Severe trauma in children

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Severe trauma in children

- <20% of pediatric trauma patients
- Leading cause of death in children >1 year
- Traumatic brain injury (TBI)
  - Observed in 80-90%
  - Severe TBI in ~ 50%
  - 30-50% of traumatic death related to severe TBI

Severe trauma in children: a life-threatening event requiring an immediate management

Goals of this review

Overview of assessment and critical care of pediatric patients with a severe trauma
Secondary brain insults of systemic origin on admission in severe TBI children

SBI: arterial hypotension, hypoxia, anemia, hypercarbia

Mortality rate: 37%

1 hypotensive episode: mortality x 3.6

SBI: yes  SBI: no

% patients

Good/moderate outcome
Bad outcome

Marescal C et al. AFAR 1998
• Retrospective study at a Level 1 pediatric Trauma Center

• Hypotension
  - Documented in 118 (39%)
  - Treated in 48%

• Hypoxemia
  - Documented in 131 (44%)
  - Treated in 92%
Early Resuscitation of Children With Moderate-to-Severe Traumatic Brain Injury
Michelle Zebrack, Christopher Dandoy, Kristine Hansen, Eric Scaife, N. Clay Mann and Susan L. Bratton
*Pediatrics* 2009;124:56-64
DOI: 10.1542/peds.2008-1006

- Non treated hypoxia
- Treated hypoxia
- No hypoxia
- Non treated hypotension
- Treated hypotension
- No hypotension

Bad neurologic outcome (%)

- Death (%)
  - Death x 3.4
  - Disability x 3.7
Overall mortality: 22%

• 45% during the first 12 hours
• 65% during the first 24 hours

585 children
Mean age: 7±5 years
GCS: 6 (3-8)
ISS: 28 (4-75)

Cerebral lesions:
Thoracic (42%)
Long bones (32%)
Abdominal (11%)
Treat first what kills first

A - Airway
B - Breathing
C - Circulation
D - Disability
E - Exposure

ASSESS - TREAT

TREAT ASSESS

Assessment of respiratory failure

<table>
<thead>
<tr>
<th>Clinical signs</th>
<th>Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apnea</td>
<td>↓ SpO2</td>
</tr>
<tr>
<td>↓ or ↑ respiratory rate</td>
<td>Hypercarbia</td>
</tr>
<tr>
<td>Cyanosis</td>
<td></td>
</tr>
</tbody>
</table>
Airway management

1. Avoid and treat hypoxemia immediately

2. Maintain SpO2 >90% and/or PaO2 >60-65 mmHg

3. Avoid hypercarbia and gastric aspiration

4. Continuous monitoring of SpO2 and EtCO2
5. Open and maintain the airway

6. *Gastric tube using the oral route*

7. Deliver high flow O2

8. Secure the airway of patients

9. Tracheal intubation: the most effective procedure to maintain the airway
Severe TBI and C-spine trauma in children

- Frequency: 2-10% according to age
- Spinal Cord Injury Without Radiographic Abnormality (SCIWORA):
  - 6%-38% of spinal trauma
  - Mainly from C1 to C8

Yucesoy K. Clin Neurol Neurosurg 2008 ; Rana AR et al. JPS 2009
Spinal cord injury without radiographic abnormalities in children, 2 decades later

Neurosurgery 55:1325-1343, 2004

Barbara Buldini · Angela Amigoni · Roberto Faggin · Anna Maria Laverda

Spinal cord injury without radiographic abnormalities
Tracheal intubation in severely traumatized children

• Tracheal intubation
  ▪ Wide indications
  ▪ At least patients with GCS <9

• Rapid sequence induction

• On line stabilization of the C-spine during intubation
Rapid sequence induction in pediatric trauma patients

- **Etomidate** 0.2-0.4 mg/kg in children > 2 years
- **Ketamine** 3.0-4.0 mg/kg in children < 2 years
- **Suxamethonium** 2 mg/kg if <24 months; 1 mg/kg otherwise
- **Tracheal intubation using the oral route**
- **Continuous sedation-analgesia**
  - Begin as soon as possible
  - Benzodiazepine ± opioids
  - Adapted to hemodynamic tolerance and level of sedation

Recommandations formalisées d’experts SFAR-SFMU 2010 : Sédation et Analgésie en Structure d’Urgence
Complications | Before guidelines (%) | After guidelines (%) | p
--- | --- | --- | ---
Age (years) | 7.5±4.3 | 7.1±5.3 | NS
GCS | 6 [3-8] | 6 [3-8] | NS
Immediate complication | 25 | 8 | 0.0015
## Causes of cardiovascular failure

<table>
<thead>
<tr>
<th>Type</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hemorrhagic shock</strong></td>
<td>• External bleeding</td>
</tr>
<tr>
<td></td>
<td>• Internal bleeding</td>
</tr>
<tr>
<td></td>
<td>- intra-abdominal</td>
</tr>
<tr>
<td></td>
<td>- intra-thoracic</td>
</tr>
<tr>
<td></td>
<td>- epidural hematoma</td>
</tr>
<tr>
<td><strong>Obstructive shock</strong></td>
<td>Tension pneumothorax</td>
</tr>
<tr>
<td><strong>Cardiogenic shock</strong></td>
<td>Cardiac tamponade</td>
</tr>
<tr>
<td><strong>Distributive shock</strong></td>
<td>Myocardial contusion</td>
</tr>
<tr>
<td></td>
<td>Allergic shock, spinal shock, severe sepsis</td>
</tr>
</tbody>
</table>
Cardiovascular response to hemorrhage in children

Variation (%) vs Blood loss (%)

- Systemic vascular resistance
- Blood pressure
- Cardiac output

Chamaides L. Pediatric ALS, 1990
Prognosis of cardiovascular collapse in children with blunt trauma

- 2120 multiple trauma children
- Overall mortality rate: 5.2%
- 38 children (1.8%) with cardiovascular collapse or cardiac arrest

1. Hypotension: systolic BP < 5\textsuperscript{th} percentile for age or clinical signs of shock

2. Lower limit of systolic BP for age estimated by:
   \[70 + (2 \times \text{age in years})\] mmHg

3. Correct hypotension as soon as possible
Stabilisation of cardiovascular failure

• Control external bleeding

• Obtain ≥ 1 IV access (22-20 G)

• Hypotonic/glucose containing fluids: contra-indicated

• Fluids and intravascular volume
  ▪ Isotonic crystalloids (NaCl 9‰) and colloids
  ▪ Blood transfusion ⇔ [Hb] >10 g/dL
  ▪ Vasopressor: dopamine or norepinephrine

• Monitoring: arterial line +++
Severe trauma and hemorrhagic shock

Vascular loading

20 mL/Kg (x 2 if required)

SBP >90 mmHg
MAP ≥50 mmHg

Blood transfusion
⇔ \([\text{Hb}] > 10\) g/dL

PTT>50%
Platelets ≥80-100.10⁹/L
Fibrinogen>1 g/L

T° > 35° C
pH > 7.2
Normocalcemia

Damage control surgery

Norepinephrine
start with 0.1 \(\mu g/kg/min\)

Novoseven®
Assessment of neurological distress

Following cardio-respiratory stabilization

- Pediatric Glasgow Coma Score
- Pupillary diameter and reactivity
- Motor deficit
- Transcranial Doppler sonography
- Cerebral CT scan
Neurological Monitoring for Congenital Heart Surgery

Dean B. Andropoulos, MD, Stephen A. Stayer, MD, Laura K. Diaz, MD, and Chandra Ramamoorthy, MB, BS, FFA (UK)

Anesth Analg 2004;99:1365–75

Table 1. Normal Transcranial Doppler Velocities for Infants and Children

<table>
<thead>
<tr>
<th>Age</th>
<th>Depth (mm)</th>
<th>Mean velocity (cm/s)</th>
<th>Peak systolic velocity (cm/s)</th>
<th>End-diastolic velocity (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–3 mo</td>
<td>25</td>
<td>24–42 ± 10</td>
<td>46–75 ± 15</td>
<td>12–24 ± 8</td>
</tr>
<tr>
<td>3–12 mo</td>
<td>30</td>
<td>74 ± 14</td>
<td>114 ± 20</td>
<td>46 ± 9</td>
</tr>
<tr>
<td>1–3 yr</td>
<td>35–45</td>
<td>85 ± 10</td>
<td>124 ± 10</td>
<td>65 ± 11</td>
</tr>
<tr>
<td>3–6 yr</td>
<td>40–45</td>
<td>94 ± 10</td>
<td>147 ± 17</td>
<td>65 ± 9</td>
</tr>
<tr>
<td>6–10 yr</td>
<td>45–50</td>
<td>97 ± 9</td>
<td>143 ± 13</td>
<td>72 ± 9</td>
</tr>
<tr>
<td>10–18 yr</td>
<td>45–50</td>
<td>81 ± 11</td>
<td>129 ± 17</td>
<td>60 ± 8</td>
</tr>
</tbody>
</table>
The prognostic value of transcranial Doppler studies in children with moderate and severe head injury
Stabilization of neurological distress

Maintain cerebral perfusion pressure (CPP)

CPP = MAP - ICP

- Infants: CPP > 40 mmHg and ICP < 15 mmHg
- Children: CPP = 65 mmHg and ICP < 20 mmHg

1. General measures:
   - Treat hypotension
     Euvolemia ± vasopressors
   - Treat hypoxia
   - Avoid occluding cerebral venous drainage
   - Sedation - analgesia

2. Specific treatment:
   - Avoid prophylactic hyperventilation (PaCO2 > 35 mmHg)
   - Mild hyperventilation if ICP > 20 mmHg despite first line therapeutics
   - Hyperosmolar therapy
   - Etc.

Assessment of the traumatized pediatric patient on admission
Clinical assessment on admission

1. Primary survey: ABC's of life-saving care
   - Check tracheal intubation
   - Check venous access
   - Check the gastric tube
   - Quick survey from head to toe
2. Adjust ventilator settings
3. Adapt the level of analgesia and sedation
Imaging studies

• “Descrambling” investigations
  - C-spine (P), Chest (P), pelvic (F) X rays
  - Abdominal US + transcranial Doppler
  - Blood sampling

• Patient stabilized and invasively monitored
  - Cerebral and C-spine CT scan without contrast
  - Thoracic and abdominal CT scan with contrast

• Other investigations: according to first results
Establishment of priorities in definitive treatment

Changes in the Management of Femoral Shaft Fractures in Polytrauma Patients: From Early Total Care to Damage Control Orthopedic Surgery

Hans-Christoph Pape, MD, Frank Hildebrand, MD, Stephanie Pertschy, MD, Boris Zelle, MD, Rayeed Garapati, MD, Kai Grimme, MD, and Christian Krettek, MD


Damage control surgery in children

J. Hamill*
Effect of applying protocols on outcome
### CLINICAL INVESTIGATIONS

**Reduction in mortality from severe head injury following introduction of a protocol for intensive care management**

T. J. Clayton, R. J. Nelson and A. R. Manara*

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
<th>Odds ratio (IC 95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 391</td>
<td>n = 452</td>
<td></td>
</tr>
<tr>
<td>Death in ICU</td>
<td>19.9%</td>
<td>13.5%</td>
<td>0.47 (0.29-0.75)</td>
</tr>
<tr>
<td>Death in hospital</td>
<td>24.5%</td>
<td>20.8%</td>
<td>0.48 (0.31-0.74)</td>
</tr>
</tbody>
</table>
Prognosis factors of bad outcome following severe TBI

<table>
<thead>
<tr>
<th>Variables</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 4–16 yrs</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age 0–3 yrs</td>
<td>3.65</td>
<td>0.75</td>
<td>17.77</td>
</tr>
<tr>
<td>Not motor vehicle occupant</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor vehicle occupant</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GCS ≥6</td>
<td>2.59</td>
<td>0.90</td>
<td>7.43</td>
</tr>
<tr>
<td>GCS &lt;6</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No pupil abnormalities</td>
<td>3.31</td>
<td>0.84</td>
<td>12.99</td>
</tr>
<tr>
<td>Pupil abnormalities</td>
<td>1.80</td>
<td>0.46</td>
<td>7.03</td>
</tr>
<tr>
<td>No acute circulatory failure</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute circulatory failure</td>
<td>1.41</td>
<td>0.44</td>
<td>4.56</td>
</tr>
<tr>
<td>Children appropriately managed</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>in an aggressive center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children appropriately managed in</td>
<td>7.56</td>
<td>1.49</td>
<td>38.42</td>
</tr>
<tr>
<td>a less-aggressive center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children inappropriately managed in</td>
<td>0.32</td>
<td>0.23</td>
<td>4.75</td>
</tr>
<tr>
<td>an aggressive center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children inappropriately managed in</td>
<td>1.83</td>
<td>0.53</td>
<td>6.30</td>
</tr>
<tr>
<td>a less-aggressive center</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Prehospital care of severe pediatric trauma patients

Acute management on site

Emergency team staffed by a physician

Stabilization of the patient on site

Maintain the head-neck-trunk axis

Infusion: NaCl 9%
Intubation (RSI)

> 1 peripheral venous access
C-spine ⇔ neck collar

Maintain normovolemia
SAP > 90 mmHg

SpO2 > 90%
EtCO2 ~ 35-38 mmHg
Gastric tube (oral route)

Sedation: midazolam ± opioids (sufentanil)
Monitoring: cardiorespiratory status + Glasgow coma scale + pupils + glycemia + [Hb]

Transport to a pediatric "Trauma Center"
Hospital care of the severe pediatric trauma patients

Hospital admission

Assessment - stabilization of vital functions
Invasive monitoring of arterial pressure

Patient stabilized and monitored (invasive arterial pressure)

Cerebral and C-spine CT scan without contrast
Thoracic and abdominal CT scan with contrast

Discuss priorities in definitive treatment
Avoid non vital surgery

Monitoring: MAP, ICP, CPP, [Hb], glycemia, diuresis
Iterative transcranial Doppler
Sedation and analgesia

Pediatric ICU

X rays:
- C-spine (P)
- Chest (P)
- Pelvic (F)

- Transcranial Doppler
- Fast ECHO
Cerebral Autoregulation Before and After Blood Transfusion in a Child

Monica S. Vavilala, Lorri A. Lee, Gregory P. Morris, and Arthur M. Lam

\[ V_{mca} \]

\[ V_{mca} \text{ and Hct} \quad R^2 = 0.9994 \]

\[ \text{Autoregulatory index (ARI)} \]

\[ V_{mca} \text{ and MABP} \]

Hct 38%  
Hct 22%
Hypothermia Therapy after Traumatic Brain Injury in Children


<table>
<thead>
<tr>
<th>Outcome</th>
<th>Hypothermia Group (N = 108)</th>
<th>Normothermia Group (N = 117)</th>
<th>Relative Risk or Absolute Difference (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCPC score 4–6 — no./total no. (%)</td>
<td>32/102 (31)</td>
<td>23/103 (22)</td>
<td>1.41 (0.89 to 2.22)</td>
<td>0.14</td>
</tr>
<tr>
<td>Secondary</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall mortality — no. (%)</td>
<td>23 (21)</td>
<td>14 (12)</td>
<td>1.40 (0.90 to 2.27)</td>
<td>0.06</td>
</tr>
</tbody>
</table>

PCPC = 4–6 at 6 months follow-up
4: severely disabled
5: vegetative state
6: death
• **Avoid prophylactic hyperventilation** (PaCO2 > 35 mmHg)

• **Considerer mild hyperventilation** (30 < PaCO2 < 35 mmHg) for intracranial hypertension refractory to first line therapeutics

• **Aggressive hyperventilation therapy** (PaCO2 < 30 mmHg)
  - In cases of cerebral herniation or acute neurological deterioration
  - Use an adapted monitoring to identify cerebral ischemia
  - Titrated to clinical effect
Mannitol: “still considered as a gold standard”
- Bolus dose: 0.25 to 1 g/kg over 15 min
- Serum osmolarity < 320 mOsm/L
- Prophylactic administration of mannitol not recommended
- For euvolemic patients with acute neurologic deterioration

Hypertonic saline: as a therapeutic option
- SSH 3%: 0.1 to 1 ml/kg/h (SSH 7.5%)
- Minimal dosing for ICP < 20 mmHg
- Serum osmolarity < 360 mOsm/L
- Particularly useful in hypovolemic patients
Review article
Management of critically ill children with traumatic brain injury

GILLES A. ORLIAGUET MD PhD, PHILIPPE G. MEYER MD
AND THOMAS BAUGNON MD
GCS ≤ 8
cerebral CT scan: diffuse lesion or focal swelling

Insert EVD or ICP monitor
Maintain CPP > 50 – 60 mmHg (age dependent)

Increased ICP → Intracranial hypertension?

Low/normal ICP

First tier therapy:
1. CSF diversion; EVD at 0 + 3 cm above tragus
2. Sedation (± paralysis)
3. HOB at +30°
4. 35 < PaCO₂ < 38 mmHg
5. O₂ saturation ≥ 92%

Low/normal ICP:
Carefully withdraw ICP treatment
Withhold one therapy at a time

Second tier therapy:
1. Mild hyperventilation (30 < PaCO₂ < 35 mmHg)
2. Mannitol (0.25 – 1.0 g/kg/IV q 4 – 6 h) with serum osmolarity < 320
3. 3% hypertonic saline (bolus or slow infusion) with serum osmolarity < 370
4. Barbiturates (low dose, i.e. 5 mg/kg IV q 6h) with escalation to burst if needed

Low/normal ICP

Third tier therapy:
1. Decompressive craniectomy or temporal lobectomy
2. Moderate hypothermia (32 – 34 °C)
3. Hyperventilation to PaCO₂ < 30 mmHg (use transiently)

Low/normal ICP
Validity of applying TRISS analysis to paediatric blunt trauma patients managed in a French paediatric level I trauma centre

<table>
<thead>
<tr>
<th></th>
<th>Adult patients [37]</th>
<th>This study (adult norms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>350</td>
<td>407</td>
</tr>
<tr>
<td>TRISS survival prob.</td>
<td>0.75 ± 0.34</td>
<td>0.83 ± 0.27</td>
</tr>
<tr>
<td>Expected survivors (%)</td>
<td>262 (75%)</td>
<td>354 (87%)</td>
</tr>
<tr>
<td>Number of survivors (%)</td>
<td>277 (79%)</td>
<td>364 (89%)</td>
</tr>
<tr>
<td>W</td>
<td>+5.10 %</td>
<td>+2.70 %</td>
</tr>
<tr>
<td>Z</td>
<td>12.25*</td>
<td>1.98*</td>
</tr>
<tr>
<td>M</td>
<td>0.64</td>
<td>0.67</td>
</tr>
<tr>
<td>Ws</td>
<td>+0.40 %</td>
<td>+1.32 %</td>
</tr>
<tr>
<td>Zs</td>
<td>0.15</td>
<td>1.80</td>
</tr>
</tbody>
</table>

* $p < 0.05$ vs MTOS [3]