DECOMPRESSIVE CRANIECTOMY – FROM OPTION TO STANDARD - PART I

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Authors intend an update to the theoretical and practical data on a seldom utilized technique but often considered as last therapeutically option, so the necessity to realize it correctly. The authors present the history, the physiopathology of the technique, the surgical steps and options, together with details on the complications, surgical indications.

Keywords: decompressive craniectomy, indications

INTRODUCTION

The decompressive craniectomy is a surgical technique known for more than a century, but its utility variated from none to everything according to neurosurgeons. Actually, it reappears after the papers of Guerra [1] from 1998 and is utilised for a wide range of pathologies, from traumatic to vascular and tumoral, but all realising an refractory intracranial pressure. Unfortunately there is a lack of consensus upon when to realize a decompressive craniectomy among authors, which leads to the fact that most neurosurgeons seldom see a correct deompressive craniectomy and even less performs one.

HISTORY

The first decompressive craniectomies were presented by Kocher in 1901, Cushing in 1903 and Horsley in 1906, in a period when most surgery was realized through a large „exploratory"bone flap – when no lesion was found, some authors suggested removing the bone flap to decompress the brain from the lesion. Unfortunately, the aesthetical results were disastrous and led to limiting the technique.

In traumatic pathology the method knew supporters and detractors [2]: Erlich (1940) suggested a decompressive craniectomy for all head injuries with persistant coma for more than 24-48 hours – without a specific diagnosis most cases woul have died anyway. Rowbotham (1942) recommanded decompressive craniectomy for all traumatic comas which improved at first and when medical treatment was ineffective for 12 hours. Munro (1952) suggested that if intraop the brain was contused and swollen to realize a large craniectomy and opening the dura mater.

Among adversaries are Mayfield, Lewin, Moody, whose papers during 1960-1970 note a high mortality rate for the technique and discourage its utilisation.

After the introduction of CT scan, in 1975 , Ramshoff, Morantz and others present series of comatose patients wiht acute subdural hematomas, operated during the first 6-12 hours, with decompressive craniectomies realized by necessity. Despite technical and esthetical problems, they report a survival rate of 40% with 27 % return back to a previous life – however the method doesn't meet a genereal approval.

The desert of redescovering the decompressive craniectomy belongs to Guerra in 1999 who presents in Journal of Neurosurgery his personal results of 20 years of decompressive craniectomy using CT scan and ICP monitoring. His good results lead to the acceptance of the technique as second-tier therapy for

refractory intracranial pressure. The following 5 years know more than 50 papers[4] dedicated to decompressive craniectomy leading to sections of neurosurgical meeting dedicated to the technique and at least 2 prospective double blind multicentric studies in going on its indication in traumatic pathology

PHYSIOLOGY

The purpose of decompressive craniectomy is to diminish the intracranial pressure, no matter its the lesion, when ICP raises to alarming values. The threshold of ICP variates from children, which tolerate larger values when sutures are still open, to adults and according to pathology. The limits of well tolerated ICP, together with lowering of CPP, variate from 18-20 mm Hg in subarachnoid hemorrhage, 20-22 mm Hg for malignant sylvian stroke, 25 mm Hg for trauma and 30-40 mm Hg for slow growing tumors and hydrocephalus [5]. Some of these values are among what is considered a normal ICP but with an ailing brain. When medical treatment becomes ineffective, the decompression realizes an „enlargement" of the intracranial space, preventing a further raise of ICP and cerebral herniations. Moreover, Doppler and perfusion MRI studies showed an increase of blood flow in leptomeningeal vessels, an increase of backward flow in the sylvian artery togther with the perfusion of the ischemic penumbra area.

In order to realize a real decompression, we need to evaluate the volume gained on surgery – considering a circular craniectomy and a bulging of just 10% of the surface to prevent ischemia on the bone flap's edge, Aschoff calculated the following [Fig. 1]:

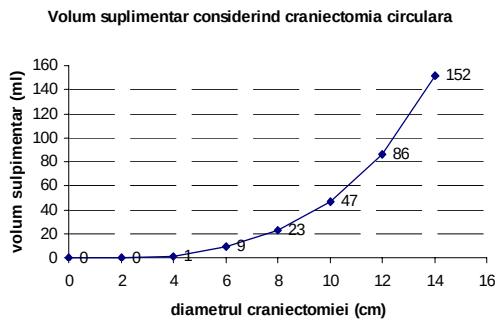

FIG. 1

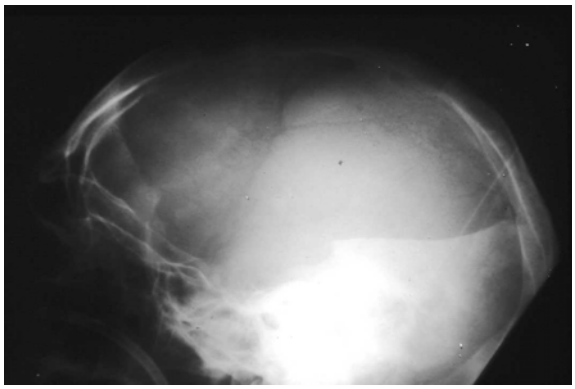

FIG. 2

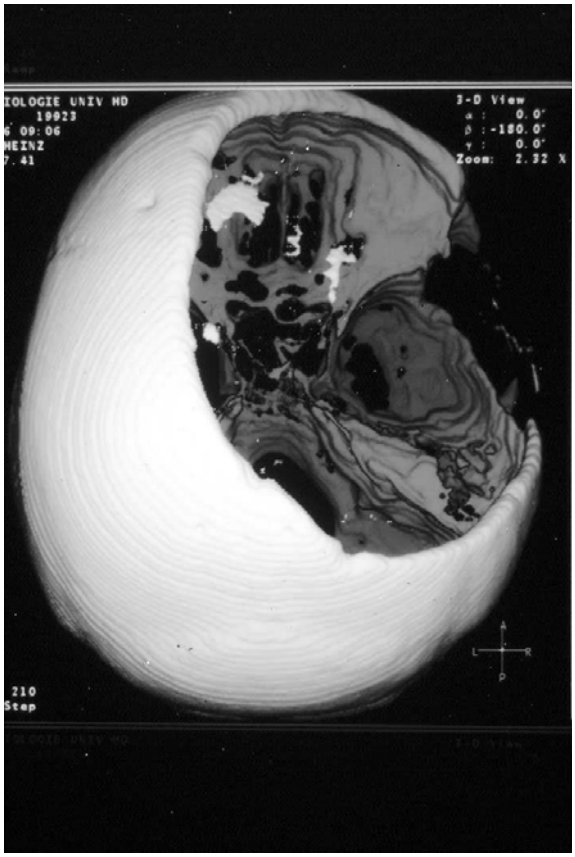

FIG. 3

Apparently a craniectomy of 8 cm large would appear large enough but in fact it gives just 23 ml additional volum so 1.5% of total cerebral volume. To obtain a real decompression, most authors recommend a minimum

diameter of 12 cm or more (86 ml additional volume) Fig. 2, 3.

The additional volume obtained by a decompressive craniectomy is consequently superior to the one realized by hyperventilation (2 ml / mm of lowering pCO2); superior to a ventricular tap of 20-30 ml and without the risk of rebound of loop diuretics.

SURGICAL PROCEDURE

Mainly there are two types of decompressive craniectomies – the hemicraniectomies, most frequent, when bone resection involves just one hemisphere; bilateral craniectomies, seldom used.

1. hemicraniectomy – ideally would imply bone resection over one whole hemisphere, including the temporal fossa till the zygomatic bone, going posterior to a line which connects the tragus with asterion and respecting the horizontal segments of the skull in the superior parietal area. Practical, more often we realize just a wide craniectomy, more than 12 cm diameter, which descends in the temporal fossa and goes posterior according to a vertical line through the asterion.

If available, the head of the patient shoyld be fixed in a Mayfield head holder, with two screws in the occipital area and one in the frontal, maintaining thus the antero-posterior axe of the head parallel to the ground. In absence of the Mayfield, any lateral supine position is convenient, providing a fixation of the head to the operatory table with no reduction of the operatory field..

The incision should provide wide access to the whole hemicranium, with two common technical options.

FIG. 4

FIG. 5

The first option [Fig. 4] is analogous to the classical "question mark" flap, utilized in traumatic pathologies but extended more posterior. The incision starts at temporal level then goes superior, in order to preserve the blood supply of the fla p from the superficial temporal artery. The temporal muscle is dissected in one plane, attached to the flap (some prefer to harvest the temporal fascia for later duroplasty). The advantage of this incision resides in the fact that most neurosurgeons are accustomed to anatomical structures – but in the posterior segment of the flap the blood supply is low and leads to several complications, especially dehiscent wound or skin necrosis.

If when starting the incision the supperficial temporal artery is accidentally cut, it is mandatory to use the second incision [Fig. 5], less classic and time consuming but withut ischemic complications at the operatory wound due to preserving the occipital artery and thus a better blood supply.

Bone resection is realized with available craniotomes or Gigli saw [Fig. 6, 7]. Dura mater is incised radial or with pedicle on the middle meningeal artery and the duroplasty with periost, muscle fascia or quicker with dural substitutes. We do not advise to let the dura mater intact because it is NOT elastic, compromising the purpose of the operation; again we do not advise to let the dura mater free because it will be more difficult to realize the dissection on cranioplasty. The bone flap is preserved, (in theory), by introduction in the abdominal fat – practical the manoeuvre extends the operation for at least one hour and that's why most prefer the organ bank (where available) or simple freezing.

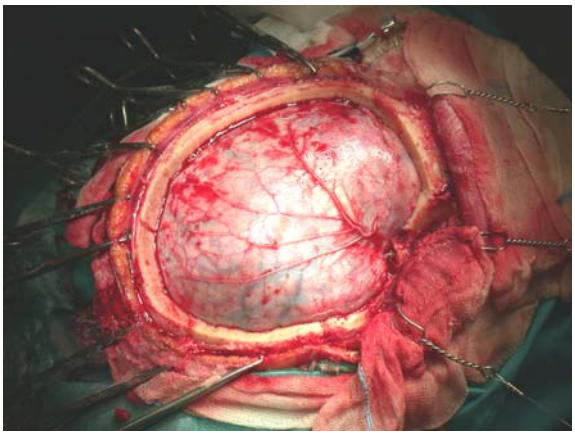

FIG. 6

FIG. 7

2. bilateral craniectomies involve the bone resection described previously on both sides while preserving a bone ridge of 3-4 cm over the superior longitudinal sinus. The intraop positioning is difficult, due to the impossibility of using the Mayfield holder. Additional problems arise later, being difficult to avoid the bone resection in a supine position and maintaining the patient head directed to the zenith.

Far more common used is the bifrontal decompressive craniectomy [Fig. 8, 9], especially on diffuse cerebral edema or contusive bifrontal lesions [6]. The dural incision is bilateral, directed towards the sagital sinus, with duroplasty at the inferior (temporal) segment, while respecting the technical indications from unilateral craniectomy. A variant of the bifrontal craniectomy implies preserving a frontal median bone ridge over the sagital sinus.

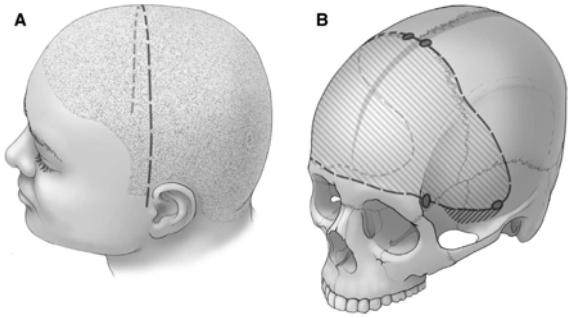

FIG. 8

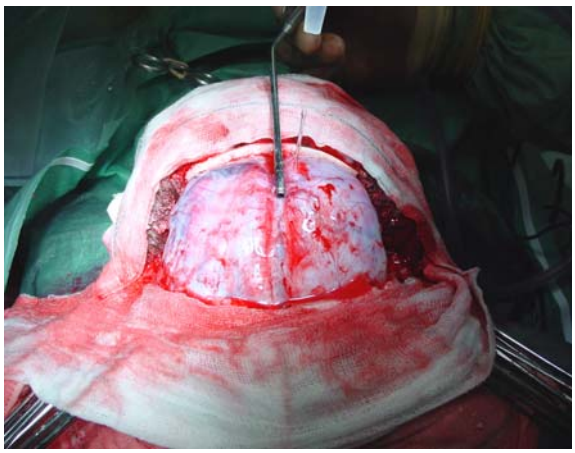

FIG. 9

COMPLICATIONS

No surgical technique is exempt of complications and decompressive craniectomy is no exception. Moreover, lack of experience of surgeons who realize it once per year or unknowing the correct technique can lead to additional complications to those inherent to a very large craniectomy.

Acute complications:

• hemorrhagic contusions at the level of the decompressed brain – classical complications,

characteristic to traumatic pathology, is due to lowering the intracranial pressure to normal values, but allowing hemorrhage from anterior compressed capillaries (initial high pressure realized hemostasis through compression). It does not represent a complication but a normal evolution of the lesion and there is no way to prevent it.

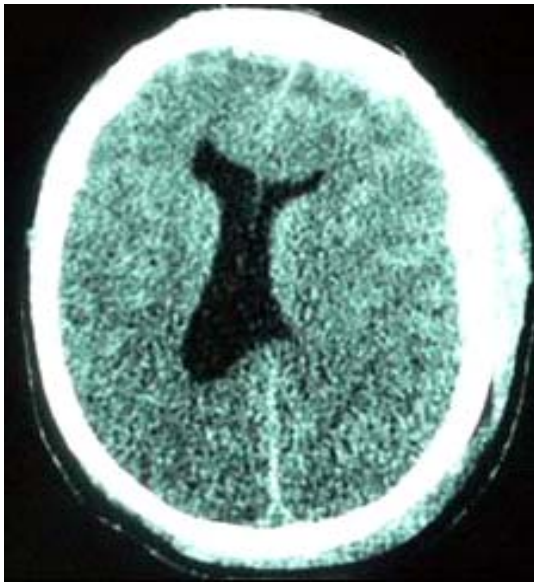

FIG. 10 A

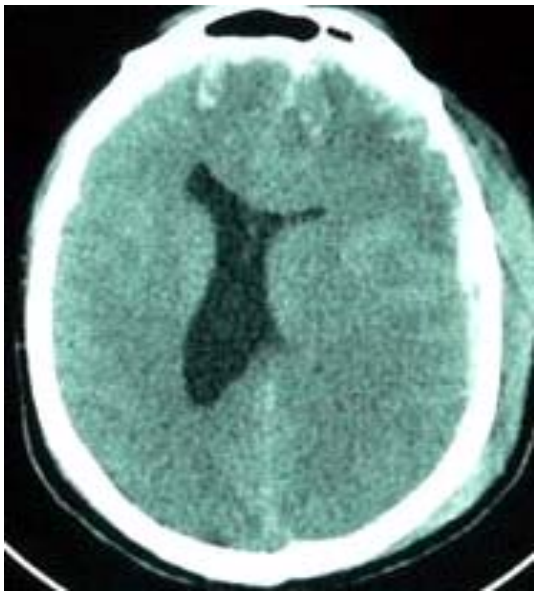

FIG. 10 B

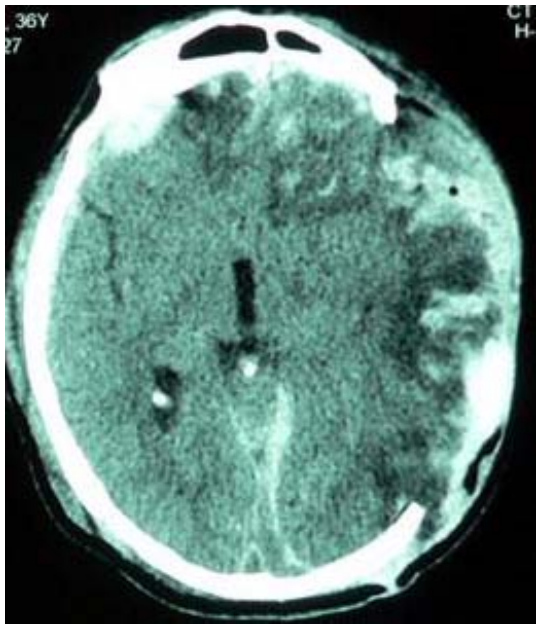

FIG. 10 C

The images present the case of a 21 y old patient, with severe head injury due to a politrauma – initial GCS at 11 (Fig. 10a), aggravated during transport to GCS = 5 (Fig. 10b) who was decompressed even before installing a monitoring of ICP. Ct scan realized on D2 reveals large areas of hemorrhagic contusions at the level of the decompressed hemisphere.

• Fongus cerebri, the herniation of the brain ("mushroom"), at the level of the bone flap is most frequent the result of a bone flap not enough large, when cerebral decompression is not sufficient and high intracranial pressure displaces the already contused brain through a small breech in the skull – aspect wide known to neurosurgeons, especially for acute subdural hematomas

To the initial raised intracranial pressure is superposed the compression of cortical veins on the bone's edge, realizing thus venous stasis and later venous infarction. The difference between these later lesions and cortical contusions resides in the moment of onset, later than for brain contusions and the more homogenous aspect of hemorrhage adjacent to the bone's edge (Fig. 11). Such compression can be avoided by realizing the "vascular tunnel" described by Csokay [9].

• The development of controlateral hematomas especially acute subdural or epidural was already described, its mechanism being similar to hemorrhagic contusions, through bleeding from a bridge vein or a bone fracture. These hematomas are characteristic to traumatic pathology decompressed in the first 24h.

FIG. 11

FIG. 12

Less frequent is the apparition of compressive higromas (Fig. 12) on the same side as decompression, with a more unclear mechanism.

• Wound dehiscence is frequent due to the high pressure from interior which maintains sutures in tensions and concomitant ischemic / necrotic phenomena due to a low blood supply for the flap's dimensions. It occurs more frequent when accidentally coagulating the superficial temporal artery when realizing the skin flap.

LATE COMPLICATIONS

• Posttraumatic hydrocephalus – frequent, due to obstruction of resorbtion of CSF by traumatic SAH and to modifications of CSF pressure and circuit by decompression. Among the factors contributing to posttraumatic hydrocephalus, Mazzini [10] calculated a p=0.01 significance fro decompressive craniectomy so high statistic.

Many problems occur on treating this hydrocephalus which is different from the classic one due to the large bone flap. It is mandatory to use an adjustable valve, initially fixed on medium pressure then progressively raising to high pressure, to avoid the overdrainage with sinking of cutaneous flap (fig 13). After realizing a cranioplasty, the pressure in the valve should be returned to nomal.

• Problems connected to cranioplasty occur due to resorbtion of autologuos bone – the devitalized bone is considered as foreign body.

• Infections are the most frequent and most dangerous among the complications of decompressive craniectomy, especially for traumatic pathology. Despite a correct bone flap and even more without a correct technique, due to a long bed rest in the ICU department, with one position of the head, wound dehiscence appear, sometimes even after a month postop, with CSF fistula, bacterial colonization. Some can be treated by resuturing the wound, but most of them realize an infection with ICU germs, multiresistant, leading to subdural empyema or brain abscess (fig 14). Another germ source is ventilated associated pneumonia, quite common after several days of intubation, on a patient with clean operatory wound.

• The «trephined patient» syndrome unites symptoms difficult explicated by othe pathologies which disappear after cranioplasty. Most frequent manifestation is as focal neurological signs, developed after 3-6 months after initial surgery and absolutely without lesions on CT/MRI.

FIG. 13 decompressive craniectomy, drained from the frontal horn with overdrainage and "sinking flap"

FIG. 14 subdural empyema under the decompressed area and frontal brain parafalx

INDICATIONS

There is actually just one class I indication for decompressive craniectomy - malignant sylvian stroke in people less than 60 old [8], and still there are controversies. Most studies involving decompressive craniectomy are retrospective and the few prospective ones were realized on patients with refractory raised intracranial pressure as salvage therapy. There are at least 2 prospective studies ongoing – RESCUE ICP – european multicentric study initiated by Cambridge (UK) and another one in Australia, initiated by teams of Sidney and Canberra, both on traumatic cases, but till summer 2008 less than 120 cases were included.

There are also several proposals of using profilactic decompressive craniectomies whenever exists a high risk of evolution towards a refractory raised intracranial pressure [7] or when the neurosurgeon's experience suggests this – like acute subdurals hematomas associated with large contusion, subarachnoid hemorrhage or severe meningitis [11, 12]. These indications will be discussed in part 2 of the article.

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