and it is not expensive, nevertheless any other fixation method i.e. mini-plates, Cranio-Fix^{R}, etc. can also be used as per surgeon´s preference[29].

The scalp flap, with the already adherent to it temporal muscle and periost is replaced in its original position and repaired with inverted interrupted sutures of Vycril 3-0 for the galea and a running suture of Neurolon 4-0 for the skin.

Conclusion

In spite of the existing uncertainties, and while these issues are eventually settled by the neurosurgical community at large, there are clinical situations

where DHC is been currently carried out, as a measure of last resort. It is in these circumstances where a careful surgical technique and attention to detail are very important to prevent potential complications and avoid turning an already difficult situation into a worse one. Only when definitive evidence establish clear DHC indications and the best timing for its performance, further improvement in these patient´s outcome could be expected.

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