Is it the end of decompressive craniectomy?

J. Marcoux, H. Al-Jehani, R.W.R. Dudley, M. Maleki

Department of Neurosurgery, Montreal General Hospital & Montreal Neurological Hospital, McGill University
Primary and secondary lesions

“Only part of the damage to the brain during head trauma occurs at the moment of impact”

Brain Trauma Foundation
Intracranial pressure (ICP)

- Normal: 0-10 mmHg
- 20 mmHg = limit chosen by most centers
  - BTF guidelines (level 2)
  - * patients can herniate with lower ICP
    - Therapy must also be guided by imaging and clinical status of the patient.
- High ICP → secondary lesion
  - Decreased cerebral blood flow, globally and regionally
ICP

- Brain = 80%
- Blood = 10%
- Cerebrospinal fluid = 10%

Pressure (mm Hg):

- Equilibrium state
- Compensated state
- Uncompensated state

Point of decompensation
High ICP treatment

- **Basic measures**
  - Sedation and analgesia
  - Patient position
  - Mechanical ventilation

- **Extended measures**
  - Hyperosmolar therapy
  - CSF drainage

- **Other invasive measures**
  - DC
  - Barbituric Coma
  - Hypothermia
  - Marked Hyperventilation
  - Arterial pressure increase
Does treating high ICP change the outcome?

**Classe III**
- Saul and Ducker, 1982
  - ICP treated at 25mmHg = 46% mortality
  - ICP treated at 15mmHg = 28% mortality
- Ghajar et al., 1993
  - GCS < 8
  - ICP 15mmHg
  - Mortality 12% vs 53% if not monitored

**Meta-analysis**
- 14 series
  - 21% mortality if CSF drainage routinely done
  - 35% mortality of done sometimes
  - 43% mortality if never done
If BTF guidelines are followed

- **Mortality rate (for survivors > 48h)**
  - Before protocol: 17.8%
  - Compliance 50%: 18.6%
  - Compliance 88%: 13.7%

- **Length of stay**
  - ICU
    - before: 9.8 days
    - after: 7.9 days
  - Hospital
    - before: 21.2 days
    - after: 15.8 days

BTF guidelines

- **GOS at discharge 4 or 5**
  - before: 43.3%
  - Compliance 50%: 50.3%
  - Compliance 88%*: 61.5%

- **RLAS at discharge of 8**
  - before: 43.9%
  - Compliance 50%: 44%
  - Compliance 88%*: 56.6%

* : GCS slightly lower in latest group

And if ICP remains high?

- High ICP not responding to standard treatment may respond to barbiturates
- High ICP not responding to barbiturate coma = death
And?

- When routine measures fail to control TBI-related brain edema, therapeutic options are limited.

Polin et al, Neurosurg 1997, July(4)
Case 1

- 17 yo
- MVC
- GCS 3 at outside hospital → intubated
- GCS 7T in ICU
- Day # 2: high ICP
- Day # 3: ICP reaches 30mmHg → barbiturate coma
- Day # 9: ICP reaches 40mmHg
A bit of history

- 1st written report by Annandale in 1894 (1 patient)
- Cushing in 1905 for high ICP from inoperable tumor
- For TBI in the 60s
  - Done in extremis and results very poor…
  - To tell other people not to do the same mistake!

Types of DC

- **Primary or prophylactic**
  - Mass lesion requiring evacuation
  - Based on CT and/or intra-op findings

- **Secondary or therapeutic**
  - To treat high ICP refractory to treatment
Surgical technic

- **Craniectomy:**
  - Bifrontal
    - In fact bi-coronal with or without SSS ligation
  - F-T-P uni or bilateral
    - Midline left intact
  - circumferential
Surgical technique

- **Dura**
  - Intact
  - Slits
  - Open +/- duraplasty
    - Clearly more efficient for ↓ ICP

---

Effect on ICP

- 24 patients with decompressive craniectomy
  - mean ICP pre-op = 33 mmHg
  - mean ICP post-op = 9 mmHg

<table>
<thead>
<tr>
<th>GOS</th>
<th>Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4 (15.4)</td>
</tr>
<tr>
<td>2</td>
<td>2 (7.7)</td>
</tr>
<tr>
<td>3</td>
<td>1 (3.8)</td>
</tr>
<tr>
<td>4</td>
<td>10 (38.5)</td>
</tr>
<tr>
<td>5</td>
<td>9 (34.6)</td>
</tr>
</tbody>
</table>

Outcome?

1 study class 1
- Pediatric
- 27 patients randomized
- ↓ mortality
- ↓ morbidity

Case 2

- 19 yo male
- Pedestrian hit by bike
- GCS 3 on arrival...reaches 6T within the 1st 24h
- < 48 h, ICP reaches 30mmHg despite maximal medical management (no second tiers)
Case 2
Case 3

- 21 yo
- MVC
- GCS 3
- EVD inserted
- 48h later, GCS reaches 8T off sedation
- Day # 5, ICP increasingly difficult to control and steadily > 20mmHg
Case 3

- ST segment changes on EKG
- By the time OR is ready, ICP reaches 40mmHg
- While draping, circulatory arrest (pulseless electrical activity)
  - Cardiomyopathic depression...neurogenic origin?
- CPR < 3min
- Post-resuscitation, pupils dilated + fixed
Complications

- Infection
- Hemorrhage
- Foreign body (duraplasty)
- Cerebral damage
  - Contusion
  - Herniation
  - Bony protection lost
- Bone resorption
- Hydrocephalus??
Decompressive Craniectomy in Diffuse Traumatic Brain Injury

D. James Cooper, M.D., Jeffrey V. Rosenfeld, M.D., Lynnette Murray, B.App.Sci., Yaseen M. Arabi, M.D., Andrew R. Davies, M.B., B.S., Paul D’Urso, Ph.D., Thomas Kossmann, M.D., Jennie Ponsford, Ph.D., Ian Seppelt, M.B., B.S., Peter Reilly, M.D., and Rory Wolfe, Ph.D., for the DECRA Trial Investigators and the Australian and New Zealand Intensive Care Society Clinical Trials Group*

Cooper et al., March 2011
DECRA trial

- **Recruitment:**
  - Dec 2002 to April 2010
  - 15 tertiary centers in Australia, New-Zealand and Saudi Arabia

- **Inclusion:**
  - age: 15-59
  - GCS 3-8 or Marshall grade III
  - Blunt trauma

- **Exclusion:**
  - Deemed non suitable for active treatment (non salvageable injury)
  - Pupils dilated + nonreactive
  - Mass lesion requiring surgery
  - SCI
  - Cardiac arrest at the scene
DECRA trial

- Treatment for ICP > 20mmHg
- Early refractory ICP:
  - if > 20mmHg
  - for > 15mins
  - Over a 1 hour period
  - Despite optimization of first-tier
    (sedation, normal CO$_2$, hypertonic saline, Mannitol, CSF drainage, neuromuscular block)
- Monitor parenchymal or intraventricular
DECRA trial

- Randomized within 72 h (DC or standard-care therapy)
- DC from Polin`s technique (bifrontal)
- In both groups:
  - Mild hypothermia
  - Barbiturates
  - DC for survival after 72h can be used in standard-care group!!!
DECRA trial

- Outcome measures:
  - Phone interview
  - Primary outcome:
    - GOSSe at 6 months of 1 to 4
    - And functional outcome
  - Secondary outcome:
    - Time with elevated ICP
    - Index of high ICP
    - GOSSe 2-4
    - Number of days in ICU and in hospital
    - Mortality in hospital and at 6 months
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Decompressive Cranietomy (N=73)</th>
<th>Standard Care (N=82)</th>
<th>P Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age — yr</td>
<td></td>
<td></td>
<td>0.89</td>
</tr>
<tr>
<td>Median</td>
<td>23.7</td>
<td>24.6</td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>19.4–29.6</td>
<td>18.5–34.9</td>
<td></td>
</tr>
<tr>
<td>Male sex — no. (%)</td>
<td>59 (81)</td>
<td>61 (74)</td>
<td>0.44</td>
</tr>
<tr>
<td>Systolic blood pressure — mm Hg</td>
<td>135.4±32.0</td>
<td>135.7±27.6</td>
<td>0.95</td>
</tr>
<tr>
<td>Glasgow Coma Scale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall score¶</td>
<td>5</td>
<td>6</td>
<td>0.31</td>
</tr>
<tr>
<td>Median</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>3–7</td>
<td>4–7</td>
<td></td>
</tr>
<tr>
<td>Motor score§</td>
<td>3</td>
<td>3</td>
<td>0.49</td>
</tr>
<tr>
<td>Median</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>1–4</td>
<td>1–5</td>
<td></td>
</tr>
<tr>
<td>Maximum score for head injury on Abbreviated Injury Scale — no. (%)§</td>
<td></td>
<td></td>
<td>0.52</td>
</tr>
<tr>
<td>3 or 4</td>
<td>35 (48)</td>
<td>44 (54)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>38 (52)</td>
<td>38 (46)</td>
<td></td>
</tr>
<tr>
<td>Injury Severity Score¶</td>
<td></td>
<td></td>
<td>0.88</td>
</tr>
<tr>
<td>Median</td>
<td>33</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>25–38</td>
<td>24–41</td>
<td></td>
</tr>
<tr>
<td>Trauma Score—Injury Severity Score **</td>
<td></td>
<td></td>
<td>0.46</td>
</tr>
<tr>
<td>Median</td>
<td>0.74</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>0.42–0.88</td>
<td>0.51–0.90</td>
<td></td>
</tr>
<tr>
<td>Reactivity of pupils — no./total no. (%)</td>
<td></td>
<td></td>
<td>0.04</td>
</tr>
<tr>
<td>* Neither pupil</td>
<td>19/71 (27)</td>
<td>10/80 (12)</td>
<td></td>
</tr>
<tr>
<td>One or both pupils</td>
<td>52/71 (73)</td>
<td>70/80 (88)</td>
<td></td>
</tr>
<tr>
<td>Hypotension — no. (%)</td>
<td>24 (33)</td>
<td>25 (30)</td>
<td>0.93</td>
</tr>
<tr>
<td>Hypoxemia — no. (%)</td>
<td>18 (25)</td>
<td>24 (29)</td>
<td>0.55</td>
</tr>
<tr>
<td>Traumatic subarachnoid hemorrhage — no. (%)</td>
<td>42 (58)</td>
<td>48 (59)</td>
<td>0.90</td>
</tr>
<tr>
<td>Cause of injury — no./total no. (%)</td>
<td></td>
<td></td>
<td>0.72</td>
</tr>
<tr>
<td>Motor-vehicle or motorcycle accident</td>
<td>45/70 (64)</td>
<td>55/81 (68)</td>
<td></td>
</tr>
<tr>
<td>Bicycle accident</td>
<td>4/70 (6)</td>
<td>2/81 (2)</td>
<td></td>
</tr>
<tr>
<td>Pedestrian accident</td>
<td>5/70 (7)</td>
<td>4/81 (5)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>16/70 (23)</td>
<td>20/81 (25)</td>
<td></td>
</tr>
</tbody>
</table>
**DECOMPRESSIONAL CRANIECTOMY IN TRAUMATIC BRAIN INJURY**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Decompressive Craniectomy (N=73)</th>
<th>Standard Care (N=82)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time from injury to hospital — hr</td>
<td></td>
<td></td>
<td>0.90</td>
</tr>
<tr>
<td>Median</td>
<td>1.0</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>0.8–1.8</td>
<td>0.7–1.9</td>
<td></td>
</tr>
<tr>
<td>Time from injury to randomization — hr</td>
<td></td>
<td></td>
<td>0.60</td>
</tr>
<tr>
<td>Median</td>
<td>35.2</td>
<td>34.8</td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>23.3–52.8</td>
<td>25.8–45.4</td>
<td></td>
</tr>
<tr>
<td>Marshall class — no. (%)††</td>
<td></td>
<td></td>
<td>0.39</td>
</tr>
<tr>
<td>Diffuse injury I</td>
<td>17 (23)</td>
<td>27 (33)</td>
<td></td>
</tr>
<tr>
<td>Diffuse injury III or IV</td>
<td>53 (73)</td>
<td>53 (65)</td>
<td></td>
</tr>
<tr>
<td>Nonevacuated mass lesion (VI)</td>
<td>3 (4)</td>
<td>2 (2)</td>
<td></td>
</tr>
</tbody>
</table>

* All P values were calculated with the use of the chi-square test to compare proportions and the Wilcoxon rank-sum test to compare distributions.
†† The overall score on the Glasgow Coma Scale ranges from 3 to 15, with lower scores indicating reduced levels of consciousness.
§ The motor score on the Glasgow Coma Scale ranges from 1 to 6, with lower scores indicating more limited motor response.
¶ The score for head injury on the Abbreviated Injury Scale ranges from 1 to 6, with higher scores indicating more severe injury.
‖ The Injury Severity Score ranges from 0 to 75, with higher scores indicating greater injury severity.
** The Trauma Score-Injury Severity Score ranges from 0 to 1, with lower scores indicating a lower probability of survival.
†† The Marshall classification is based on findings on computed tomography as follows: class I, diffuse injury with no visible signs; class II, diffuse injury with basal cisterns intact, a midline shift of 0 to 5 mm, and a high- or mixed-density lesion of 25 ml or less with the possibility of bone fragments or foreign bodies; class III, diffuse injury with swelling, including compressed or absent cisterns with a midline shift of 0 to 5 mm and a high- or mixed-density lesion of 25 ml or less; class IV, diffuse injury with shift, including a midline shift of more than 5 mm and a high- or mixed-density lesion of 25 ml or less; class V, surgical evacuation of a mass lesion; and class VI, a high- or mixed-density lesion of more than 25 ml that has not been surgically evacuated.
Figure 1. Intracranial Pressure before and after Randomization.

Shown are the mean measurements of intracranial pressure in the two study groups during the 12 hours before and the 36 hours after randomization. The I bars indicate standard errors.
DECRA trial

- 4 patients in standard-care group and DC within 72 h
- 15 patients more had DC after 72 h

Therefore 19/82 (23.2%) had DC!!
Table 2. Primary and Secondary Outcomes.*

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Decompressive Craniectomy (N = 73)</th>
<th>Standard Care (N = 82)</th>
<th>P Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intracranial pressure and cerebral perfusion pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intracranial pressure after randomization — mm Hg</td>
<td>14.4±6.8</td>
<td>19.1±8.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No. of hr of intracranial pressure &gt;20 mm Hg — median (IQR)</td>
<td>9.2 (4.4–27.0)</td>
<td>30.0 (14.9–60.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Intracranial hypertension index — median (IQR)‡</td>
<td>11.5 (5.9–20.3)</td>
<td>19.9 (12.5–37.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cerebral hypoperfusion index — median (IQR)§</td>
<td>5.7 (2.5–10.2)</td>
<td>8.6 (4.0–13.8)</td>
<td>0.03</td>
</tr>
<tr>
<td>Duration of hospital intervention</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days of mechanical ventilation — median (IQR)</td>
<td>11 (8–15)</td>
<td>15 (12–20)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Days of ICU stay — median (IQR)</td>
<td>13 (10–18)</td>
<td>18 (13–24)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Days of hospitalization — median (IQR)</td>
<td>28 (21–62)</td>
<td>37 (24–44)</td>
<td>0.82</td>
</tr>
<tr>
<td>Extended Glasgow Outcome Scale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Score — no. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (dead)</td>
<td>14 (19)</td>
<td>15 (18)</td>
<td></td>
</tr>
<tr>
<td>2 (vegetative state)</td>
<td>9 (12) *</td>
<td>2 (2)</td>
<td></td>
</tr>
<tr>
<td>3 (lower severe disability)</td>
<td>18 (25)</td>
<td>17 (21)</td>
<td></td>
</tr>
<tr>
<td>4 (upper severe disability)</td>
<td>10 (14)</td>
<td>8 (10)</td>
<td></td>
</tr>
<tr>
<td>5 (lower moderate disability)</td>
<td>13 (18)</td>
<td>20 (24)</td>
<td></td>
</tr>
<tr>
<td>6 (upper moderate disability)</td>
<td>6 (8)</td>
<td>13 (16)</td>
<td></td>
</tr>
<tr>
<td>7 (lower good recovery)</td>
<td>2 (3)</td>
<td>4 (5)</td>
<td></td>
</tr>
<tr>
<td>8 (upper good recovery)</td>
<td>1 (1)</td>
<td>3 (4)</td>
<td></td>
</tr>
<tr>
<td>Median score (IQR)</td>
<td>3 (2–5)</td>
<td>4 (3–5)</td>
<td>0.03</td>
</tr>
<tr>
<td>Unfavorable score of 1 to 4 — no. (%)</td>
<td>51 (70)</td>
<td>42 (51)</td>
<td>0.02</td>
</tr>
</tbody>
</table>
**Table 3. Medical and Surgical Complications.**

<table>
<thead>
<tr>
<th>Adverse Event</th>
<th>Decompressive Cranietomy (N=73)</th>
<th>Standard Care (N=82)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number (percent)</td>
<td></td>
</tr>
<tr>
<td>Wound infection or breakdown</td>
<td>5 (7)</td>
<td>7 (9)</td>
</tr>
<tr>
<td>Meningitis or ventriculitis</td>
<td>2 (3)</td>
<td>3 (4)</td>
</tr>
<tr>
<td>Subgaleal infection</td>
<td>2 (3)</td>
<td>3 (4)</td>
</tr>
<tr>
<td>Cerebral abscess</td>
<td>2 (3) *</td>
<td>0</td>
</tr>
<tr>
<td>Cerebrospinal fluid leak</td>
<td>4 (5) *</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Hematoma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subgaleal</td>
<td>5 (7) *</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Subdural, extradural, or intracerebral</td>
<td>3 (4) *</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Cerebral infarction</td>
<td>1 (1)</td>
<td>0</td>
</tr>
<tr>
<td>Hydrocephalus</td>
<td>7 (10) **</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Cranioplasty revision for cosmetic defect</td>
<td>2 (3) *</td>
<td>0</td>
</tr>
<tr>
<td>Pulmonary embolus</td>
<td>1 (1)</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>0</td>
<td>3 (4) *</td>
</tr>
<tr>
<td>Septic shock</td>
<td>1 (1)</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Acute renal failure</td>
<td>1 (1)</td>
<td>1 (1)</td>
</tr>
</tbody>
</table>
Figure 2. Cumulative Proportions of Results on the Extended Glasgow Outcome Scale.

In this study, an unfavorable outcome was defined as a composite of death, vegetative state, or severe disability, corresponding to a score of 1 to 4 on the Extended Glasgow Outcome Scale, as indicated by the vertical line. According to this measure, an unfavorable outcome occurred in 70% of patients in the craniectomy group and 51% of those in the standard-care group (P=0.02). The cumulative proportion is the percentage of all scores that are lower than the given score.
DECRA trial

- More surgical complications
- Survivors ‘shifted’ from good outcome to poor outcome
- Better ICP control with DC
- Shorter ICU / hospital stay
DECRA trial

But:

- Pupils non-reactive? – bias??
- Timing is very early?
- ICP not necessarily uncontrolled?
- Surgical technique used more prone to complications (hydrocephalus)?
- Surgical technique not maximizing reduction in ICP?
- Nearly ¼ in standard-care group had DC!
- Restricted to a very precise population (155/3500)
Do not forget

- Pediatric study
- RESCUE ICP Trial

Randomized Evaluation of Surgery with Craniectomy for Uncontrollable Elevation of Intracranial Pressure