Chapter 15. Surgical treatment of pediatric intracranial hypertension

I. RECOMMENDATIONS

A. Standards. There are insufficient data to support a treatment standard for this topic.

B. Guidelines. There are insufficient data to support a treatment guideline for this topic.

C. Options. Decompressive craniectomy should be considered in pediatric patients with severe traumatic brain injury (TBI), diffuse cerebral swelling, and intracranial hypertension refractory to intensive medical management.

Decompressive craniectomy should be considered in the treatment of severe TBI and medically refractory intracranial hypertension in infants and young children with abusive head trauma.

Decompressive craniectomy may be particularly appropriate in children with severe TBI and refractory intracranial hypertension who have a potentially recoverable brain injury. Decompressive craniectomy appears to be less effective in patients who have experienced extensive secondary brain insults. Patients who experience a secondary deterioration on the Glasgow Coma Scale (GCS) and/or evolving cerebral herniation syndrome within the first 48 hrs after injury may represent a favorable group. Patients with an unimproved GCS of 3 may represent an unfavorable group.

II. OVERVIEW

The Traumatic Coma Data Bank has established the poor prognosis (34% mortality rate, 16% good or moderately disabled) of pediatric and adult patients with severe TBI and diffuse cerebral injury on computed tomography (CT) scan (compressed cisterns, <5 mm midline shift, mass lesion <25 mL) (2, 3). Because maximum postinjury intracranial pressure (ICP) is a leading predictor of outcome in severe TBI, some have advocated the use of decompressive craniectomy to treat medically refractory intracranial hypertension in children (4–7).

The main objective of decompressive craniectomy is to control ICP and thus maintain cerebral perfusion pressure and cerebral oxygenation, as well as prevent herniation, in the face of refractory cerebral swelling. There are a number of surgical interventions for the treatment of refractory intracranial hypertension. This chapter addresses only the use of decompressive craniectomy. Four questions regarding the use of decompressive craniectomy in children are evaluated:

1. Is decompressive craniectomy successful in controlling ICP?
2. Does decompressive craniectomy improve clinical outcomes?
3. What surgical technique is appropriate?
4. Which patients are appropriate candidates for decompressive craniectomy?

III. PROCESS

We searched Medline and Healthstar from 1966 to 2001 by using the search strategy for this question (see Appendix A) and supplemented the results with literature recommended by peers or identified from reference lists. Of 21 potentially relevant studies, three were used as evidence for this question (Table 1).

IV. SCIENTIFIC FOUNDATION

Is Decompressive Craniectomy Successful in Lowering ICP?

The measured value of ICP may be artifactually altered due to the cranial defect in patients who have undergone decompressive craniectomy. However, given that this surgical procedure is generally undertaken with the goal of controlling severe refractory intracranial hypertension, its effect on ICP is of interest. Taylor and colleagues (8) reported a significant reduction in mean ICP after decompressive craniectomy for severe TBI in children (average mean decrease, 9 mm Hg). Hieu and colleagues (9) illustrated graphically the intraoperative and immediate postoperative ICP at the time of decompressive craniectomy in two pediatric patients. Sequential decreases in ICP seen at the point of craniectomy and of duraplasty were sustained in the immediate postoperative period.

Cho and colleagues (10) reported significantly decreased ICP after decompressive craniectomy (preoperative mean, 59 mm Hg; postoperative mean, 12 mm Hg) in 10 children <2 yrs of age with severe TBI and refractory intracranial hypertension from abusive head trauma.

Key Elements from Adult Evidence Relevant to Pediatric TBI

Polin et al. (4) documented a statistically significant decrease in ICP from 32 to 21 mm Hg after decompressive craniectomy in 26 pediatric and adult patients. In their study, ICP after craniectomy was also lower than ICP at an equivalent postinjury interval in a matched control group taken from the Traumatic Coma Data Bank. Kunze and colleagues (6) reported decreased ICP (mean preoperative, 42 mm Hg; mean postoperative, 21 mm Hg) and increased cerebral perfusion pressure in 28 children and adults who underwent decompressive craniectomy to treat severe TBI. Gaab and colleagues (7) illustrated graphically a single "representative" case from their study of 37 pediatric and adult severe TBI patients showing immediate decrease in ICP and increase in GCS after decompressive craniectomy.

Table 1. Evidence table

Reference	Description of Study	Data Class	Conclusion
Polin et al. (4), 1997	In a single-center, case-controlled study, 35 severely head-injured patients underwent decompressive craniectomy with pre- and postoperative ICP monitoring and medical management.	III	A significantly increased rate of favorable outcome was seen in surgical patients compared with matched controls. Young age, early operation, and avoidance of ICP >40 mm Hg may improve outcome.
Cho et al. (10), 1995	In a single-center, case-controlled study, 23 severely head-injured children with shaking-impact syndrome underwent either decompressive craniotomy or medical management.	III	Of patients with severe (>30 mm Hg) intracranial hypertension, those undergoing surgery had improved survival and neurological outcomes compared with those undergoing medical therapy alone.
Taylor et al. (8), 2001	In a single-center PRCT, 27 severely head-injured children with intracranial hypertension refractory to medical management and ventricular drainage were randomized to bitemporal decompressive craniectomy vs. no surgery.	III	Decompressive craniectomy significantly lowered mean ICP in the 48 hrs after randomization and resulted in a marginally nonsignificant trend toward improved clinical outcome at 6 mos.

ICP, intracranial pressure; PRCT, prospective, randomized controlled trial.

Does Decompressive Craniectomy Improve Clinical Outcomes?

Three class III studies evaluated outcome after decompressive craniectomy for the treatment of severe TBI in children. Taylor and colleagues (8) performed a single-center, prospective, randomized clinical trial of decompressive craniectomy in the treatment of pediatric patients (age 1–18) with severe TBI and refractory intracranial hypertension (n = 27). These patients were randomized to receive maximal medical therapy and ventricular drainage alone or in addition to decompressive bitemporal craniectomy. Patients in this study who underwent craniectomy had a trend toward better clinical outcome at 6 months after injury (modified Glasgow Outcome Scale [GOS]). Although this study is a prospective, randomized clinical trial, concerns about size and generalizability of the sample limited the evidence to class III with respect to outcome.

Polin et al. (4) reported the outcomes of 35 patients with mean age 18 yrs who underwent bifrontal decompressive craniectomy for severe TBI and medically refractory intracranial hypertension. Favorable outcome (GOS at discharge from rehabilitation) was more frequent in pediatric (44%) than adult (29%) patients. There was no concurrent control group in this study. However, the authors matched control patients from the Traumatic Coma Data Bank to each study patient. They reported a significantly higher rate of favorable outcome in pediatric patients undergoing decompressive craniectomy vs. controls, based on a univariate analysis. This beneficial effect was also evident in a multivariate analysis restricted to pediatric patients operated on within 48 hrs of injury and without sustained ICP elevation beyond 40 mm Hg. Hieu and colleagues (9) reported good neurologic recovery in two 8-yr-old patients who underwent decompressive craniectomy within 12 hrs of TBI because of severe intracranial hypertension and evolving transtentorial herniation syndrome. Their operative procedure also included the resection of severely contused brain.

Cho and colleagues (10) reported outcomes in 23 children <2 yrs of age treated with medical therapy or medical therapy plus decompressive craniectomy for severe TBI due to abusive head trauma. In this prospective, single-center, case control study, ten patients with severe intracranial hypertension (>30 mm Hg) received medical ICP management plus decompressive craniectomy, whereas seven patients with severe intracranial hypertension and six patients with less severe intracranial hypertension (<30 mm Hg) were treated with medical therapy alone. Patients with severe intracranial hypertension managed with surgery, and patients with less severe intracranial hypertension, had Child Outcome Scores significantly higher than patients with severe intracranial hypertension managed medically. Among children with severe intracranial hypertension, survival was also significantly improved in those children undergoing decompressive surgery. Decompressive craniectomy in this study was generally performed within 24 hrs of injury. A mean of 32 mL of subdural hematoma was also evacuated at the time of decompressive surgery.

Key Elements from Adult Scientific Literature Relevant to Pediatric TBI

Venes and Collins (11) reported a series of 13 severe TBI patients who underwent decompressive craniectomy, including six children. Although the authors suggested that survival in this retrospective, uncontrolled study was increased relative to historical experience, only two patients, including one child, made a significant neurologic recovery. Kunze et al. (6) performed decompressive craniectomy on 28 severe TBI patients with refractory intracranial hypertension and mean age of 22 (range, 8–44). Although statistical analysis was not performed in this uncontrolled study, the descriptive data suggest markedly better GOS in patients ≤30 yrs of age. Guerra et al. (5) prospectively studied the results of decompressive craniectomy in 57 pediatric and adult patients with severe TBI and medically refractory intracranial hypertension. These authors excluded patients with CT demonstration of severe brainstem injury, absent brainstem auditory evoked responses, absence of oscillatory cerebral blood flow on transcranial Doppler ultrasound, initial GCS of 3 without improvement, or bilateral fixed and dilated pupils. Using these exclusion criteria, the authors estimated that only 3% of severely TBI patients presenting to their institution over a 20-yr period were entered into the decompression protocol. Fifty-eight percent of this highly restricted patient population, however, achieved a GOS of 4 or 5. Logistic regression analysis in this study failed to support young age as a predictor of improved outcome.

What Surgical Technique Is Appropriate?

Studies from the CT imaging era have generally recommended unilateral frontal-temporal-parietal decompressive craniectomy for unilateral cerebral swelling or bilateral frontal craniectomy for bilateral cerebral swelling in both children and adults (5–7). The historical literature is cited as a caution against small craniectomies, due to the potential for inadequate relief of intracranial hypertension and for cerebral incarceration and infarction (5, 12). However, one prospective study of decompressive craniectomy in pediatric patients demonstrated a trend toward improved outcome after 4-cm bitemporal craniectomies (8). Most authors describe a combined craniectomy and expansion duraplasty (4–7, 9, 10). Bilateral procedures used by various authors include separate bilateral craniectomies with a strip of intact bone over the sagittal sinus (5, 7) vs. bifrontal craniectomy with section of the anterior falx cerebri at the skull base (4, 11, 13). No studies have evaluated the differential efficacy of these various techniques.

Which Patients Are Appropriate Candidates for Decompressive Craniectomy?

Three studies of outcome in pediatric patients suggest specific criteria for the performance of decompressive craniectomy. After conducting logistic regression analysis of 35 severe TBI patients treated in their institution, Polin and colleagues (4) recommended decompressive craniectomy for pediatric patients with cerebral swelling and medically refractory intracranial hypertension who are within 48 hrs of injury and who have not experienced a sustained ICP elevation >40 mm Hg. They also recommended against decompressive craniectomy for patients with initial and sustained GCS of 3. Taylor et al. (8) recommended decompressive craniectomy for pediatric patients with refractory intracranial hypertension (ICP 20–24 mm Hg for >30 mins, 25–29 for >10 mins, ≥30 for >1 min) or cerebral herniation syndrome on the first day after injury, despite ventricular drainage.

Cho and colleagues (1995) suggested the use of decompressive craniectomy within 24 hrs of injury in children <2 yrs of age with severe TBI and medically refractory intracranial hypertension (>30 mm Hg) from nonaccidental trauma.

Key Elements from Adult Evidence Relevant to Pediatric TBI

Guerra and colleagues (5) recommended decompressive craniectomy for pediatric and adult patients with severe TBI, cerebral swelling on CT imaging, refractory intracranial hypertension, and witnessed deterioration in clinical variables (GCS, neurologic examination), electrophysiological variables (electroencephalogram, somatosensory evoked potentials), and/or transcranial Doppler ultrasound variables (increased pulsatility, decrease in diastolic flow). These authors excluded patients with CT imaging demonstration of severe brainstem injury, absent brainstem auditory evoked responses, absence of oscillatory cerebral blood flow on transcranial Doppler ultrasound, initial GCS of 3 without improvement, and bilateral fixed and dilated pupils.

V. SUMMARY

Decompressive craniectomy for severe TBI and medically refractory intracranial hypertension in children lowers ICP and may improve outcome. Decompressive craniectomy also may be appropriate in young children with severe TBI and refractory intracranial hypertension from abusive head trauma. Insufficient evidence is available to evaluate the efficacy of various described surgical techniques for decompressive craniectomy. Decompressive craniectomy for children with severe TBI and refractory intracranial hypertension may be most appropriate in patients meeting some or all of the following criteria:

1. Diffuse cerebral swelling on cranial CT imaging
2. Within 48 hrs of injury
3. No episodes of sustained ICP >40 mm Hg before surgery
4. GCS >3 at some point subsequent to injury
5. Secondary clinical deterioration
6. Evolving cerebral herniation syndrome

VI. KEY ISSUES FOR FUTURE INVESTIGATION

- Randomized controlled trials of the safety and efficacy of decompressive craniectomy in severe pediatric TBI should be undertaken. The only study of this type may have failed to demonstrate a statistically significant benefit of decompression on long-term outcome due to small sample size.
- It may be useful for future studies to compare decompressive craniectomy to other "second-tier" interventions for severe, refractory intracranial hypertension, such as barbiturate therapy, hypothermia, or lumbar CSF drainage.
- The safety and efficacy of decompressive craniectomy for severe TBI in infants and for severe TBI due to abusive head trauma should be further studied.
- Studies of decompressive craniectomy for severe TBI should include careful monitoring of ICP, cerebral perfusion pressure, cerebral blood flow, and other important physiologic variables to correlate alterations in the latter variables with successful clinical outcome. Such data may clarify the pathophysiological variables involved and provide better information about the indications for and appropriate timing of decompressive surgery.
- Studies are needed to evaluate the optimal surgical approach to decompressive craniectomy.

Decompressive craniectomy for severe traumatic brain injury and medically refractory intracranial hypertension in children lowers intracranial pressure and may improve outcome.

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APPENDIX: LITERATURE SEARCH STRATEGIES

SEARCHED MEDLINE AND HEALTHSTAR FROM 1966 TO 2001

Chapter 15. Surgical Treatment

1. exp craniocerebral trauma/
2. head injur$.tw.
3. brain injur$.tw.
4. 1 or 2 or 3
5. exp intracranial hypertension/ or “intracranial hypertension”.mp.
6. 4 and 5
7. limit 6 to (newborn infant <birth to 1 month> or infant <1 to 23 months> or preschool child <2 to 5 years> or child <6 to 12 years> or adolescence <13 to 18 years>)
8. limit 7 to English language
9. su.fs.
10. drain$.mp.
11. exp cerebrospinal fluid shunts/ or “cerebrospinal fluid shunts”.mp.
12. Neurosurgery/ or “neurosurgery”.mp.
13. shunt$.mp.
14. 9 or 10 or 11 or 12 or 13
15. 8 and 14