La craniectomia decompressiva
Indicazioni e complicanze

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Past President SINch
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Changing patterns in the epidemiology of traumatic brain injury

Bob Roozenbeek, Andrew I. R. Maas and David K. Menon

Abstract | Traumatic brain injury (TBI) is a critical public health and socio-economic problem throughout the world. Reliable quantification of the burden caused by TBI is difficult owing to inadequate standardization and incomplete capture of data on the incidence and outcome of brain injury, with variability in the definition of TBI being partly to blame. Reports show changes in epidemiological patterns of TBI: the median age of individuals who experience TBI is increasing, and falls have now surpassed road traffic incidents as the leading cause of this injury. Despite claims to the contrary, no clear decrease in TBI-related mortality or improvement of overall outcome has been observed over the past two decades. In this Perspectives article, we discuss the strengths and limitations of epidemiological studies, address the variability in its definition, and highlight changing epidemiological patterns. Taken together, these analyses identify a great need for standardized epidemiological monitoring in TBI.

Roozenbeek, B. et al. Nat. Rev. Neurol. 9, 231–236 (2013); published online 26 February 2013;

<table>
<thead>
<tr>
<th>Study</th>
<th>Year of study</th>
<th>n</th>
<th>Median age (years)</th>
<th>% of patients &gt;50 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traumatic Coma Data Bank⁴⁴</td>
<td>1984–1987</td>
<td>746</td>
<td>25</td>
<td>15</td>
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<tr>
<td>UK four-centre study⁴⁵</td>
<td>1986–1988</td>
<td>988</td>
<td>29</td>
<td>27</td>
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<tr>
<td>European Brain Injury Consortium core data survey⁴⁶</td>
<td>1995</td>
<td>847</td>
<td>38</td>
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<tr>
<td>Prospective Observational COhort Neurotrauma (POCON)⁴⁷</td>
<td>2008–2009</td>
<td>339</td>
<td>45</td>
<td>43</td>
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<tr>
<td>Austrian severe TBI study⁴⁸</td>
<td>1999–2004</td>
<td>415</td>
<td>48</td>
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<tr>
<td>Italian intensive care unit cohort⁴⁹</td>
<td>1997–2007</td>
<td>1,478</td>
<td>45</td>
<td>44</td>
</tr>
</tbody>
</table>

Abbreviation: TBI, traumatic brain injury.
Epidemiological trends of TBI
Italy from Fabbri, Servadei et al, Injury, 2012

Fig. 1. Number of cases visited in the Emergency Department for mild head injury in four time periods, divided according to age-decades. Note the disappearance of the bimodal distribution of age along the years.
CASE REPORT:

71 years M
GCS I 14/15
GCS II 10/15  **patient under clopidogrel**
HEMISPHERICAL SDH DX + appearance of ICH
Cyclist pushed by a car, no helmet
CENTRALIZATION and SURGICAL EVACUATION
GOS GR
## Epidemiology in countries with less resources

### TOTAL 2004

<table>
<thead>
<tr>
<th>RANK</th>
<th>LEADING CAUSE</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ischaemic heart disease</td>
<td>12.2</td>
</tr>
<tr>
<td>2</td>
<td>Cerebrovascular disease</td>
<td>9.7</td>
</tr>
<tr>
<td>3</td>
<td>Lower respiratory infections</td>
<td>7.0</td>
</tr>
<tr>
<td>4</td>
<td>Chronic obstructive pulmonary disease</td>
<td>5.1</td>
</tr>
<tr>
<td>5</td>
<td>Diarrhoeal diseases</td>
<td>3.6</td>
</tr>
<tr>
<td>6</td>
<td>HIV/AIDS</td>
<td>3.5</td>
</tr>
<tr>
<td>7</td>
<td>Tuberculosis</td>
<td>2.5</td>
</tr>
<tr>
<td>8</td>
<td>Trachea, bronchus, lung cancers</td>
<td>2.3</td>
</tr>
<tr>
<td>9</td>
<td>Road traffic injuries</td>
<td>2.2</td>
</tr>
<tr>
<td>10</td>
<td>Prematurity and low birth weight</td>
<td>2.0</td>
</tr>
<tr>
<td>11</td>
<td>Neonatal infections and other</td>
<td>1.9</td>
</tr>
<tr>
<td>12</td>
<td>Diabetes mellitus</td>
<td>1.9</td>
</tr>
<tr>
<td>13</td>
<td>Malaria</td>
<td>1.7</td>
</tr>
<tr>
<td>14</td>
<td>Hypertensive heart disease</td>
<td>1.7</td>
</tr>
<tr>
<td>15</td>
<td>Birth asphyxia and birth trauma</td>
<td>1.5</td>
</tr>
<tr>
<td>16</td>
<td>Self-inflicted injuries</td>
<td>1.4</td>
</tr>
<tr>
<td>17</td>
<td>Stomach cancer</td>
<td>1.4</td>
</tr>
<tr>
<td>18</td>
<td>Cirrhosis of the liver</td>
<td>1.3</td>
</tr>
<tr>
<td>19</td>
<td>Nephritis and nephrosis</td>
<td>1.3</td>
</tr>
<tr>
<td>20</td>
<td>Colon and rectum cancers</td>
<td>1.1</td>
</tr>
</tbody>
</table>

### TOTAL 2030

<table>
<thead>
<tr>
<th>RANK</th>
<th>LEADING CAUSE</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
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<td>3</td>
<td>Chronic obstructive pulmonary disease</td>
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</tr>
<tr>
<td>4</td>
<td>Lower respiratory infections</td>
<td>5.1</td>
</tr>
<tr>
<td>5</td>
<td>Road traffic injuries</td>
<td>3.6</td>
</tr>
<tr>
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<td>Trachea, bronchus, lung cancers</td>
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<td>7</td>
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</tr>
<tr>
<td>8</td>
<td>Hypertensive heart disease</td>
<td>2.3</td>
</tr>
<tr>
<td>9</td>
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<td>1.9</td>
</tr>
<tr>
<td>13</td>
<td>Liver cancer</td>
<td>1.7</td>
</tr>
<tr>
<td>14</td>
<td>Colon and rectum cancers</td>
<td>1.7</td>
</tr>
<tr>
<td>15</td>
<td>Oesophagus cancer</td>
<td>1.5</td>
</tr>
<tr>
<td>16</td>
<td>Violence</td>
<td>1.4</td>
</tr>
<tr>
<td>17</td>
<td>Alzheimer and other dementias</td>
<td>1.4</td>
</tr>
<tr>
<td>18</td>
<td>Cirrhosis of the liver</td>
<td>1.3</td>
</tr>
<tr>
<td>19</td>
<td>Breast cancer</td>
<td>1.3</td>
</tr>
<tr>
<td>20</td>
<td>Tuberculosis</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Future trends in epidemiology

- Tremendous increase of TBI in developing countries due to road traffic accidents with more epidural and acute subdural hematomas

- Changes in the TBI population in Europe, Japan and USA: older population, falls as the first cause of trauma, more co-morbidities, more contusions and CrSDH
Selection of patients is biased by the literature
89% of published papers in TBI come from USA-Canada-Australia-Japan –Europe
Where is located less than 18% of injuries according to the WHO report on worldwide injuries
http://www.who.int/topics/injuries/en/2013

If we look from a worldwide perspective there are far more patients with trauma due to road traffic accidents with more epidural and acute subdural hematomas
The evidence based guidelines
US Guidelines
BTF and AANS

1. **Decompressive Craniectomy**

**Changes from Prior Edition**

DC is a new topic for the 4th Edition. DC had been included in the surgical guidelines.

**Level I**

There was insufficient evidence to support a Level I recommendation for this topic.

**Level II A**

Bifrontal DC is not recommended to improve outcomes as measured by the Glasgow Outcome Scale – Extended (GOS-E) score at 6 months post-injury in severe TBI patients with diffuse injury (without mass lesions), and with ICP elevation to values >20 mm Hg for more than 15 minutes within a 1-hour period that are refractory to first-tier therapies. However, this procedure has been demonstrated to reduce ICP and to minimize days in the intensive care unit (ICU).

*The committee is aware that the results of the RESCUEicp trial may be released soon after the publication of these Guidelines. The results of this trial may affect these recommendations and may need to be considered by treating physicians and other users of these Guidelines. We intend to update these recommendations after the results are published if needed. Updates will be available at https://braintrauma.org/coma/guidelines*
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*

In most part of the world these patients are not decompressed.
Patients with severe traumatic brain injury assessed for eligibility (n=3478)

Excluded (n=3302)
- Mass lesions (n=1222)
- Unsurvivable/poor prognosis (n=420)
- Age <15 & >60 years (n=211)
- ICP controlled (n=1105)
- Other (n=344)

Declined Consent (n=21)

Randomized (n=155)
Of 3478 patients who were assessed for trial eligibility, 155 were enrolled (Fig. 1 in the Supplementary Appendix). Fifteen patients (18%) in the standard-care group underwent delayed decompressive craniectomy as a lifesaving intervention, according to the protocol. In four patients (5%) in the standard-care group, craniectomy was performed less than 72 hours after admission, contrary to the protocol.

The patients were randomly assigned to one of the two treatment groups: 73 to undergo early decompressive craniectomy and 82 to receive standard care. Baseline characteristics of the two study groups were similar in most respects, except that fewer patients in the craniectomy group had reactive pupils (Table 1). The median age was

**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 bars indicate standard errors.
Table 2. Primary and Secondary Outcomes.*

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Decompressive Cranietomy (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>
</tbody>
</table>

GOSE 1 is dead; 2 is vegetative survival; 3/4 is severe disability; 5/6 is moderate disability (independent); 7/8 is good (independent). Grade 8 is pre-injury neurological function. “Favorable outcome” is GOSE 5-8.
1. **Decompressive Craniectomy**

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*A large frontotemporoparietal DC (not less than 12 x 15 cm or 15 cm diameter) is recommended over a small frontotemporoparietal DC for reduced mortality and improved neurologic outcomes in patients with severe TBI.*

*The committee is aware that the results of the RESCUEicp trial may be released soon after the publication of these Guidelines. The results of this trial may affect these recommendations and may need to be considered by treating physicians and other users of these Guidelines. We intend to update these recommendations after the results are published if needed. Updates will be available at [https://braintrauma.org/coma/guidelines](https://braintrauma.org/coma/guidelines)*
Unilateral F-T-P decompression for bone decompression plus Hematoma evacuation Primary Decompression
Acute subdural haematoma
Plus important midline shift
Lesion evacuation plus Decompression on emergency

Primary Decompression no ICP monitoring
The complications: acute phase

Suboptimum hemicraniectomy as a cause of additional cerebral lesions in patients with malignant infarction of the middle cerebral artery

Simone Wagner, M.D., Holger Schnippering, M.D., Alfred Aschoff, M.D., James A. Koziol, Ph.D., Stefan Schwab, M.D., and Thorsten Steiner, M.D.
### Table 2. Outcomes in STC and LC Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>GR/MD</th>
<th>SD/PVS</th>
<th>Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>STC</td>
<td>241</td>
<td>96 (39.8%)(96/241)</td>
<td>82 (34.0%)(82/241)</td>
<td>63 (26.2%)(63/241)</td>
</tr>
<tr>
<td>LC</td>
<td>245</td>
<td>70 (28.6%)(70/245)</td>
<td>89 (36.3%)(89/245)</td>
<td>86 (35.1%)(86/245)</td>
</tr>
</tbody>
</table>

STC, standard trauma craniectomy; LC, limited craniectomy; GR, good recovery; MD, moderate deficit; SD, severe deficit; PVS, persistent vegetative status.
The complications: acute phase
Significant Hygroma with shift
Problems in treating acute hydrocephalus in decompressed patients
PD, f 16y
2008 DC for Politrauma acute SDH - 2009 Autologous CP
Postoperative right frontal hemorrhagic stroke and CSF fistula
2010 prostesis dislocation and resorption
DC for TBI

Secondary DC
- Early therapy
  - DECRA
    - 155 patients
    - Published in 2011
    - 15-60 years
    - Severe diffuse TBI within 72 hours post-injury
    - ICP > 20 mmHg, 15 mins
- Last-tier / rescue therapy
  - RESCUEicp
    - 400 patients
    - Published 2016
    - 10-65 years
    - Raised ICP refractory to protocol-based medical management
    - ICP > 25 mmHg, 60 mins

Primary DC
- RESCUE-ASDH
  - New study

Courtesy of prof Hutchinson
Bilateral decompression
In the case of Bilateral or diffuse lesions
Aimed to ICP control
Secondary Decompression
VI day from injury – ICP 40

ICU SMN Hospital Reggio Emilia, W Bottari
CT Perfusion

ROI Statistics for Slice 2

<table>
<thead>
<tr>
<th>ROI#</th>
<th>CBV (ml/100g)</th>
<th>CBF (ml/100g/min)</th>
<th>MTT (s)</th>
<th>TTP (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.53</td>
<td>2.52</td>
<td>13.33</td>
<td>24.34</td>
</tr>
<tr>
<td>5</td>
<td>2.49</td>
<td>18.38</td>
<td>8.13</td>
<td>20.68</td>
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<tr>
<td>6</td>
<td>2.72</td>
<td>25.57</td>
<td>6.38</td>
<td>20.52</td>
</tr>
</tbody>
</table>
VI day from injury – ICP  40
Secondary Decompression
driven by ICP monitoring
Trial of Decompressive Craniectomy for Traumatic Intracranial Hypertension

Hypothesis: Decompressive craniectomy can improve outcomes as last-tier therapy for refractory post-traumatic intracranial hypertension
RESCUEicp – decompressive craniectomy

Recruitment
n= 400 / 400
50 centres
19 countries
70% UK
To undergo randomization in the trial, patients had to be between 10 and 65 years of age, have a TBI with an abnormal computed tomographic (CT) scan of the brain, have an intracranial-pressure monitor already in place, and have raised intracranial pressure (>25 mm Hg for 1 to 12 hours, despite stage 1 and 2 measures, as defined below and in Fig. 1). Patients who had undergone an immediate operation for evacuation of an intracranial hematoma could be included as long as the operation was not a craniectomy (i.e., the bone flap was replaced at the end of procedure). Patients with bilateral fixed and dilated pupils, bleeding diathesis, or an injury that was deemed to be unsurvivable were excluded. Trial sites were
Stage 1

INITIAL TREATMENT MEASURES:
Nurse head up
Ventilation
Sedation
Analgesia
+- Paralysis

Monitoring:
CVP
Arterial line
ICP

Stage 2

ICP > 25 mm Hg

OPTIONS:
- Ventriculostomy
- Inotropes
- Mannitol
- Hypertonic saline
- Loop diuretics
- Hypothermia 36-34°C
- BARBITURATES NOT PERMITTED

Stage 3

ICP > 25 mm Hg
1-12 hours post start stage 2

Continued Medical Treatment* (stage 2 options) + barbiturates permitted

Decompressive craniectomy** + continued medical treatment (stage 2 options)

MEDICAL
4-6 hours

SURGICAL

RANDOMISE

*If continued medical treatment is drawn no decompressive surgery will be performed at that time. However, decompressive surgery may be performed later if the patient deteriorates.

**If decompressive craniectomy is drawn barbiturates should not be administered at that time. However barbiturates may be given later if the patient deteriorates.
The surgical treatment was either large unilateral frontotemporoparietal craniectomy (hemicranieotomy), which was recommended for patients with unilateral hemispheric swelling, or bifrontal craniectomy, which was recommended for patients with diffuse brain swelling that affected both hemispheres on imaging studies. The exact type of craniectomy was left to the discretion of the surgeons. Details of the recom-
2. Trial flowchart

Excluded (n=1599)
- ICP not raised (n=601)
- Primary DC (n=240)
- Unsurvivable injury (n=128)
- Bilateral mydriasis (n=109)
- DC outside trial (n=82)
- Consent refused (n=66)
- Outside age range of 10-65 (n=50)
- Follow-up not possible (n=39)
- Lack of equipoise (n=37)
- Brainstem involvement (n=31)
- Recruited to another trial (n=28)
- Bleeding diathesis (n=16)
- Received barbiturates pre-randomisation (n=16)
- Unable to randomize (n=3)
- No reason given (n=153)

Assessed for eligibility (n=2008)

Randomized (n=408)
- Randomized twice in error (n=1)
### Table 1. Characteristics of the Patients at Baseline.*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Surgical Group (N = 202)</th>
<th>Medical Group (N = 196)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age — yr</strong></td>
<td>32.3±13.2</td>
<td>34.8±13.7</td>
</tr>
<tr>
<td><strong>Male sex — no./total no. (%)</strong></td>
<td>165/202 (81.7)</td>
<td>156/195 (80.0)</td>
</tr>
<tr>
<td><strong>GCS motor score at first hospital — no./total no. (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 or 2</td>
<td>96/181 (53.0)</td>
<td>85/170 (50.0)</td>
</tr>
<tr>
<td>3–6</td>
<td>85/181 (47.0)</td>
<td>85/170 (50.0)</td>
</tr>
<tr>
<td><strong>Pupillary abnormality — no. (%)</strong></td>
<td>59 (29.2)</td>
<td>57 (29.1)</td>
</tr>
<tr>
<td><strong>Hypotension — no. (%)</strong></td>
<td>40 (19.8)</td>
<td>42 (21.4)</td>
</tr>
<tr>
<td><strong>Hypoxemia — no. (%)</strong></td>
<td>49 (24.3)</td>
<td>52 (26.5)</td>
</tr>
<tr>
<td><strong>History of drug or alcohol abuse — no. (%)</strong></td>
<td>50 (24.8)</td>
<td>69 (35.2)</td>
</tr>
<tr>
<td><strong>Extracranial injury — no. (%)</strong></td>
<td>75 (37.1)</td>
<td>83 (42.3)</td>
</tr>
<tr>
<td><strong>Injury classification on basis of CT imaging — no./total no. (%)</strong></td>
<td>161/198 (81.3)</td>
<td>141/186 (75.8)</td>
</tr>
<tr>
<td><strong>Diffuse injury</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mass lesion</strong></td>
<td>37/198 (18.7)</td>
<td>45/186 (24.2)</td>
</tr>
</tbody>
</table>
**Table 2. Treatments and Interventions.***

<table>
<thead>
<tr>
<th>Treatment or Intervention</th>
<th>Surgical Group (N = 202)</th>
<th>Medical Group (N = 196)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Craniotomy for evacuation of hematoma — no. (%)</td>
<td>26 (12.9)</td>
<td>30 (15.3)</td>
</tr>
<tr>
<td>Ventriculostomy — no. (%)</td>
<td>34 (16.8)</td>
<td>43 (21.9)</td>
</tr>
<tr>
<td>Neuromuscular paralysis — no. (%)</td>
<td>101 (50.0)</td>
<td>103 (52.6)</td>
</tr>
<tr>
<td>Pharmacologic blood-pressure augmentation — no. (%)</td>
<td>112 (55.4)</td>
<td>116 (59.2)</td>
</tr>
<tr>
<td>Osmotherapy — no. (%)</td>
<td>146 (72.3)</td>
<td>144 (73.5)</td>
</tr>
<tr>
<td>Therapeutic hypothermia — no. (%)</td>
<td>47 (23.3)</td>
<td>53 (27.0)</td>
</tr>
<tr>
<td>Decompressive craniectomy — no. (%)†</td>
<td>187 (92.6)</td>
<td><strong>73 (37.2)</strong></td>
</tr>
<tr>
<td>Bifrontal — no./total no. (%)</td>
<td>109/173 (63.0)</td>
<td>NA</td>
</tr>
<tr>
<td>Unilateral — no./total no. (%)</td>
<td>64/173 (37.0)</td>
<td>NA</td>
</tr>
<tr>
<td>Barbiturates — no. (%)‡</td>
<td>19 (9.4)</td>
<td>171 (87.2)</td>
</tr>
</tbody>
</table>
1 (dead)
2 (vegetative state)
3 (lower severe disability)
4 (independent at home)
5 (independent at home and outside the home)
6 (upper moderate disability)
7 (lower good recovery)
8 (upper good recovery)
Figure S1 – Stacked bar chart of 6 month GOSE collapsed into three categories (sensitivity analysis)

Extended Glasgow Outcome Scale at 6 months (collapsed into three categories)

Table S14 – Patients aged ≤40 years

<table>
<thead>
<tr>
<th></th>
<th>Surgical Group</th>
<th>Medical Group</th>
<th>Absolute Difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfavourable outcome</td>
<td>69 (48.6%)</td>
<td>81 (63.8%)</td>
<td></td>
</tr>
<tr>
<td>Favourable outcome</td>
<td>73 (51.4%)</td>
<td>46 (36.2%)</td>
<td>15.2% (3.5% to 26.9%)</td>
</tr>
</tbody>
</table>
Figure S2 – Stacked bar chart of 12 month GOSE collapsed into three categories (sensitivity analysis)

Extended Glasgow Outcome Scale at 12 months (collapsed into three categories)

- **Surgical group**
  - DEAD: 30.4%
  - VS / LSD: 24.2%
  - USD or better: 45.4%

- **Medical group**
  - DEAD: 52.0%
  - VS / LSD: 15.6%
  - USD or better: 32.4%

p 0.01
“The effect of early intensive care unit (ICU) adherence to 2007 Brain Trauma Foundation Guideline indicators after traumatic brain injury (TBI) on in-patient mortality at a level 1 trauma center in India (JPNATC) and Harborview Medical Center (HMC) in U.S. among adults >18 years with severe TBI.”

Gupta et al, World Neurosurgery 2016
Results

Post Discharge Outcomes

**JPNATC:** overall TBI clinic follow up rates (including deaths) were 99% at 3, 6 and 12 months.

**HMC:** overall TBI follow up rates (N=200) were 83%, 72% and 60% at 3, 6 and 12 months.

**Mortality**

**JPNATC:** mortality: 24% at discharge to 29% at 3 months, to 34% at 6 months and to 36% at 12 months.

**HMC:** Mortality 26% but there was only one new known death among HMC patients post discharge.
In patients with malignant MCA infarction, decompressive surgery undertaken within 48h of stroke onset reduces mortality and increases the number of patients with a favourable functional outcome. The decision to perform decompressive surgery should, however, be made on an individual basis in every patient.

**DECIMAL (NCT00190203) F**
- Started in 2001
- MRI-based inclusion
- Early surgery (<30h)
- Stroke severity NIH≥15
- Projected sample size 60 (30/30)
- Interrupted after 38 patients for slow recruitment, significant difference in mortality and the perspective of a pooled analysis

**DESTINY (ISRTN0125859) G**
- Started 2004
- CT-based inclusion
- Early surgery within 36h
- Stroke severity NIH≥18/20
- Projected sample size 68 (34/34)
- Per protocol on hold for randomization after 32 patients (after significance for mortality, to assess mRS)

**HAMLET (ISRCTN94237756) NL**
- Started in 2002
- CT-based inclusion
- Surgery (within 99 h)
- Stroke severity NIH≥16/21
- Projected sample size 112 patients
- 57 patients included

Different statistical analysis
Different surgical timing
Different inclusion criteria
Significant improvement in favorable outcome by recategorizing favorable as a mRS score of ≤4

**MODIFIED RANKIN SCALE (mRS)**

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No symptoms at all</td>
</tr>
<tr>
<td>1</td>
<td>No significant disability despite symptoms; able to carry out all usual duties and activities</td>
</tr>
<tr>
<td>2</td>
<td>Slight disability; unable to carry out all previous activities, but able to look after own affairs without assistance</td>
</tr>
<tr>
<td>3</td>
<td>Moderate disability; requiring some help, but able to walk without assistance</td>
</tr>
<tr>
<td>4</td>
<td>Moderately severe disability; unable to walk without assistance and unable to attend to own bodily needs without assistance</td>
</tr>
<tr>
<td>5</td>
<td>Severe disability; bedridden, incontinent and requiring constant nursing care and attention</td>
</tr>
<tr>
<td>6</td>
<td>Dead</td>
</tr>
</tbody>
</table>
MAIN RESULT:
If poor result is defined as mRS > 3

was no different between the treatments

(OR 0.56, 95% CI 0.27 to 1.15)
• Some ethical considerations for the future .....
Finally and most importantly, the RESCUEicp trial showed that decompressive surgery in patients with traumatic brain injury and raised intracranial pressure was associated with lower mortality than medical management. However, more survivors in the surgical group than in the medical group were dependent on others, a finding that emphasizes the fact that lifesaving procedures may not ensure a return to normal functioning. In particular, the larger proportion of survivors in the vegetative state in the surgical group than in the medical group is noteworthy. The findings of this trial
Rather than accept a generic or absolute ICP threshold, e.g., 20 mmHg, it may be preferable to individualize thresholds based on patient characteristics, pathology, other physiologic parameters, and on a risk-benefit analysis of treating the specific ICP. Conceptually, ICP values then become an epiphenomenon of cerebral compliance, ischemia, hypoxia, cellular dysfunction, or the likelihood of herniation among other pathophysiological processes. This requires multimodal monitoring that in its simplest form means interpreting the ICP value according to the clinical and CT findings or in a more sophisticated approach using other physiologic parameters as well. This can be challenging and requires further research validation, and so for the present, it is reasonable to set the treatment threshold at 20–25 mm Hg at the onset of management but consider altering the threshold when other clinical data support this.

From Le Roux et al., 2016
I CT SCAN (h17:00)

II CT SCAN (h23:00)

Osmotherapy
Sedation
CT scan
Surgery
Do we know when to stop ???
Out of 47 neurosurgeons, 16 said they will reverse the coagulation and operate the patient and 7 even decompress.

Women, 86 years, Anticoagulants, GCS 3, Anisocoria
DG, aged 74
GCS 4
Miosis non reacting

CT scan sent from a peripheral Hospital at one hour drive from Neurosurgery

Will you accept patient’s transfer?
DG, aged 74
GCS 4
Miosis non reacting

CT scan sent from a peripheral Hospital at one hour drive from Neurosurgery

Will you accept patient’s transfer?
EANS Course:
35% NO
65% YES of these

60% will operate and decompress the patient
Devastating SAH:

Patient aged 45 yrs

GCS 3 but reacting pupils on admission to peripheral Hospital

**Webinar case:**
Immediate transfer
Endovascular treatment
ICP monitoring
Possible bifrontal decompression
No mention of the outcome (back to Middle Age...)

![Brain CT scan](image)
Male, 15 yrs, RTA
GCS 3 on the scene but reacting pupils at Hospital arrival
OUTCOME

GOS
Persistent Vegetative State
6 years
After-trauma
Do we know when to stop ???

NO
Surgery for TBI cannot cure unsalvageable patients providing them a reasonable quality of life ...

Cooper PR, 1979

The “over-treatment”
Reconsidering the role of decompressive craniectomy for neurological emergencies

Objective: There would appear to be little doubt that decompressive craniectomy can reduce mortality. However for many years there has been concern that any reduction in mortality may come at an increase in the number of survivors with severe neurological disability. This narrative review assesses the evidence currently available. Method: Over the past decade there have been several randomised controlled trials comparing surgical decompression with standard medical therapy in the context of ischaemic stroke and severe traumatic brain injury. The results of each trial were evaluated. Results: There is now unequivocal evidence that a decompressive craniectomy reduces mortality in the context of “malignant” middle infarction and following severe traumatic brain injury. However, it has only been possible to demonstrate an improvement in outcome by categorizing a mRS of 4 and upper severe disability as favourable outcome. This is contentious and an alternative interpretation is that surgical decompression reduces mortality but exposes a patient to a greater risk of survival with severe disability. Conclusion: It would appear unlikely that further randomised controlled trials will be possible and it may be that observational cohort studies and outcome prediction models may provide data to determine those patients that may benefit from surgical decompression.
<table>
<thead>
<tr>
<th>Case No.</th>
<th>3+ Years’ Outcome per GOS-E</th>
<th>Patient Responses</th>
<th>Next of Kin Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1. Knowing your eventual outcome would you have provided consent?</td>
<td>Q2. How much of your life prior to the injury can you remember?</td>
<td>Q1. Were you asked to provide consent?</td>
</tr>
<tr>
<td>1</td>
<td>vegetative</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>lower severe</td>
<td>yes</td>
<td>some parts</td>
</tr>
<tr>
<td>3</td>
<td>lower severe</td>
<td>not sure</td>
<td>some parts</td>
</tr>
<tr>
<td>5</td>
<td>upper severe</td>
<td>yes</td>
<td>some parts</td>
</tr>
<tr>
<td>6</td>
<td>lower severe</td>
<td>unable</td>
<td>unable</td>
</tr>
<tr>
<td>7</td>
<td>lower severe</td>
<td>yes</td>
<td>completely</td>
</tr>
<tr>
<td>10</td>
<td>lower severe</td>
<td>yes</td>
<td>some parts</td>
</tr>
<tr>
<td>11</td>
<td>upper severe</td>
<td>yes</td>
<td>completely</td>
</tr>
<tr>
<td>12</td>
<td>lower severe</td>
<td>unable</td>
<td>unable</td>
</tr>
<tr>
<td>13</td>
<td>upper severe</td>
<td>no</td>
<td>some parts</td>
</tr>
<tr>
<td>15</td>
<td>vegetative</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>16</td>
<td>upper severe</td>
<td>yes</td>
<td>completely</td>
</tr>
<tr>
<td>17</td>
<td>vegetative</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>19</td>
<td>lower severe</td>
<td>yes</td>
<td>completely</td>
</tr>
<tr>
<td>21</td>
<td>upper severe</td>
<td>yes</td>
<td>completely</td>
</tr>
<tr>
<td>22</td>
<td>vegetative</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>23</td>
<td>lower severe</td>
<td>yes</td>
<td>some parts</td>
</tr>
<tr>
<td>25</td>
<td>lower severe</td>
<td>yes</td>
<td>some parts</td>
</tr>
<tr>
<td>26</td>
<td>upper severe</td>
<td>yes</td>
<td>some parts</td>
</tr>
<tr>
<td>27</td>
<td>vegetative</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
The disability paradox reflects the observation that many people with disabilities report a good or excellent quality of life, when to most observers they would appear to live in a very undesirable state.
WHO’S CANDIDATE FOR DC?

**CLEAR inclusion criteria**
- Basal cistern effacement +
- Midline shift +
- ICP > 30 +
- Intraoperative brain swelling +
- Young GCS 5-8

**CLEAR exclusion criteria**
- Brainstem +/-
- Diffuse Axonal Injury +/-
- Elderly GCS 3-4

?
Possible solutions

• Decision in favor of surgery always taken together by Neurosurgeons Neurologists and Intensivists

• Do not consider only a number (ICP >25 mmHg) But all the informations we have about patient’s brain (CBF,Radiology,GCS on arrival, pre-trauma/stroke morbidities and quality of life ...)

• Inform the relatives about the high possibility of a bad outcome and investigate the willings of the patient before the brain damage
The resources are limited therefore:

"...desperately radical result: the curable, the salvageable, can thus be sacrificed to the hopelessly damaged and unconscious who consume the time and space and money better devoted to those who could be helped. To pretend that no such alternative exists is non sense: what one gets the other is deprived of...."

H.K. Beecher

Ethical problems created by the hopelessly unconscious patients

NEJM 278, 1425-1430, 1968
Thanks for your attention
University of Bologna Anatomical Theatre
At JPNATC, the overall ICU adherence rate was 74.9\% [SD 11.0\%], and the following indicators had adherence rates greater than 90\%: achieving target temperature, not using prophylactic barbiturates, timely start of nutritional support, and avoidance of intravenous steroids. Intracranial pressure (ICP) monitors were placed in 63\% of patients, and 52\% of patients with intracranial hypertension received some form of ICP reduction treatment. Among patients with ICP monitoring, 94\% of patients had all cerebral perfusion pressures between 50-70 mmHg.

At HMC, the overall ICU adherence rate was 71.6\% [SD 10.4\%], and the following indicators had adherence rates greater than 90\%: achieving target temperature, not using prophylactic barbiturates, timely start of nutritional support, and avoidance of intravenous steroids. ICP monitors were placed in 84\% of patients, and 98\% of patients with intracranial hypertension received some form of ICP reduction treatment. Among patients with ICP monitoring, 63\% of patients had all cerebral perfusion pressures between 50-70 mmHg. Forty-two percent of patients received prophylactic antiepileptic medications.

### Table: ICU Guideline Adherence

<table>
<thead>
<tr>
<th>Indicators</th>
<th>JPNATC N (%)</th>
<th>HMC N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adherence rate mean [SD]</td>
<td>74.9 [11.0]</td>
<td>71.6 [10.4]</td>
</tr>
<tr>
<td>1) Hypoxia treated within 30 minutes after onset (Hypoxia - JPNATC [N = 2]; HMC [N = 10])</td>
<td>1 (50.0)</td>
<td>7 (70.0)</td>
</tr>
<tr>
<td>2) Hypotension treated within 30 minutes after onset (Hypotension - JPNATC [N = 2]; HMC [N = 82])</td>
<td>1 (50.0)</td>
<td>55 (67.1)</td>
</tr>
<tr>
<td>3) Intracranial pressure (ICP) monitor used</td>
<td>126 (63.0)</td>
<td>167 (83.5)</td>
</tr>
<tr>
<td>4) All cerebral perfusion pressure between 50-70 mmHg (Among those with ICP monitoring - JPNATC [N = 126]; HMC [N = 167])</td>
<td>119 (94.4)</td>
<td>105 (62.9)</td>
</tr>
<tr>
<td>5) Any treatment given for high ICP (clinical or by ICP monitors) (High ICP - JPNATC [N = 25]; HMC [N = 96])</td>
<td>13 (52.0)</td>
<td>94 (97.9)</td>
</tr>
<tr>
<td>6) Mannitol used for treatment of high ICP (High ICP - JPNATC [N = 25]; HMC [N = 96])</td>
<td>10 (40.0)</td>
<td>52 (54.2)</td>
</tr>
<tr>
<td>7) Propofol used for treatment of high ICP (High ICP - JPNATC [N = 25]; HMC [N = 96])</td>
<td>6 (24.0)</td>
<td>91 (94.8)</td>
</tr>
<tr>
<td>8) Prophylactic hyperventilation is not used for treatment of high ICP (High ICP - JPNATC [N = 25]; HMC [N = 96])</td>
<td>22 (88.0)</td>
<td>96 (100)</td>
</tr>
<tr>
<td>9) Target temperatures maintained (T 35-38.5\°C)</td>
<td>195 (97.5)</td>
<td>200 (100)</td>
</tr>
<tr>
<td>10) Pre-intubation antibiotics used</td>
<td>136 (68.0)*</td>
<td>3 (1.5)</td>
</tr>
<tr>
<td>11) Early tracheostomy performed</td>
<td>5 (2.5)</td>
<td>40 (20.0)</td>
</tr>
<tr>
<td>12) Deep Vein Thrombosis (DVT) prophylaxis used</td>
<td>110 (55.0)</td>
<td>197 (98.5)</td>
</tr>
<tr>
<td>13) Treatment thresholds of (S_{O2} \geq 50%) or (P_{brO2} \geq 15) mmHg used ((S_{O2} or P_{brO2} monitored) - JPNATC [N = 3]; HMC [N = 64])</td>
<td>3 (100.0)</td>
<td>37 (57.8)</td>
</tr>
<tr>
<td>14) Prophylactic barbiturate coma not induced</td>
<td>190 (95.0)</td>
<td>194 (97.0)</td>
</tr>
<tr>
<td>15) Prophylactic antiepileptic drugs used to prevent early seizures</td>
<td>198 (99.0)</td>
<td>83 (41.5)</td>
</tr>
<tr>
<td>16) Nutrition† started within 72 hours</td>
<td>188 (94.0)</td>
<td>187 (93.5)</td>
</tr>
<tr>
<td>17) No steroids used</td>
<td>198 (99.0)</td>
<td>199 (99.5)</td>
</tr>
</tbody>
</table>

---

*At JPNATC, 68\% patients received antibiotics in the Emergency Department around the time of tracheal intubation.
† Nutrition includes enteral, parenteral or combined.
Results

Discharge Outcomes and Disposition

. At JPNATC, in-hospital mortality was 24% and among survivors, the most common (50%) discharge GOS score was 4 and 8% returned to baseline level of functioning. At JPNATC, discharge disposition largely bimodal: 24% died in-hospital and 72% of patients were discharged home. No patients received in-patient rehabilitation care or were discharged to a skilled nursing facility. Approximately 4% of patients received outpatient rehabilitation care.

. At HMC, in-hospital mortality was 26.5% and among survivors, the most common (34%) discharge GOS score was 4 and 21% of patients returned to baseline level of functioning at discharge. Sixteen percent were discharged home, 27% of patients were discharged to an inpatient rehabilitation facility and 26% of TBI patients were discharged to a skilled nursing facility.
Correggio (Antonio Allegri, detto), Assunzione della Vergine, Parma, cupola del Duomo, 1526-1528, affresco, cm. 1093 x 1195
Inclusion criteria: Radiology

**One of**

**Primary sign**
- **CT scan:** volume > 25 ml

**Secondary signs**
- midline shift > 5 mm
- Compression / obliteration of III° ventricle
- Compression / obliteration of ipsilateral basal cisterns
- Compression of ipsilateral ventricle
- Dilatation of contralateral ventricle
Multicentre Study of Intradural Lesions

• GCSm on admission to the first hospital
  • Mean 4.24 +/- 1.78
  • Median 5  Range 1-6

• At least one reacting pupil:
  • 72%
Intracranial Operation

- Yes: 71%
- No: 29%
• When do we operate patients with post traumatic Haematomas?
Timing of Surgery

- Immediate (within 24 hours): 65%
- Delayed: 22%
- Both: 13%
• Which are the more frequent surgical haematomas?
Type of lesions
(immediate surgery n=454)

66% of the patients is operated because of an ASDH
Type of lesion (deferred surgery n=162)

- EDH: 18%
- SDH: 25%
- ICH: 44%
- ESD + ICH: 13%

69% of patients is operated because of contusions / t-ICH
Why do we operate our patients?
What about associated decompression?
<table>
<thead>
<tr>
<th>Diagnoses</th>
<th>Emergency surgery</th>
<th>Delayed surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total number of procedures</strong> (decompressive craniectomies)</td>
<td>404 (134) - 33,2%</td>
<td>154 (47) - 30,5%</td>
</tr>
<tr>
<td>Extradural hematoma</td>
<td>60 (8) - 13,3%</td>
<td>18 (3) - 16,6</td>
</tr>
<tr>
<td>Acute subdural hematoma</td>
<td>169 (34) - 20,1%</td>
<td>12 (1) - 8,3%</td>
</tr>
<tr>
<td>Contusion/intracerebral hematoma</td>
<td>51 (10) - 19,6%</td>
<td>48 (8) - 16,7%</td>
</tr>
<tr>
<td>ASHD and contusion</td>
<td>79 (23) - 29,1%</td>
<td>32 (8) - 25,0%</td>
</tr>
<tr>
<td>Other</td>
<td>45 (4) - 8,9%</td>
<td>44 (12) - 27,3%</td>
</tr>
<tr>
<td>Variable</td>
<td>Emergency surgery</td>
<td>Delayed surgery</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>No. of procedures</td>
<td>134(^b)</td>
<td>47(^b)</td>
</tr>
<tr>
<td>Isolated procedure</td>
<td>1 (0.7%)</td>
<td>8 (17%)</td>
</tr>
<tr>
<td>Inadequate decompression</td>
<td>38 (28%)</td>
<td>5 (11%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>15 (11%)</td>
<td>10 (21%)</td>
</tr>
<tr>
<td>Adequate decompression</td>
<td>81 (61%)</td>
<td>32 (68%)</td>
</tr>
<tr>
<td>Adequate decompression (&gt;30 cm(^2))(^c)</td>
<td>Mean (SD) area = 92 (51)</td>
<td>Mean (SD) area = 90 (65)</td>
</tr>
<tr>
<td></td>
<td>Median = 80</td>
<td>Median = 80</td>
</tr>
<tr>
<td>Size of decompression</td>
<td>Range = 32–300</td>
<td>Range = 32–361</td>
</tr>
<tr>
<td></td>
<td>IQR = 56–120</td>
<td>IQR = 48–100</td>
</tr>
<tr>
<td>Associated surgical treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extradural hematoma</td>
<td>8 (10%)</td>
<td>3 (9%)</td>
</tr>
<tr>
<td>Acute subdural hematoma</td>
<td>36 (44%)</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>Contusion/intracerebral hematoma</td>
<td>10 (12%)</td>
<td>8 (25%)</td>
</tr>
<tr>
<td>ASDH and contusion</td>
<td>23 (28%)</td>
<td>8 (25%)</td>
</tr>
<tr>
<td>Other</td>
<td>4 (5%)</td>
<td>12 (37%)</td>
</tr>
<tr>
<td>Reason for surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass effect</td>
<td>56 (71%)</td>
<td>Increased ICP 14 (45%)</td>
</tr>
<tr>
<td>Lesion Size</td>
<td>8 (10%)</td>
<td>Clinical deterioration 10 (32%)</td>
</tr>
<tr>
<td>Clinical deterioration</td>
<td>11 (14%)</td>
<td>Radiological deterioration 5 (16%)</td>
</tr>
<tr>
<td>Other</td>
<td>11 (14%)</td>
<td>Other 2 (6%)</td>
</tr>
</tbody>
</table>

\(^a\) SD, standard deviation; IQR, interquartile range, ASDH, acute subdural hematoma.

\(^b\) Seven patients were decompressed twice and are included in both columns.

\(^c\) The size of decompression was unknown in 15 patients (11%) who underwent emergency surgery and in 10 (21%) who underwent delayed surgery.
The European Brain Injury Consortium survey, which was conducted in 2001, demonstrated that a decompressive craniectomy (DC) was undertaken in approximately one quarter of operations performed for ASDH. Since then, there has been a resurgence of interest in the use of DC after TBI:

From Kolas et al, 2012

Are these data still reliable or there is an underestimation of the use of associated decompression??
Number of papers published on decompressive craniectomies
Refractory intracranial hypertension and “second-tier” therapies in traumatic brain injury

Nino Stocchetti, Clelia Zanaboni, Angelo Colombo, Giuseppe Citerio, Luigi Beretta, Laura Ghisoni, Elisa Roncati Zanier, Katia Canavesi

Parma 2010-12 5.3% Mergoni, Volpi, Servadei

19.6%

4.4% 5,1% Aarabi '06
4.9% Albanese '03

Surgical management of traumatic brain injury: a comparative-effectiveness study of 2 centers

Clinical article

Jed A. Hartings, Ph.D.,1 Steven Vidgeon, M.D.,2 Anthony J. Strong, M.D.,2 Chris Zacko, M.D.,3 Achala Vagal, M.D.,4 Norberto Andaluz, M.D.,1 Thomas Ridder, M.D.,5 Richard Stanger, M.D.,5 Martin Fabricius, D.M.Sc,6 Bruce Mathern, M.D.,5 Clemens Pahl, M.D.,7 Christos M. Tolias, M.D., Ph.D., F.R.C.S.(Eng), F.R.C.S.(Sn),2 and M. Ross Bullock, M.D., Ph.D.,3 for the Co-Operative Studies on Brain Injury Depolarizations

Departments of 1Neurosurgery and 4Radiology, University of Cincinnati Neuroscience Institute, University of Cincinnati College of Medicine, Cincinnati, Ohio; Departments of 2Clinical Neuroscience and 7Critical Care Medicine, King’s College London, United Kingdom; 3Department of Neurological Surgery, University of Miami, Florida; 4Division of Neurosurgery, Virginia Commonwealth University, Richmond, Virginia; and 6Department of Clinical Neurophysiology, Glostrup Hospital, Copenhagen, Denmark
Object. Mass lesions from traumatic brain injury (TBI) often require surgical evacuation as a life-saving measure and to improve outcomes, but optimal timing and surgical technique, including decompressive craniectomy, have not been fully defined. The authors compared neurosurgical approaches in the treatment of TBI at 2 academic medical centers to document variations in real-world practice and evaluate the efficacies of different approaches on postsurgical course and long-term outcome.

Methods. Patients 18 years of age or older who required neurosurgical lesion evacuation or decompression for TBI were enrolled in the Co-Operative Studies on Brain Injury Depolarizations (COSBID) at King’s College Hospital (KCH, n = 27) and Virginia Commonwealth University (VCU, n = 24) from July 2004 to March 2010. Subdural electrode strips were placed at the time of surgery for subsequent electrocorticographic monitoring of spreading depolarizations; injury characteristics, physiological monitoring data, and 6-month outcomes were collected prospectively. CT scans and medical records were reviewed retrospectively to determine lesion characteristics, surgical indications, and procedures performed.

Results. Patients enrolled at KCH were significantly older than those enrolled at VCU (48 vs 34 years, p < 0.01) and falls were more commonly the cause of TBI in the KCH group than in the VCU group. Otherwise, KCH and VCU patients had similar prognoses, lesion types (subdural hematomas: 30%–35%; parenchymal contusions: 48%–52%), signs of mass effect (midline shift ≥ 5 mm: 43%–52%), and preoperative intracranial pressure (ICP). At VCU, however, surgeries were performed earlier (median 0.51 vs 0.83 days posttrauma, p < 0.05), bone flaps were larger (mean 82 vs 53 cm², p < 0.001), and craniectomies were more common (performed in 75% vs 44% of cases, p < 0.05). Postoperatively, maximum ICP values were lower at VCU (mean 22.5 vs 31.4 mm Hg, p < 0.01). Differences in incidence of spreading depolarizations (KCH: 63%, VCU: 42%, p = 0.13) and poor outcomes (KCH: 54%, VCU: 33%, p = 0.14) were not significant. In a subgroup analysis of only those patients who underwent early (< 24 hours) lesion evacuation (KCH: n = 14; VCU: n = 16), however, VCU patients fared significantly better. In the VCU patients, bone flaps were larger (mean 85 vs 48 cm² at KCH, p < 0.001), spreading depolarizations were less common (31% vs 86% at KCH, p < 0.01), postoperative ICP values were lower (mean: 20.8 vs 30.2 mm Hg at KCH, p < 0.05), and good outcomes were more common (69% vs 29% at KCH, p < 0.05). Spreading depolarizations were the only significant predictor of outcome in multivariate analysis.

Conclusions. This comparative-effectiveness study provides evidence for major practice variation in surgical management of severe TBI. Although ages differed between the 2 cohorts, the results suggest that a more aggressive approach, including earlier surgery, larger craniotomy, and removal of bone flap, may reduce ICP, prevent cortical spreading depolarizations, and improve outcomes. In particular, patients requiring evacuation of subdural hematomas and contusions may benefit from decompressive craniectomy in conjunction with lesion evacuation, even when elevated ICP is not a factor in the decision to perform surgery.

(http://thejns.org/doi/abs/10.3171/2013.9.JNS13581)

Key Words • decompressive craniectomy • intracranial hypertension • cortical spreading depression • traumatic brain injury • acute subdural hematoma • brain contusion
Examination of the management of traumatic brain injury in the developing and developed world: focus on resource utilization, protocols, and practices that alter outcome

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Object. We evaluated management and outcome of traumatic brain injury (TBI) in a developed country (US) and a developing country (Jamaica).

Methods. Data were collected prospectively at Grady Memorial Hospital (GMH) in the US and at University Hospital of the West Indies (UHWI) and Kingston Public Hospital (KPH) in Jamaica between September 1, 2003, and September 30, 2004.

Results. Complete data were available for 1607 patients. Grady Memorial Hospital had a higher proportion of females (p = 0.003), and patients were older at GMH (p = 0.0009) compared with patients at KPH and UHWI. The most common mode of injury was a motor vehicle accident at KPH and GMH (42 and 66%, respectively) and assaults at UHWI (37%). Grady Memorial Hospital admitted more patients with severe head injuries (25.5%) than KPH (18.5%) and UHWI (14.4%). More CT scans were performed (p < 0.0001) and a higher proportion of patients were admitted to the intensive care unit (p < 0.0001) at GMH. There were no statistically significant differences in median stays in the intensive care unit among the 3 hospitals. Patients experienced statistically significant differences in days undergoing ventilation between GMH, KPH, and UHWI (p = 0.004). Intracranial pressure monitoring was performed in 1 patient at KPH, in 6 at UHWI, and in 91 at GMH. There were 174 total deaths, but no statistically significant differences in mortality rates between the 3 sites (p = 0.3). Hospital location and TBI severity were associated with a decreased risk of mortality; patients with severe TBI at GMH had a 53% decrease in the risk of mortality (odds ratio = 0.47, p = 0.04). Patients at GMH had lower mean Glasgow Outcome Scale scores (p < 0.0001) and lower Functional Independence Measure self-feed (p = 0.0003), locomotion (p = 0.04), and verbal scores (p < 0.0001).

Conclusions. Despite the availability of advanced technology and more aggressive neurological support at GMH, the overall mortality rate for TBI was similar at all locations. Patients identified with severe TBI had a significantly decreased risk of mortality if they were treated at GMH compared with those patients treated at hospitals in the developing world. (DOI: 10.3171/JNS/2008/109/9/0433)
Patients with brain contusions: predictors of outcome and relationship between radiological and clinical evolution

Clinical article

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Object. Traumatic parenchymal mass lesions are common sequelae of traumatic brain injuries (TBIs). They occur in up to 8.2% of all TBI cases and 13%–35% of severe TBI cases, and they account for up to 20% of surgical intracranial lesions. Controversy exists concerning the association between radiological and clinical evolution of brain contusions. The aim of this study was to identify predictors of unfavorable outcome, analyze the evolution of brain contusions, and evaluate specific indications for surgery.

Methods. In a retrospective, multicenter study, patients with brain contusions were identified in separate patient cohorts from 11 hospitals over a 4-year period (2008–2011). Data on clinical parameters and course of the contusion were collected. Radiological parameters were registered by using CT images taken at the time of hospital admission and at subsequent follow-up times. Patients who underwent surgical procedures were identified. Outcomes were evaluated 6 months after trauma by using the Glasgow Outcome Scale-Extended.

Results. Multivariate analysis revealed the following reliable predictors of unfavorable outcome: 1) increased patient age, 2) lower Glasgow Coma Scale score at first evaluation, 3) clinical deterioration in the first hours after trauma, and 4) onset or increase of midline shift on follow-up CT images. Further multivariate analysis identified the following as statistically significant predictors of clinical deterioration during the first hours after trauma: 1) onset of or increase in midline shift on follow-up CT images (p < 0.001) and 2) increased effacement of basal cisterns on follow-up CT images (p < 0.001).

Conclusions. In TBI patients with cerebral contusion, the onset of clinical deterioration is predictably associated with the onset or increase of midline shift and worsened status of basal cisterns but not with hematoma or edema volume increase. A combination of clinical deterioration and increased midline shift/basal cistern compression is the most reasonable indicator for surgery.

(http://thejns.org/doi/abs/10.3171/2013.12.JNS131090)
Retrospective cohort of 352 pts
Brain contusion as main lesion and/or
the primary reason for surgery

15 pts
Surgery after first CT scan

- 2 pts CR (13.4%)
- 13 pts DC (86.6%)

46 pts
Surgery after second CT scan

- 11 pts DC (23.9%)
- 36 pts CR (76.1%)

291 pts NO Surgery

15/15 GCS < 8
15/15 Volume > 20 ml
14/15 Midline Shift > 5 mm
12/15 Cisterns effacement
11/15 Single Contusion
Outcome following evacuation of acute subdural haematomas: a comparison of craniotomy with decompressive craniectomy

170 operations entered as ‘acute subdural’ and ‘craniotomy’ or ‘craniectomy’ OR ‘decompressive craniectomy’

79 exclusions: non-traumatic ASDH, secondary DC for raised ICP, mini-craniotomy, acute on chronic subdural haematoma

91 evacuations of traumatic ASDH

40 craniotomies (44%)

51 DC (56%)

38 patients had 6 month GOS available (2 lost to follow-up)
GOS 1: 12 (32%)
GOS 2: 1 (2%)
GOS 3: 8 (21%)
GOS 4: 11 (29%)
GOS 5: 6 (16%)

50 patients had 6 month GOS available (1 lost to follow-up)
GOS 1: 19 (38%)
GOS 2: 0
GOS 3: 10 (20%)
GOS 4: 17 (34%)
GOS 5: 4 (8%)

We believe that the absence of outcome differences despite a higher predicted risk for mortality/poor outcome in the DC group possibly suggests that primary DC may be more effective than CR for selected patients with ASDH.

indications of DC versus CR remain a matter of debate

However, the role of primary DC for evacuation of acute subdural hematomas (ASDH) has not been the subject of any randomized trials to date.
Factors which influence surgical decision taking process

**Radiological**
- Lesion volume
- Midline shift
- Lesion evolution

**Clinical**
- Age
- GCS- clinical deterioration

**Physiopathological**
- ICP increase / CPP decrease
- Relationship with medical therapy to control ICP
Factors which influence surgical decision taking process

Radiological

• Lesion volume

The lesion volume is only one parameter
Pragmatic Approach
( Misunderstanding )

“Epidural or Subdural Hematoma”,
“contusion”, “traumatic intracerebral hematoma” No matter

If it is greater than 25 ml
Take it out!

Single or multiple lesions?
Lesion + / - edema

DG, aged 74
GCS 4

Not even trasferred to Neurosurgery !!
Factors which influence surgical decision taking process

Radiological

- Lesion volume
- Midline shift
Midline shift at the level of the foramen of Monro should be determined by first measuring the width of the intracranial space in order to determine the midline (“A”). Next, the distance from the bone to the septum pellucidum is measured.

Small haematomas With significant Midline shift Are surgical....
Patients with brain contusions: predictors of outcome and relationship between radiological and clinical evolution

TABLE 7: Patients with and without neurological deterioration: distribution of different neuroradiological parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Neurological Deterioration (No. [%])</th>
<th>Univariate p Value</th>
<th>Multivariate p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present (n = 111)</td>
<td>Absent (n = 241)</td>
<td></td>
</tr>
<tr>
<td>hematoma evolution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes (n = 149)</td>
<td>63 (56.7)</td>
<td>86 (35.7)</td>
<td>0.0003</td>
</tr>
<tr>
<td>no (n = 203)</td>
<td>48 (43.3)</td>
<td>155 (64.3)</td>
<td></td>
</tr>
<tr>
<td>edema increase</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>yes (n = 162)</td>
<td>77 (69.4)</td>
<td>85 (35.3)</td>
<td></td>
</tr>
<tr>
<td>no (n = 190)</td>
<td>34 (30.6)</td>
<td>156 (64.7)</td>
<td></td>
</tr>
<tr>
<td>onset or increase in midline shift</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>yes (n = 97)</td>
<td>89 (80.2)</td>
<td>8 (3.3)</td>
<td></td>
</tr>
<tr>
<td>no (n = 255)</td>
<td>22 (19.8)</td>
<td>233 (96.7)</td>
<td></td>
</tr>
<tr>
<td>onset or increase in effacement of basal cisterns</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>yes (n = 107)</td>
<td>74 (66.7)</td>
<td>33 (13.7)</td>
<td></td>
</tr>
<tr>
<td>no (n = 245)</td>
<td>37 (33.3)</td>
<td>208 (86.3)</td>
<td></td>
</tr>
</tbody>
</table>

Conclusions. In TBI patients with cerebral contusion, the onset of clinical deterioration is predictably associated with the onset or increase of midline shift and worsened status of basal cisterns but not with hematoma or edema volume increase. A combination of clinical deterioration and increased midline shift/basal cistern compression is the most reasonable indicator for surgery.
The concept of lesion progression

Progressive hemorrhage after head trauma: predictors and consequences of the evolving injury

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W. JOHN BOSCARDIN, PH.D., THOMAS C. GLENN, PH.D., JAE HONG LEE, M.D., M.P.H.,
TOORAJ GRAVRI, M.D., DENNIS OBUKHOV, M.S., DUNCAN Q. McBRIDE, M.D.,
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Factors Associated with Neurological Outcome and Lesion Progression in Traumatic Subarachnoid Hemorrhage Patients

OBJECTIVE: Traumatic subarachnoid hemorrhage (SAH) is a frequent finding after closed-head injuries, and its presence is a powerful factor associated with poor outcomes. The exact mechanism linking SAH and an adverse outcome is poorly understood. The aim of this study was to identify the factors that may predict outcomes and changes in the computed imaging (CT) scans of lesions in a selected population of SAH patients.

METHODS: We evaluated 143 patients admitted consecutively from January 1, 1997, to January 1, 1999, with a CT diagnosis of SAH. The admission and “worst” CT scans were recorded. CT scan changes were reported as “significant CT progression” (changes in the Marshall classification) or “any CT progression.” The amount of subarachnoid blood was recorded using a modified Fisher classification. Outcome was assessed at 6 months after injury with the Glasgow Outcome Scale.

RESULTS: Twenty-eight patients (19.9%) had an unfavorable Glasgow Outcome Scale outcome. In the univariate analysis, predictors significantly related to age, admission Glasgow Coma Scale score, Marshall CT classification score at admission and on the worst CT scan, amount of SAH, and volume of the associated brain contusions. From multivariate analysis, the only factors independently related to outcome were the Glasgow Coma Scale score at admission, Marshall CT classification score, and the amount of subarachnoid blood.

CONCLUSION: The outcome of patients with SAH at admission is related to a logistic regression analysis of the admission Glasgow Coma Scale score and to the amount of subarachnoid blood. These patients also have a significant risk of CT progression. The amount of subarachnoid blood and the presence of associated parenchymal damage are powerful independent factors associated with CT progression, thus linking poor outcomes and CT changes.

KEY WORDS: Brain contusions, Head injury, Lesion progression, Outcome, Subarachnoid hemorrhage

Acute Traumatic Intraparenchymal Hemorrhage: Risk Factors for Progression in the Early Post-injury Period

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Accepted: October 27, 2005

OBJECTIVE: To characterize the natural course of traumatic intracerebral hematomas (ICHs) and to identify risk factors for ICH progression in the acute post-injury period.

METHODS: A retrospective analysis was performed on a prospective observational database containing 113 head trauma patients exhibiting 229 initially nonoperated acute ICHs. The main outcome variable was radiographic evidence of ICH progression on serially obtained head computed tomographic (CT) scans. Secondary outcomes included the actual amount of ICH growth and later surgical evacuation. Univariate and multivariate analyses (using a generalized estimate equation) were applied to both demographic and initial radiographic features to identify risk factors for ICH progression and surgery.

RESULTS: Overall, 10 ICHs (4.5%) shrank. 133 (59%) remained unchanged, and 86 (38%) grew between the first and second head CT scan. ICH progression was independently associated with the presence of subarachnoid hemorrhage (odds ratio [OR], 1.6; 95% confidence interval [CI], 1.1–2.3), presence of a subdural hematoma (OR, 1.9; 95% CI, 1.1–3.4), and initial size (OR, 1.11; 95% CI, 1.02–1.21), for each cm³ volume. Size of initial ICH proportionately correlated with the amount of subsequent growth (linear regression, P < 0.0001). Worsened Glasgow Coma Score between initial and follow-up head CT scan (OR, 6.6; 95% CI, 1.5–50), ICH growth greater than 5 cm³ (OR, 7.3; 95% CI, 1.6–34), and effacement of basal cisterns on initial head CT scan (OR, 9.0; 95% CI, 1.5–52) were strongly associated with late surgical evacuation.

CONCLUSION: A large proportion of ICHs progress in the acute post-injury period. ICHs associated with subarachnoid hemorrhage, a subdural hematoma, or large initial size should be monitored carefully for progression with repeat head CT imaging. Effacement of cisterns on the initial head CT scan was strongly predictive of failure of nonoperative management, thereby leading to surgical evacuation. These findings should be important factors in the understanding and management of ICH.

KEY WORDS: Computed tomography, Contusion, Intracerebral hematomas, Progression, Risk factors, Traumatic brain injury

Neurosurgery 56:467-476, 2005
DOI: 10.1227/01.NEU.0000177055.82752.8A
www.neurosurgery-online.com
Initial and worst CT after Trauma:
GT aged 60 GCS on admission 12
Factors which influence surgical decision taking process

**Radiological**
- Lesion volume
- Midline shift
- Lesion evolution

**Clinical**
- Age
Traumatology: relationship age/ transfer
From Servadei et al., Br J Neurosurg 2002

Mean age
Mean age transferred
Mean age not transferred

52 41 54
Effect of patients age on management of acute intracranial haematomas

Patients aged >65 years had lower survival rates than patients < 65 years.

Older patients were less likely to be transferred to specialist neurosurgical care (10 (56%) vs 142 (85%) for extradural haematoma (P=0.005) and 56 (60%) vs 192 (77%) for subdural haematoma (P=0.004)).

Munro et al, BMJ NOVEMBER 2002
Age has been shown to be an independent factor in the process of trauma care in elderly patients.

This may be because of differences in management, particularly in rates of transfer to neurosurgical care.

In Europe Age is by far the most important unspoken triage criterion .......

Munro et al, BMJ NOVEMBER 2002
Factors which influence surgical decision taking process

**Radiological**
- Lesion volume
- Midline shift
- Lesion evolution

**Clinical**
- Age
- GCS- clinical deterioration
Coma scales

Assessment of consciousness level is crucial in the care of patients with acute brain damage. Yet, for a long time, how it should be done was debatable, with diverging views and an array of approaches. Many of these approaches contained imprecisely defined concepts such as “stupor” or “lethargy”, and depended on subjective judgment. The resulting absence of a common language caused confusion in management. There was also a lack of consistent communication in scientific publications. An approach was needed that could be used in all patients with acute brain damage. A study by Teasdale and Jennet colleagues tested their scale in a neurological intensive care unit in 120 patients with a range of intracranial disorders. FOUR was as reliable as the GCS at assessing these patients. Because FOUR included brainstem indices, it provided a more detailed assessment of patients in deep coma, while assessment of patients in a less deep coma was better with the GCS. FOUR gave a more detailed assessment of patients with the lowest possible GCS score because it measures pupil reaction—a standard test in all such patients. Overall, the two scales were equally effective in predicting outcome.
Should we relay only upon CT images for surgical indications in TBI patients??
Small Acute subdural haematoma
Plus important midline shift

Difference ???
Operate ???
ICP monitoring ??

Admission
GCS is still important in 2007 ????
GCS 11 deteriorating

GCS 15
Only headache
Patient never seen in an ICU .....
Acute subdural haematoma  
Plus important midline shift  
Case 1  
Operated and decompressed  
Good recovery

Acute subdural haematoma  
Plus important midline shift  
Case 2  
Conservative Management  
With good outcome
Factors which influence surgical decision taking process

**Radiological**
- Lesion volume
- Midline shift
- Lesion evolution

**Clinical**
- Age
- GCS- clinical deterioration

**Physiopathological**
- ICP increase / CPP decrease
- Relationship with medical therapy to control ICP
IZ 48 yrs, GCS on admission 7, GOS = GR
The uncertainties
MB age 26 years
Repeat of CT scanning 8 hours after the first exam. - GCS 11 stable
MB aged 26 years, GCS 11 stable
Day 1 following CT control on admission

• Immediate surgery ?

• Surgical decision based on clinical deterioration ?

• Surgical decision based on radiological evolution ?
Answers
(60 EU Neurosurgeons)

1. Alternative A: 32.1%
2. Alternative B: 39.3%
3. Alternative C: 28.6%
TABLE 3: Association between clinical and radiological parameters and need for surgery after second CT scan

<table>
<thead>
<tr>
<th>Variable</th>
<th>Surgery (n = 46)</th>
<th>No Surgery (n = 291)</th>
<th>Univariate p Value</th>
<th>Multivariate p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCS score at admission</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14–15</td>
<td>2</td>
<td>144</td>
<td>&lt;0.0001</td>
<td>0.03</td>
</tr>
<tr>
<td>9–13</td>
<td>12</td>
<td>93</td>
<td>0.5</td>
<td>0.078</td>
</tr>
<tr>
<td>3–8</td>
<td>32</td>
<td>54</td>
<td>&lt;0.0001</td>
<td>0.019</td>
</tr>
<tr>
<td>mean patient age (yrs) ± SD</td>
<td>55.6 ± 28.3</td>
<td>74. ± 25.1</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>worsening clinical condition</td>
<td>36</td>
<td>75</td>
<td>&lt;0.0001</td>
<td>0.03</td>
</tr>
<tr>
<td>radiological appearance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>increase or onset of midline shift</td>
<td>31</td>
<td>66</td>
<td>&lt;0.0001</td>
<td>0.013</td>
</tr>
<tr>
<td>worsening of basal cistern status</td>
<td>29</td>
<td>78</td>
<td>&lt;0.0001</td>
<td>0.002</td>
</tr>
<tr>
<td>evolution of hematoma</td>
<td>28</td>
<td>121</td>
<td>0.02</td>
<td>0.277</td>
</tr>
<tr>
<td>increased edema</td>
<td>22</td>
<td>140</td>
<td>0.06</td>
<td>0.102</td>
</tr>
<tr>
<td>patient outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>favorable</td>
<td>21 (45.6%)</td>
<td>204 (70.1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>severe disability</td>
<td>18 (39.1%)</td>
<td>44 (15.1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>death</td>
<td>7 (15.2%)</td>
<td>43 (14.7%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Boldface indicates statistical significance.

increased ICP (in monitored comatose patients). But what can we decide when hematoma progression does not correspond to clinical worsening (86/149 cases [57.7%]) or, to the contrary, when clinical worsening does not correspond to hematoma progression (48/203 cases [23.6%])?
Conclusions

In surgery there is still a grey area where «the surgeon in duty» decides, without clear scientific evidence, by taking into account different parameters.

From our data clinical and radiological deterioration (when in agreement) seem to be the most important.

There is a need for further studies about the association between haematoma evacuation and decompression.
General Criteria Emergency Transferral in Neurosurgery (traumatic/non traumatic)

- Need of early surgery
- **Potential evolution**
- Not “hopeless cases”

Decision based upon Clinical & Radiological criteria

The volume of the lesion ALONE is not eligible criteria
76 years M
GCS I 14/15
GCS II 15/15
TEMPORO-PARIETAL SHA DX + TEMPORAL SDH SX
Fall at home
Unchanged situation at the CT scan after 6 hours
CONSERVATIVE THERAPY and MANAGEMENT IN SPOKE
GOS GR AFTER 6 MONTHS
CASE REPORT:

61 years M
GCS I 14/15
GCS II 10/15
HEMISPHERICAL SDH DX + appearance of ICH
Cyclist pushed by a car, no helmet
CENTRALIZATION and SURGICAL EVACUATION
GOS GR
All patients with post traumatic intracranial lesions 
Should be transferred to Neurosurgical Hospitals?

No, not every TBI patient should be transferred to NSU but you need a telemedicine network and an area protocol
A Trial of Intracranial-Pressure Monitoring in Traumatic Brain Injury

Randall M. Chesnut, M.D., Nancy Temkin, Ph.D., Nancy Carney, Ph.D., Sureyya Dikmen, Ph.D., Carlos Rondina, M.D., Walter Videtta, M.D., Gustavo Petroni, M.D., Silvia Lujan, M.D., Jim Pridgeon, M.H.A., Jason Barber, M.S., Joan Machamer, M.A., Kelley Chaddock, B.A., Juanita M. Celix, M.D., Marianna Chernier, Ph.D., and Terence Hendrix, B.A.

Intensive Care Med

Randall M. Chesnut

EDITORIAL

Intracranial pressure monitoring: headstone or a new head start. The BEST TRIP trial in perspective
The apparently oversimplified concepts surrounding manipulating ICP do not produce improved recovery in the general sTBI population.
• men, 40 yrs
• biker (collision with car)

• GCS pre-H 5 (E1, V1, M2)

• intubation in the field
• no hypotension, no arterial desaturation
• right femur fracture (external fixation)

• ICP
worst ct scan in ICU
ICU

- episodes of ICP > 25 mmHg (longer duration max 15 min) within the first week treated with:
  - osmotherapy (mannitol and saline)
  - bolus sedation
  - max Na during ICU stay: 152 meq/Lt

- ICU stay 20 days (GOS six months 4)
The RESCUEicp trial addressed these concerns by including more commonly encountered types of patients with traumatic intracranial mass lesions and by refining the definition of refractory intracranial-pressure elevation (>25 mm Hg for 1 to 12 hours, as compared with >20 mm Hg for 15 minutes within a 1-hour period in the DECRA study)

The primary-outcome measure was the 6-month Extended Glasgow Outcome Scale (GOS-E) rating (on an 8-point scale, ranging from death to upper good recovery).

The trial showed better intracranial-pressure control, lower mortality, and higher rates of vegetative state, lower severe disability, and upper severe disability in the surgical group than in the medical group; the rates of moderate and good recovery were similar in the two groups.
In a prespecified sensitivity analysis, the authors compared the proportion of patients in each group who had outcomes of upper severe disability or better (GOS-E score of 4 to 8), which were defined as “favorable outcomes.” In keeping with other studies, the RESCUEicp trial included upper severe disability as a favorable outcome; patients in the upper-severe-disability category may be independent in the home but rely on others for assistance outside the home. The dichotomized GOS-E results did not show a significantly higher percentage of patients with a favorable outcome in the surgical group than in the medical group at 6 months (42.8% and 34.6%, respectively; \( P=0.12 \)), but there was a significant difference at 12 months (45.4% vs. 32.4%; \( P=0.01 \)).
A New Procedure?

Cranieotomy Performed to Permit Brain Swelling after Traumatic Brain Injury.

Some surgeons leave the dura mater intact, as it appears here; others open the dura to give the brain more room to swell. The excised piece of skull is implanted under the skin and subcutaneous tissue of the abdomen, outside the muscle wall, so that it can be replaced after the brain has recovered.
Fig. 32. — Tracé des différents lambeaux :
En 1, 2, 3 les orifices faits à la fraise par l'instrumentation électrique.
L'orifice 3 peut être reporté en 3', le tracé du lambeau devient 1 à 2, 2 et 3.
CC' charnière ou pédicule.
Les lignes 1-a, 2-b', 3-b sont sectionnées à la scie à curseur.
b-b', 2-a représentent les ponts fissurés au ciseau.
b'e2, 2'd b', fragment osseux réséqué.
If there's no CSF pressure, but brain pressure exists, then pressure relief must be achieved by opening the skull.
“Nihil novi sub sole“: the role of decompressive craniectomy in the treatment of malignant brain oedema

- In 1971 Ranshoff published encouraging results with the use of Hemicraniectomy in the treatment of malignant brain edema related to traumatic hematomas (ASDH).

- In 1975 the same group (Cooper) showed the “futility of Hemicraniectomy in treating severely head injured patients with acute subdural hematomas”: end of the story?

- No we will see.........
How important is surgery for trauma???

• In our Unit out of 3800 consecutive surgeries (3 years), 1330 (34%) are brain and spine injuries (Level I Trauma Center)

• Japan all over the country, 2014, 240000 Neurosurgical procedures: 53000 trauma procedures (22%), from Morita et al

• Indonesia (Univ of Surabaya): 450 trauma surgeries out of 1850 procedures (25%)

• Ruanda 47/147 (one month), 37%
Incidence, hospital costs and in-hospital mortality rates of epidural hematoma in the United States

Shyamal C. Bir, Tanmoy Kumar Maiti, Sudheer Ambekar, Anil Nanda

Department of Neurosurgery, LSU Health-Shreveport, 1501 Kings Highway, Shreveport, LA 71130-3932, USA
<table>
<thead>
<tr>
<th>Topic</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intracranial pressure monitoring</td>
<td>Level IIb</td>
</tr>
<tr>
<td></td>
<td>• Management of severe TBI patients using information from ICP monitoring is recommended to reduce in-hospital and 2-week post-injury mortality.</td>
</tr>
<tr>
<td></td>
<td>Recommendations from the prior (Third) Edition not supported by evidence meeting current standards.</td>
</tr>
<tr>
<td></td>
<td>ICP should be monitored in all salvageable patients with a TBI (GCS 3-8 after resuscitation) and an abnormal CT scan. An abnormal CT scan of</td>
</tr>
<tr>
<td></td>
<td>the head is one that reveals hematomas, contusions, swelling, hemiation, or compressed basal cisterns.</td>
</tr>
<tr>
<td></td>
<td>ICP monitoring is indicated in patients with severe TBI with a normal CT scan if ≥2 of the following features are noted at admission: age</td>
</tr>
<tr>
<td></td>
<td>&gt;40 years, unilateral or bilateral motor posturing, or SBP &lt;90 mm Hg.</td>
</tr>
<tr>
<td>Cerebral perfusion pressure</td>
<td>Level IIb</td>
</tr>
<tr>
<td>monitoring</td>
<td>• Management of severe TBI patients using guidelines-based recommendations for CPP monitoring is recommended to decrease 2-wk mortality.</td>
</tr>
<tr>
<td>Advanced cerebral monitoring</td>
<td>Level III</td>
</tr>
<tr>
<td></td>
<td>• Jugular bulb monitoring of AVDO₂, as a source of information for management decisions, may be considered to reduce mortality and improve</td>
</tr>
<tr>
<td></td>
<td>outcomes at 3 and 6 mo post-injury.</td>
</tr>
</tbody>
</table>

*AVDO₂, arteriovenous oxygen content difference; CPP, cerebral perfusion pressure; CT, computed tomography; GCS, Glasgow Coma Scale; ICP, intracranial pressure; SBP, systolic blood pressure; TBI, traumatic brain injury.

*Bold: New or revised recommendations.*
### TABLE 3. Updated Recommendations: Thresholds

<table>
<thead>
<tr>
<th>Topic</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood pressure thresholds</td>
<td>Level III</td>
</tr>
<tr>
<td></td>
<td>• Maintaining SBP at $\geq 100$ mm Hg for patients 50 to 69 years old or at $\geq 110$ mm Hg or above for patients 15 to 49 or $\geq 70$ years old may be considered to decrease mortality and improve outcomes.</td>
</tr>
<tr>
<td>Intracranial pressure thresholds</td>
<td>Level IIIB</td>
</tr>
<tr>
<td></td>
<td>• Treating ICP $&gt;22$ mm Hg is recommended because values above this level are associated with increased mortality.</td>
</tr>
<tr>
<td></td>
<td>Level III</td>
</tr>
<tr>
<td></td>
<td>• A combination of ICP values and clinical and brain CT findings may be used to make management decisions.</td>
</tr>
<tr>
<td></td>
<td>*The committee is aware that the results of the RESCUEicp trial$^2$ were released after the completion of these Guidelines. The results of this trial may affect these recommendations and may need to be considered by treating physicians and other users of these Guidelines. We intend to update these recommendations if needed. Updates will be available at <a href="https://braintrauma.org/coma/guidelines">https://braintrauma.org/coma/guidelines</a>.</td>
</tr>
<tr>
<td>Cerebral perfusion pressure thresholds</td>
<td>Level IIIB</td>
</tr>
<tr>
<td></td>
<td>• The recommended target CPP value for survival and favorable outcomes is between 60 and 70 mm Hg. Whether 60 or 70 mm Hg is the minimum optimal CPP threshold is unclear and may depend upon the autoregulatory status of the patient.</td>
</tr>
<tr>
<td></td>
<td>Level III</td>
</tr>
<tr>
<td></td>
<td>• Avoiding aggressive attempts to maintain CPP $&gt;70$ mm Hg with fluids and pressors may be considered because of the risk of adult respiratory failure.</td>
</tr>
<tr>
<td>Advanced cerebral monitoring thresholds</td>
<td>Level III</td>
</tr>
<tr>
<td></td>
<td>• Jugular venous saturation of $&lt;50%$ may be a threshold to avoid in order to reduce mortality and improve outcomes.</td>
</tr>
</tbody>
</table>

$^a$CPP, cerebral perfusion pressure; CT, computed tomography; ICP, intracranial pressure; RESCUEicp trial, Randomised Evaluation of Surgery with Cranectomy for Uncontrollable Elevation of ICP; SBP, systolic blood pressure.

$^b$Bold: New or revised recommendations.
VI. Indications for Intracranial Pressure Monitoring

A. Level I

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

B. Level II

Intracranial pressure (ICP) should be monitored in all salvageable patients with a severe traumatic brain injury (TBI; Glasgow Coma Scale [GCS] score of 3–8 after resuscitation) and an abnormal computed tomography (CT) scan. An abnormal CT scan of the head is one that reveals hematomas, contusions, swelling, herniation, or compressed basal cisterns.

C. Level III

ICP monitoring is indicated in patients with severe TBI with a normal CT scan if two or more of the following features are noted at admission: age over 40 years, unilateral or bilateral motor posturing, or systolic blood pressure (BP) < 90 mm Hg.
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*
In most part of the world these patients are not decompressed.

Within the first 72 hours after injury, we randomly assigned patients either to undergo decompressive craniectomy plus standard care or to receive standard care alone, using an automated telephone system. Randomization was stratified

Standard care from the time of enrollment followed clinical practice guidelines that were based on those recommended by the Brain Trauma Foundation.
Patients with severe traumatic brain injury assessed for eligibility (n=3478)

Excluded (n=3302)
- Mass lesions (n=1222)
- Unsurvivable/poor prognosis (n=420)
- Age <15 & >60 years (n=211)
- ICP controlled (n=1105)
- Other (n=344)

Declined Consent (n=21)

Randomized (n=155)
Of 3478 patients who were assessed for trial eligibility, 155 were enrolled (Fig. 1 in the Supplementary Appendix). Fifteen patients (18%) in the standard-care group underwent delayed decompressive craniectomy as a lifesaving intervention, according to the protocol. In four patients (5%) in the standard-care group, craniectomy was performed less than 72 hours after admission, contrary to the protocol.

The patients were randomly assigned to one of the two treatment groups: 73 to undergo early decompressive craniectomy and 82 to receive standard care. Baseline characteristics of the two study groups were similar in most respects, except that fewer patients in the craniectomy group had reactive pupils (Table 1). The median age was

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 1 bars indicate standard errors.
Unfavorable outcomes occurred in 51 patients (70%) in the craniectomy group and in 42 patients (51%) in the standard-care group (odds ratio, 2.21; 95% CI, 1.14 to 4.26; P=0.02) (Table 2, and Fig. 2 in the Supplement; 3.79; P=0.07). A total of 14 patients (19%) in the craniectomy group and 15 patients (18%) in the standard-care group died. (Details about the increased rate of survival of severely injured patients in a vegetative state (grade 2 on the Extended Glasgow Outcome Scale), because even though the number of such patients increased after craniectomy, the rates of death were similar in the two study groups. Decompressive craniectomy.}

Another possible explanation for the inferior outcomes with craniectomy concerns the characteristics of the surgical procedure. Some surgeons prefer a unilateral procedure, with studies (in retrospective, nonrandomized series with mixed causes of brain injury) suggesting that the bilateral approach may have more complications.33

**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.
GOSE 1 is dead; 2 is vegetative survival; 3/4 is severe disability; 5/6 is moderate disability (independent); 7/8 is good (independent). Grade 8 is pre-injury neurological function. “Favorable outcome” is GOSE 5-8.
• The Letters and comments

• The study for sure was not well received by the worldwide neurosurgical community

• Six contra – editorials
• Four clinical papers
• 38 published letters
• The Australian authors of the DECRA study have been interrupted during their presentation in Two International Meetings

Only one letter in favour of the study

The surgical management
Which patients should be operated for sure ...
The Management of Patients with Intradural Post-Traumatic Mass Lesions: A Multicenter Survey of Current Approaches to Surgical Management in 729 Patients Coordinated by the European Brain Injury Consortium

OBJECTIVE: Controversy exists about the indications and timing for surgery in head injured patients with an intradural mass lesion. The aim of this study was to survey contemporary approaches to the treatment of head injured patients with an intradural lesion, placing a particular focus on the utilization of decompressive craniectomy.

METHODS: A prospective international survey was conducted over a 3-month period in 67 centers from 24 countries on the neurosurgical management of head injured patients with an intradural mass lesion and/or radiological signs of raised intracranial pressure. Information was obtained about demographic, clinical, and radiological features; surgical management, and mortality at discharge.

RESULTS: Over the period of the study, data were collected about 729 patients consecutively admitted to one of the participating centers. The survey included 397 patients with a severe head injury (Glasgow Coma Scale [GCS] 3-8), 135 with a moderate head injury (GCS 9-12) and 143 patients with a mild head injury (GCS 13-15). An operation was performed on 502 patients (69%). Emergency surgery (<24 h) was most frequently performed for patients with an extracerebral mass lesion (subdural hematomas) whereas delayed surgery was most frequently performed for an intracerebral hematoma or contusion. Decompressive craniectomy was performed in a substantial number of patients, either during an emergency procedure (n = 134, 18%) or a delayed procedure (n = 47, 31%). The decompressive procedure was nearly always combined with evacuation of a mass lesion. The size of the decompression was however considered too small in 25% of cases.

CONCLUSION: The results provide a contemporary picture of neurosurgical surgical approaches to the management of head injured patients with an intradural mass lesion and/or signs of raised intracranial pressure in some Neurosurgical Units across the world. The relative benefits of early versus delayed surgery in patients with intraparenchymal lesions and on the indications, technique and benefits of decompressive craniectomy could be topics for future head injury research.

KEY WORDS: Decompressive craniectomy, Intradural mass lesions, Surgical management, Traumatic brain injury

Neurosurgery. 57:731-739, 2005 DOI: 10.1227/01.NEU.0000163250.13515.59 www.neurosurgery-online.com

There is controversy about the indications and timing for surgery in the management of head-injured patients. This applies especially to those with intradural lesions such as an acute subdural hematoma (29, 33), parenchymal brain contusions and/or an intracerebral posttraumatic hematoma (3, 5). These controversies reflect the lack of high quality data relating surgical approach to outcome. Consequently, the uncertainties in the management of a patient with an intradural lesion are not satisfactorily dealt with in pub-
Factors which influence surgical decision taking process

**Radiological**
- Lesion volume
- Midline shift
- Lesion evolution

**Clinical**
- Age
- GCS- clinical deterioration

**Physiopathological**
- ICP increase / CPP decrease
- Relationship with medical therapy to control ICP
Reason for Surgery (immediate surgery n=399)

From Compagnone et al, Neurosurgery, 2005
RECOMMENDATIONS
(see Methodology)

Indications for Surgery
• An epidural hematoma (EDH) greater than 30 cm$^3$ should be surgically evacuated regardless of the patient’s Glasgow Coma Scale (GCS) score.
Midline shift at the level of the foramen of Monro should be determined by first measuring the width of the intracranial space in order to determine the midline ("A"). Next, the distance from the bone to the septum pellucidum is measured.

Small haematomas with significant midline shift are surgical....
Parenchymal post traumatic lesions with large volume and midline shift present a clear surgical indication.
Open questions

- When to operate  

Lesions may evolve...
Reason for Surgery (delayed surgery n=159)

From Compagnone et al, Neurosurgery, 2005
RADIOLOGICAL AND CLINICAL PROGRESSION

Patients with brain contusions: predictors of outcome and relationship between radiological and clinical evolution

First 12 hours post-trauma:

Clinical parameters:
- 111 cases of clinical deterioration (31.5%)
- 22 cases of clinical improvement (6.3%)
- 219 cases of neurological stability (62.2%)

CT parameters:
- 103 cases of no changing in lesion volume (29.2%)
- 43 cases of diminution of lesion volume (12.2%)
- 206 cases of radiological evolution (58.5%)
IZ 48 yrs, GCS on admission 7, GOS = GR

ICP monitoring - worst CT

ICP

hrs

0
20
40
60
1
9
17
25
33
41
49
57
65
73
81
89
97
105
TABLE 7: Patients with and without neurological deterioration: distribution of different neuroradiological parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Neurological Deterioration (No. [%])</th>
<th>Univariate p Value</th>
<th>Multivariate p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present (n = 111)</td>
<td>Absent (n = 241)</td>
<td></td>
</tr>
<tr>
<td>hematoma evolution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes (n = 149)</td>
<td>63 (56.7)</td>
<td>86 (35.7)</td>
<td>0.0003</td>
</tr>
<tr>
<td>no (n = 203)</td>
<td>48 (43.3)</td>
<td>155 (64.3)</td>
<td></td>
</tr>
<tr>
<td>edema increase</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>yes (n = 162)</td>
<td>77 (69.4)</td>
<td>85 (35.3)</td>
<td></td>
</tr>
<tr>
<td>no (n = 190)</td>
<td>34 (30.6)</td>
<td>156 (64.7)</td>
<td></td>
</tr>
<tr>
<td>onset or increase in midline shift</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>yes (n = 97)</td>
<td>89 (80.2)</td>
<td>8 (3.3)</td>
<td></td>
</tr>
<tr>
<td>no (n = 255)</td>
<td>22 (19.8)</td>
<td>233 (96.7)</td>
<td></td>
</tr>
<tr>
<td>onset or increase in effacement of basal cisterns</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>yes (n = 107)</td>
<td>74 (66.7)</td>
<td>33 (13.7)</td>
<td></td>
</tr>
<tr>
<td>no (n = 245)</td>
<td>37 (33.3)</td>
<td>208 (86.3)</td>
<td></td>
</tr>
</tbody>
</table>

**Conclusions.** In TBI patients with cerebral contusion, the onset of clinical deterioration is predictably associated with the onset or increase of midline shift and worsened status of basal cisterns but not with hematoma or edema volume increase. A combination of clinical deterioration and increased midline shift/basal cistern compression is the most reasonable indicator for surgery.
Open questions

• When to operate ???? Lesions may evolve...
• What about associated decompression ????
Level I and II A
There was insufficient evidence to support a Level I or II A recommendation for this topic.

Level II B
Management of severe TBI patients using information from ICP monitoring is recommended to reduce in-hospital and 2-week post-injury mortality.
Intracranial Pressure Thresholds

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

Treatment should be initiated with intracranial pressure (ICP) thresholds above 20 mm Hg.

C. Level III

A combination of ICP values, and clinical and brain CT findings, should be used to determine the need for treatment.

Level I and II A

There was insufficient evidence to support a Level I or II A recommendation for this topic.

Level II B

Treating ICP above 22 mm Hg is recommended because values above this level are associated with increased mortality.

Level III

A combination of ICP values and clinical and brain CT findings may be used to make management decisions.

*The committee is aware that the results of the RESCUEicp trial may be released soon after the publication of these Guidelines. The results of this trial may affect these recommendations and may need to be considered by treating physicians and other users of these Guidelines. We intend to update these recommendations after the results are published if needed. Updates will be available at https://braintrauma.org/coma/
A Trial of Intracranial-Pressure Monitoring in Traumatic Brain Injury

Randall M. Chesnut, M.D., Nancy Temkin, Ph.D., Nancy Carney, Ph.D., Sureyya Dikmen, Ph.D., Carlos Rondina, M.D., Walter Videtta, M.D., Gustavo Petroni, M.D., Silvia Lujan, M.D., Jim Pridgeon, M.H.A., Jason Barber, M.S., Joan Machamer, M.A., Kelley Chaddock, B.A., Juanita M. Celix, M.D., Marianna Cherner, Ph.D., and Terence Hendrix, B.A.

Intensive Care Med

EDITORIAL

Intracranial pressure monitoring: headstone or a new head start. The BEST TRIP trial in perspective

Randall M. Chesnut
The apparently oversimplified concepts surrounding manipulating ICP do not produce improved recovery in the general sTBI population.

**Figure 1. Cumulative Survival Rate According to Study Group.**
A Kaplan–Meier survival plot based on the prespecified analysis shows the cumulative survival rate at 6 months.