Decompressive craniectomy (DC)

see also Osteoplastic decompressive craniotomy.

It is a neurosurgical procedure in which part of the skull is removed and the underlying dura opened to reduce brain swelling-related raised ICP, thereby preventing intracranial tissue shifts and life-threatening downward herniation.

It can be performed as a primary or secondary procedure.

Once performed, patients are obligated to undergo another surgical procedure known as cranioplasty to reconstruct the cranial defect.

History

The concept of decompressive surgery for treatment of intracranial hypertension has been developed already in the beginning of the 20th century by Emil Theodor Kocher.

The first modern report of the use of DC following TBI was published by Harvey Williams Cushing in 1908. [1)].

The use of decompressive hemicraniectomy (DHC) in the context of ischemic brain edema had been reported already in 1956 [2)].

Classification

Decompressive craniectomy classification.

Indications

Decompressive craniectomy indications.

Follow-up treatment

After a craniectomy, the risk of brain injury is increased, particularly after the patient heals and becomes mobile again. Therefore, special measures must be taken to protect the brain, such as a helmet or a temporary implant in the skull. When the patient has healed sufficiently, the opening in the skull is usually closed with a cranioplasty. If possible, the original skull fragment is preserved after the craniectomy in anticipation of the cranioplasty.

Trials

RESCUEicp study

DECRA Trial

RESCUE ASDH Trial

In addition to reducing ICP, studies have found decompressive craniectomy to improve cerebral perfusion pressure and cerebral blood flow in head injured patients.

Decompressive craniectomy is also used to manage major strokes, associated with “malignant” edema and intracranial hypertension. The pooled evidence from three randomised controlled trials in Europe supports the retrospective observations that early (within 48 hours) application of decompressive craniectomy after “malignant” stroke may result in improved survival and functional outcome in patients under the age of 55, compared to conservative management alone.

The procedure is recommended especially for young patients in whom ICP is not controllable by other methods.

Age of greater than 50 years is associated with a poorer outcome after the surgery.

Size

Decompressive craniectomy size.

Biomechanical aspects

The brain tissue deformation occurring in these patients is difficult to quantify. Twenty-six patients suffering from a large bone defect after craniectomy were examined in supine position. The third ventricle's axial diameter was measured by transcranial ultrasound. Subsequently, the patient was brought into a sitting position. After 5 minutes, another measurement was taken. This procedure was repeated about 7 days after cranioplasty. The patients were grouped according to “early cranioplasty” (cranioplasty within 40 days after craniectomy, median 30 days) and “late cranioplasty”, (cranioplasty more than 40 days, median 80 days). Data of 13 healthy volunteers were used as a reference standard. In the healthy volunteers, the third ventricle was enlarging after reaching the sitting position. The median diameter was 2.35 mm in the lying and 2.9 mm in the sitting position ($p > 0.05$). In the patients before early cranioplasty, a decrease of the diameter after reaching the sitting position was observed. The mean diameter was 7.0 mm in the lying and 5.9 mm in the sitting position ($p > 0.01$). This difference was not significant in patients before late cranioplasty (9.7 vs. 9.4 mm). After cranioplasty, the mean diameter was 6.6 and 6.2 mm in the early cranioplasty group and 9.2 mm and 9.4 mm in the late cranioplasty group (lying and sitting position, respectively). This data demonstrate for the first time that unphysiological orthostatic brain tissue deformation occurs in patients after craniotomy [3).

Complications

see Decompressive craniectomy complications.

Outcome

A retrospective study based on analysis of clinical and neurological outcome, using the Extended Glasgow Outcome Scale in 56 consecutive patients diagnosed with severe traumatic brain injury treated from February 2004 to July 2012. The variables assessed were age, mechanism of injury, presence of pupillary changes, Glasgow coma scale (GCS) score on admission, CT scan findings (volume, type and association of intracranial lesions, deviation from the midline structures and classification in the scale of Marshall computed tomography classification and Rotterdam CT score.

96.4% of patients underwent unilateral decompressive craniectomy (DC) with expansion duraplasty, and the remainder to bilateral DC, 53.6% of cases being on the right 42.9% on the left, and 3.6% bilaterally, with predominance of the fourth decade of life and males (83.9%) [4).].

The stretching of axons may contribute to an unfavorable outcome in patients treated with DC.

The deformation of the brain tissue in the form of a Lagrangian finite strain tensor for the entire brain was obtained by a non-linear image registration method based on the CT scanning data sets of the patient. Axonal fiber tracts were extracted from diffusion-weighted images. Based on the calculated brain tissue strain tensor and the observed axonal fiber tracts, the deformation of axonal fiber tracts in the form of a first principal strain, axonal strain and axonal shear strain were quantified. The greatest axonal fiber displacement was predominantly located in the treated region of the craniectomy, accompanied by a large axonal deformation close to the skull edge of the craniectomy. The distortion (stretching or shearing) of axonal fibers in the treated area of the craniectomy may influence the axonal fibers in such a way that neurochemical events are disrupted. A quantitative model may clarify some of the potential problems with this treatment [5)].

Formation of postoperative subdural hygroma after the operation was found to be associated with favorable outcome (p=0.019) [6)].

Case series

Decompressive craniectomy case series.

Case reports

Two patients who underwent decompressive craniectomy after head trauma deteriorated secondary to paradoxical herniation, one after lumbar puncture and the other after ventriculoperitoneal shunting. They motivated the authors to investigate further provoked paradoxical herniation.

The authors reviewed the records of 205 patients who were treated at a single hospital with decompressive craniectomy for head trauma to identify those who had had lumbar puncture performed or a ventriculoperitoneal shunt placed after craniectomy but before cranioplasty. Among the patients who met these criteria, those with provoked paradoxical herniation were identified. The authors also sought to identify similar cases from the literature. Exact binomials were used to calculate 95% CIs. RESULTS None of 26 patients who underwent a lumbar puncture within 1 month of craniectomy deteriorated, whereas 2 of 10 who underwent a lumbar puncture 1 month afterward did so (20% [95% CI 2.4%-55.6%]). Similarly, after ventriculoperitoneal shunting, 3 of 10 patients deteriorated (30% [95% CI 6.7%-65.2%]). Timing of the procedure and the appearance of the skin flap were important factors in deterioration after lumbar puncture but not after ventriculoperitoneal shunting. A review of the literature identified 15 additional patients with paradoxical herniation provoked by lumbar puncture and 7 by ventriculoperitoneal shunting.

Lumbar puncture and ventriculoperitoneal shunting carry substantial risk when performed in a patient after decompressive craniectomy and before cranioplasty. When the condition that prompts decompression (such as brain swelling associated with stroke or trauma) requires time to resolve, risk is associated with lumbar puncture performed ≥ 1 month after decompressive craniotomy [7].

1)

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2)

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3)

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4)

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5)

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6)

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7)

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