Decompressive craniectomy following brain injury: factors important to patient outcome

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Background: Decompressive craniectomy (DC) is often performed as an empirical lifesaving measure to protect the injured brain from the damaging effects of propagating oedema and intracranial hypertension. However, there are no clearly defined indications or specified guidelines for patient selection for the procedure.

Aims: To evaluate outcome determinants and factors important in patient selection for the procedure.

Methods: We reviewed the literature on DC, including single case reports and reported case series, to identify factors affecting outcome following the procedure, as well as its pitfalls and associated complications.

Results: Glasgow coma score of 8 and above, age less than 50 years and early intervention were found to be among the most significant determinants of prognosis.

Conclusion: Improving patient selection for DC may be expected to further improve the outcome following the procedure in severely brain-injured patients.

Keywords: decompressive craniectomy; indications; intracranial hypertension; outcome; patient selection

Decompressive craniectomy (DC) is a surgical procedure in which an area of skull is removed to relieve intracranial pressure. It is often performed as an empirical measure to protect the injured brain from the damaging effects of propagating oedema and intracranial hypertension. However, there are no clearly defined indications or specified guidelines for patient selection for the procedure.

Objective: The objective of this study is to evaluate outcome determinants and factors important in patient selection for decompressive craniectomy.

Methods: We reviewed the literature on decompressive craniectomy, including single case reports and reported case series, to identify factors affecting outcome following the procedure, as well as its pitfalls and associated complications.

Results: Glasgow coma score of 8 and above, age less than 50 years and early intervention were found to be among the most significant determinants of prognosis.

Conclusion: Improving patient selection for decompressive craniectomy may be expected to further improve the outcome following the procedure in severely brain-injured patients.

Keywords: Decompressive craniectomy; Indications; Intracranial hypertension; Outcome; Patient selection.

Decompressive craniectomy (DC) refers to the removal of an area of skull in order to enhance the potential volume of the intracranial compartment. It was first described by Kocher in the treatment of post-traumatic brain oedema which was refractory to conventional medical treatment in 1901 (1). Since then, interest in the procedure has either increased or decreased at various times. At present, however, it is commonly accepted as a means of rapidly relieving intracranial hypertension associated with a number of clinical conditions. The procedure however remains controversial owing to unresolved issues (2).

Despite the renewed interest in DC during the last decade, there are as yet no clear-cut guidelines regarding the indications for, or optimal timing of the procedure (3, 4).

In this paper, we briefly review aspects of DC including: its documented benefits, the outcome determinants and the associated complications using the following search terms: ‘decompressive craniectomy’, ‘outcome of’, ‘complications of’, ‘indications for’, ‘infarction’, ‘brain injury’ and ‘cranioplasty’.

Cerebral oedema and intracranial hypertension

Cerebral oedema and intracranial hypertension are among the most fundamental pathophysiological processes occurring in several neurologic conditions including: subarachnoid haemorrhage (SAH), traumatic brain injury (TBI), cerebral infarction, cerebral blood flow abnormalities, inadequate oxygen delivery and energy failure. The impaired cerebral perfusion resulting from the increased pressure precipitates further increases and accounts for the vicious cycle leading to cell injury and death. A major goal in the treatment of these patients is, therefore, the interruption of the vicious cycle by controlling the brain swelling and maintaining the intracranial pressure (ICP) below target. Failure to interrupt this cycle is thought to be a significant contributor to poor outcome in the patients – many of whom will either die or survive with severe disability (with mortality exceeding 80% being reported in some series) (5).

Several modes of intervention have been applied in cases of intracranial hypertension. Most of them are effective and include therapies like the use of osmotic diuretics (such as mannitol or hypertonic saline), sedation, high-dose barbiturates, mild hyperventilation, moderate hypothermia, maintenance of oxygenation and drainage of cerebrospinal fluid by ventriculostomy (5). Clinical evidence, however, shows that these measures are not always effective, and as a result the vicious cycle continues to propagate. In such situations, more
aggressive methods of treatment are indicated. Furthermore, some of the conventional measures have been associated with significant side effects. For example, whereas mannitol is known to cause adverse effects like pulmonary congestion, convulsions, rebound intracranial hypertension, paradoxical increase of ICP (3) as well as fluid and electrolyte disorders; barbiturates have been reported to cause hypotension and depressed cardiac function while rebound increase in ICP has been known to occur following hyperventilation.

DC is thought to be a potential option in these instances (5), with the decision to intervene preferably being based on invasive monitoring of the ICP (6, 7).

**Decompressive craniectomy (DC)**

Surgical decompression as a means of relieving ICP is an old neurosurgical concept (3). Mainly, it involves raising a bone flap, duraplasty, cerebrospinal fluid drainage and removal of any intracranial mass lesions. The modern concept of decompression for TBI was introduced by Harvey Cushing in the early 20th century (8). DC refers to the removal of an area of skull bone with the aim of converting the ‘closed’ intracranial compartment into an ‘open’ one.

Interest in the procedure has fluctuated through the years partly due to a number of unresolved issues including: whether the results justify the treatment as well as the associated complications (such as the increased tendency of brain injury to occur at the craniectomy site) (9). There has also been concern about the functional outcome in surviving patients. Nevertheless, there has been a revival of interest during the last couple of decades; and it has come to gain wide acceptance as a salvage procedure in the treatment of refractory intracranial hypertension in a number of clinical conditions which are accompanied by massive oedema and brain swelling (10-12). The adverse effects of intracranial hypertension are due to compression of the brain as well as impairment of cerebral blood flow. DC reduces this pressure and enhances blood flow; and it has been shown that the larger the craniectomy, the greater the reduction of the ICP (14).

Clinical data show that DC is a safe and effective primary surgical procedure. Its role in the treatment of patients with intracranial hypertension associated with post-traumatic brain swelling is, however, still controversial (3, 12).

Even though the optimum size of the craniectomy is still a subject of controversy, clinical evidence shows that sub-optimal bone windows increase the chances of brain injury and thereby contribute to poor outcome. A craniectomy of at least 12 cm is recommended (15). However, the size of the bone flap should be tailored to meet the individual need. In their retrospective study of 263 patients with severe TBI that were treated with large DC (135 patients) or routine DC (128 patients), Li et al. (13) compared the treatment outcome and postoperative complications of the two treatment methods during a six-month follow-up period. They found that whereas large DC is superior to routine DC in improving the outcome of severe TBI and effectively reducing the chances of reoperation, it is also associated with a higher incidence of delayed complications such as intracranial haematoma and contralateral subdural effusion (13).

Other controversial aspects of DC include: the functional outcome following the procedure as it relates to patient selection criteria as well as surgical timing; its benefits in the treatment of patients with massive infarction of the territory of the middle cerebral artery (MCA) territory (16); whether the craniectomy should be unilateral or bilateral; and whether or not durotomy or duraplasty should be performed.

Despite the controversies, several studies have documented beneficial effects due to its performance. The advantages DC has over more conservative approaches to ICP control are thought to be due to the rapid and generally permanent decline in ICP, maintenance of neurologic status and the ability to obtain a neurologic examination after it is performed (8). Some studies have found that DC also improves cerebral perfusion pressure and cerebral blood flow in head-injured patients (17, 19).

Clinical data also indicate that DC reduces mortality, improves functional recovery, reduces duration of stay in intensive care unit and improves the Barthel Index Score, especially when it is performed early (3, 19-30). Guerra et al. reported that up to 65% of their patients who underwent DC for diffuse brain swelling refractory to medical management had a good recovery at one year (1). In experimental models of TBI and ischaemic stroke, it has been demonstrated that DC minimises post-traumatic ICP increase, improves cerebral perfusion, significantly reduces secondary brain damage and improves survival and functional outcome. These effects are thought to be the result of increases in collateral circulation, reductions in tissue oedema and improvements in oxygenation and energy metabolism in injured tissues (9, 31).

**Children**

Studies have shown that the majority of severely brain-injured children in whom early DC was performed benefited from the procedure as demonstrated by the prompt control of the ICP, improvement in radiological findings and good neurological recovery. It is suggested that the procedure has advantage over non-surgical methods of treatment among children (32-35).

**Indications**

In spite of the fact that there are numerous reports in the literature supporting good clinical outcome after DC,
there are no clearly defined indications for, or optimal
timing of the procedure (3, 4, 9). DC has most commonly
been performed in patients with TBI (5, 36) and cerebral
infarction (37) associated with intractable intracranial
hypertension. Other indications, which have mostly been
described in single case reports or small case series,
include meningoencephalitis (39), acute disseminated encephalomyelitis (40), encephalopathy due to Reye syndrome (41), toxoplasmosis (42), and cerebral venous and dural sinus thrombosis (43).

Various workers have based their decision to operate
don different premises. Reddy et al., for example, based
their decision to perform DC on the presence of mass
effect with midline shift on neuroimaging and the
impairment of consciousness to Glasgow Coma Scale
(GCS) of 12 and below (3). Albanese et al., on the other
hand, performed early DC (within 24 hours) among their
head-injured patients, if they had a GCS score of less
than 6 and showed clinical signs of cerebral herniation
(which were correlated with abnormalities on computed
tomography scan – such as the presence of haematoma or
brain swelling). Similarly, they used as indications for
‘late’ decompression (i.e. more than 24 hours) an
intractable intracranial hypertension – with ICP of above
35 mm Hg, absence of pupillary reflexes and CT
abnormalities (12).

Outcome determinants
Clinical data show that outcome in many of the survivors
of DC is acceptable (44-47). Using the Glasgow Outcome
Score Extended (GOSE), functional outcome was
generally adjudged as good in several studies. Evidence from
some of these studies indicates that one of the most
important determinants of outcome is the timing of the
procedure: with good outcome correlating with early
surgery (generally within 48 hours). Younger patients
generally fare better, with age greater than 50 years being
associated with a poorer outcome. GCS score of 8 and
above is associated with favourable outcome, while
mortality rates and the incidence of residual disabilities
are much higher in patients with admission GCS of 5 and
below (3, 5, 48, 49) (see Table 1).

Other factors that have been associated with poor
outcome include: polytrauma and significant pupillary
abnormalities (anisocoria or mydriasis). It is, however,
believed that of all these factors, the only one that is
statistically related to bad prognosis is GCS at the time of
admission.

Pitfalls and complications
Despite the documented benefits of DC, a number of
workers have expressed concern as to whether the
procedure has always been performed only on patients that
actually needed it, or whether it has also been performed in
cases that probably would have benefited from medical
treatment alone. This is pertinent in view of the fact that
the risk of complications following the procedure is
comparatively high, with some studies reporting as much
as 50% complication rate postoperatively (50).

A very important drawback of DC is the increased risk of
brain injury. Honeybul reports the case of a middle-aged
man who had a DC following TBI as a result of a fall. The
patient was reported to be making good recovery when he
fell a second time and injured the unprotected cranietomy
site. As a result, he suffered further cerebral injury and
subsequently died (51). The case highlights the need to view
these patients as particularly high risk and emphasises the
importance of measures aimed at protecting the brain after
the procedure.

The fact that a minimum of two surgical procedures
are required – the first being the actual removal of the
bone flap and the second to repair the defect (cranio-
plasty) – is also a potential cause of concern (8, 52) since
the latter has also been associated with a number of
complications.

A major specific complication that has been associated
with DC is the syndrome of sinking skin flap described by
Yamaura and Makino. It is characterised by progressive
neurological deterioration with the depression of the skin
at the site of the cranial defect, and develops within a few
weeks to several months after large external cerebral
decompression. These authors argue that the neurologi-
cal deterioration may be due solely to the effect of the
concavity of the skin flap with consequent distortion of
the underlying brain which is subjected to the atmos-
pheric pressure through it (2).

Other reported complications of DC include: contral-
ateral subdural effusions (53), infections (such as menin-
gitis or brain abscess) and hydrocephalus (10). Persistent
vegetative state is probably one of the most devastating
outcomes following DC (54). It is thus necessary that in
taking the decision to operate, the risk of complications
should be weighed against the potential benefits of the
procedure in the context of the life-threatening circum-
stances.

Cranioplasty, which is commonly indicated for large
cranial defects following DC, is also associated with
several complications including extradural haematoma,
infections and instability of the implant (52, 55, 56),
among others. Cranioplasty is generally performed three
months after the DC. Clinical data, however, reveal that
the rate of complications is reduced when it is performed
early. Thus, there is at present, a tendency to perform it
within 5–8 weeks of the craniectomy (57).

Ongoing trials
There are at present two prospective randomised con-
trolled trials aimed at providing Class I evidence on the role
of DC in the treatment of intracranial hypertension
following severe TBI. The DECompressive CRAniectomy
(DECRA) Trial is a multi-centre prospective randomised trial designed to evaluate the effect of early DC on neurological function in patients with severe TBI. It is based on the theory that early DC can improve long-term neurological outcome in patients with severe TBI and intracranial hypertension which is refractory to conventional management (58). Randomised Evaluation of Surgery with Craniectomy for Uncontrollable Elevation of ICP(RESCUEicp) is another prospective, randomised international multi-centre trial aimed at providing Class I evidence as to whether DC is effective for the management of patients with refractory intracranial hypertension following TBI as compared with medical management alone (59).

A major limitation of this review is that standard data meta-analysis techniques could not be applied; and like several other publications on DC in the literature, it tended to be biased in favour of publications with good outcome. There was non-uniformity in several aspects of the studies evaluated, many of which were based on uncontrolled retrospective data and small case series. Some of the areas of variation in the reports were the differences in detail in the surgical procedures performed as well as their indications: e.g. the choice of hemicraniectomy instead of bilateral craniectomy, durotomy or duraplasty, GCS score that was deemed acceptable, etc. – all of which without doubt impacted (at least to some extent) the interpretation of the results.

### Conclusion

DC is commonly performed as an empiric lifesaving measure in an attempt to protect the brain from the damaging effects of propagating oedema and intracranial hypertension (60). Improving patient selection and optimising timing of the procedure may be expected to further improve outcome in severely brain-injured patients.
An important way of achieving this is to have clearly defined guidelines that may be applied in every case for which the procedure is envisaged. Table 1 shows the factors and considerations in patient selection and timing of DC that have been found to be important to patient outcome.

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References


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