Physiological Response To Trauma

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Objectives

- Physiological response to trauma
- Better understanding of early total care versus damage control principles
- Review relevant literature
- Case examples
Case 1

Male, 19 years
Motorcycle accident

Airway - ok
Breathing – RR32, right pneumothorax
Circulation - pulse 120, BP 100/70
Disability - GCS 15
Exposure - temp 34°C
Male, 19 years
Motorcycle accident

- chest drain
  - RR 30
  - SaO₂ 95%

- IV fluids
  - Pulse 100
  - BP 110/80
SaO$_2$: 95%
on 40% O$_2$ via mask
Secondary survey (including CT)
Male, 19 years
Motorcycle accident

Neck & spine

normal
- spine cleared
Male, 19 years
Motorcycle accident

Pelvis

normal - pelvis cleared
Male, 19 years
Motorcycle accident

Chest

2 hours since accident
Intubated
Ventilated 50% O₂

PaO₂: 13.1
PaCO₂: 4.5
pH: 7.21
base excess: -7.4
Male, 19 years
Motorcycle accident

Right femur

Closed
Neurovascular normal

Thomas’ splint applied

Severe swelling thigh
- compartment pressure
  = 67 mmHg
Male, 19 years
Motorcycle accident

Right tibia

Open – IIIa
Neurovascular normal
No compartment syndrome
Right shoulder

Male, 19 years
Motorcycle accident

Closed
Brachial plexus ok
No vascular problem
elbow/forearm/hand ok
Damage limitation or early total care?
Damage limitation or early total care?

BP 100/57  Hb 9.8
P 100      pl 92
Temp 34.8°C INR 1.1
PaO₂ 13 on 50% O₂
pH 7.21
Base excess -7.4
Case 1

What happened.................
Emergency surgery

- Thigh compartment decompressed
- Tibial wound debrided
- Spanning ExFix prox. femur → calcaneus

to ITU as quickly as possible
Timing of definitive care?
Pathophysiology

Several factors working in synergy:

- Haemodynamic / Metabolic (acidosis)
- Pulmonary / Systemic Emboli
- Coagulation
- Inflammation
- ‘Associated Injuries’ (Injury Severity Score (ISS))
Haemodynamic / Metabolic

- Femoral Fracture
  - Up to 1.5L blood loss / 40% transfusion rate
  - Higher transfusion rates after bilateral injuries
  - Early stabilisation reduces bleeding

- ‘Occult hypoperfusion’
  - pulse and BP corrected
  - elevated lactate levels persist
  - inadequate resuscitation
Key Publication – Crowl 2000

‘Major Trauma’ - IM femoral nail required

1. Uncorrected blood acidosis > 24 hours after injury increased mortality

2. Complication rates (ARDS / infection) doubled if femoral nailing performed with elevated (>2.5mmole/L) lactate levels
‘Fat Embolus’

- Long Bone fractures produce fat emboli
  - Transient drop in arterial [oxygen]
  - Multiple fractures increase this embolic load

- An unstabilsed femoral fracture produces emboli
  - Sevitt 1979

- IM reaming produces pulmonary fat emboli
  - Christie 1995 - Detectable transoesophageal echo -

- Less pulmonary embolic events using ex fix
  - Gray 2009 (JOT). Bilateral femoral fractures – animal model
‘Fat Embolus Syndrome’

- Clinical triad - dyspnoea / confusion / petechial hemorrhages

- Pulmonary and systemic emboli

- Certain patients predisposed to this syndrome
  - Genetics
  - Patent foramen ovale
  - Pulmonary arterial / venous shunt
Key Publications

- Pinney & Keating 1997
  - 250 isolated femoral fractures stabilised with IM nail
  - 11 developed fat embolus syndrome
  - All < 35 years old with a delay to surgery > 10 hours

- Pell (1995)
  - Acute confusion after femoral IM nail
  - Patent foramen ovale (Population incidence = 20% )
  - Predisposes to detectable systemic emboli
IM nailing - Technique matters

- Instrumentation of IM canal produces high pressures

- Embolic load can be reduced
  - Unreamed nails
  - Reamer Irrigation Aspiration RIA
  - Reamer design
    - Sharp / Large flutes / narrow & flexible shaft
  - Reaming technique
    - High speed / advance slowly
Coagulation

- Trauma activates systemic coagulation
- Uncontrolled coagulopathy predisposes ARDS
Key Publication - Robinson 2001

- reamed IM nail activates coagulation
- prolonged APTT (intrinsic) and PTT (extrinsic) times
- fibrinogen and platelets consumed
- pulmonary embolic load seen on echocardiography
  - correlated to the degree of coagulation activation
  - correlated to the degree of arterial hypoxemia
Inflammation

- Systemic Inflammatory Response Syndrome (SIRS)
- Helps remove damaged tissue and begin repair
- Potential immune imbalance after severe injury
- Peaks 24-48 hours after injury – often during surgery
- ‘2nd hit’ of surgery after major injury
Key Publication - Giannoudis 1998

- Pro-inflammatory serum cytokine [IL 6]
  - correlates to severity of blunt trauma
  - Elevated after IM nailing
  - level linked to ARDS and other systemic complications
  - may be a useful prognostic marker
    - Half-life 4-6 hours - ideal
    - ? Change surgical strategy if elevated
Associated Injuries

- Concern over reamed IM nailing after chest injury

- Secondary pulmonary damage of IM nail exacerbates the initial trauma

- White et al 2006. Risk factors for ARDS:
  - High injury severity score
  - Femoral fracture
  - Combination of blunt abdominal or thoracic injury
  - Physiological compromise on admission
  - Uncorrected metabolic acidosis prior to surgery.
Key Points

- Adequately resuscitate patient
- Avoid over aggressive medical management
  - Damage control resuscitation
  - Replace blood with blood
  - Replace clotting factors and platelets
- Don’t delay long bone fracture stabilisation
- Injury severity main determinant of outcome
Damage Control Surgery

Principles:

- Limited surgery to control haemorrhage and stabilise life-threatening injuries

- Resuscitation and correction of physiological parameters in an ITU environment

- Definitive treatment of injuries involving reoperation once patient has been stabilised
Early Total Care

**Bone 1989**

Early (<24 hours) femoral IM stabilisation reduced mortality rate and shortened hospital/ITU stay.

**Pinney/Keating 1998**

Consecutive series of isolated femoral fractures. FES only developed in those aged under 35 who waited >10 hours for IM nail.
Damage Control

Pape 1993
Reduced incidence of respiratory complications in seriously injured patients by initial external femoral fixation and delayed IM nail (within 7 days)

Giannoudis – Leeds
Biochemical (reduced serum IL-6 levels), but not reflected in improved clinical outcome in more recent prospective studies
Risks of Delayed Conversion

- Infection rate 1.5% \( (\text{Notowarski 2002}) \)
- No increased complication rate
- Reasonable surgical strategy
Clinical Example-May 07 JBJS A

- 23 year old female admitted June 2004
- Low energy closed femoral fracture
- O2 sats 98% on admission. Splint applied
- 6 hours later – acute dyspnoea + confusion
- O2 sats < 84% on maximum therapy
- CXR – diffuse pulmonary infiltrates
- ABG’s - PaO2 = 8.3 kPa FiO2 = 0.6
Clinical Example (cont.)

- T/F to ITU. Intubation + positive pressure ventilation to maintain oxygen saturations
- Reamed intramedullary nail 18 hours after injury
- Widespread petichial haemorrhages
- Alveolar lavage (4 days) – ventilatory associated pneumonia. Antibiotics commenced
- Extubated on day 7
- ‘Complete’ recovery
American-European Consensus Definition

Acute lung injury and ARDS criteria

- Timing: acute onset

- Hypoxaemic
  - $\text{Pao}_2/\text{Fio}_2$ ratio = $8.6/0.6 = 14.3^{**}$
  - ALI < 40  ARDS < 26.7

- CXR – bilateral lung infiltrates on AP view
- Pulmonary Artery occlusion pressure < 18mmHg
# Cognitive Testing – 6 weeks

<table>
<thead>
<tr>
<th>Tests</th>
<th>Description</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weschler Test of Adult Reading (WTAR)</td>
<td>Predicted Full Scale Intelligence Quotient – PFSIQ (%)</td>
<td>&gt; 75%</td>
</tr>
<tr>
<td>Colour Trails Tests 1 and 2</td>
<td>Visual processing speed. Sensitive measure of cerebral injury.</td>
<td>12% (I) 1% (II)</td>
</tr>
<tr>
<td>Controlled Oral Word Association Test</td>
<td>Measures verbal fluency</td>
<td>1%</td>
</tr>
</tbody>
</table>
| Weschler Memory Scale (WMS-III)                 | **Digit span**: immediate memory (numbers)  
**Word list subtests**:  
• Word List A – immediate recall  
• Word List D – delayed recall  
• Retention score  
• Interference score | 50%                                                 |
Cognitive Testing – 6 and 18 months

- Normal MRI – 6 mth.
- Gradual improvement
- Significant long term impairment persisted
- Rehabilitation issue
- ? Cognitive effects of injury

<table>
<thead>
<tr>
<th>Test Type</th>
<th>6 months</th>
<th>18 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 = WAIS-III Processing Speed Index</td>
<td>39</td>
<td>73</td>
</tr>
<tr>
<td>2 = COWAT</td>
<td>15</td>
<td>54</td>
</tr>
<tr>
<td>3 = Stroop</td>
<td>19</td>
<td>58</td>
</tr>
<tr>
<td>4 = Colour Trails I</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>5 = Colour Trails II</td>
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</tbody>
</table>
Cognitive Effects of ARDS

Hopkins 1999

- 55 ARDS survivors
- 100% cognitive impairment at discharge
- 30% cognitive decline at 1 year
- Impaired memory, reduced concentration and mental processing speeds
- Possible hypoxic cerebral injury
In polytrauma and isolated long bone fractures early stabilisation is protective against respiratory complications.
Timing and Type of Surgery

- Early stabilisation of long bone fractures should not be delayed

- Effects of reamed intramedullary stabilisation with the associated embolic, coagulative and inflammation processes in physiologically vulnerable patients
Bilateral Femoral Fractures

- 26% mortality rate
- 3.5 x higher than unilateral injuries
- Underestimated Injury Severity Score
- Higher rate of systemic complications (ARDS)
1998 JOT – Baltimore

- 800 unilat. fem. fractures vs. 80 bilat.
- Mortality rate 27% vs. 12%
- ISS 30 vs 24
- Mortality linked to bilateral injury
- Regression analysis linked mortality more closely to shock and thoracic injury
Mortality rate correlated more closely with initial physiological compromise rather than presence of bilateral femoral injury.
Nork & Routt-Seattle (Harbourview)

- Blunt trauma
- 700 unilat. fem. fractures vs. 55 bilat.
- Mortality rate 5.5% vs. 1.5%
- ISS higher in bilat. group
- Analysis when corrected for ISS and age still showed a higher mort in the bilat. gp
- ISS underestimated the 2nd femoral fracture
Giannoudis 2000

- 14 cases over 6 year period
- Compared to unilateral injuries
  - Higher ISS
  - Higher transfusion requirements (mean of 10L of crystalloid/colloid and 8 units of blood)
  - Higher mortality
  - Higher rate of ARDS
  - Longer hospital stay
Review of the literature

197 cases / 4 studies

96% had reamed IM nailing

High rate of systemic complications

Damage Control recommended where ‘clinician anticipates’ systemic problems
How to ‘anticipate’ problems

Hanover group (Pape)

- Injury Severity Score > 20 with a chest injury
- Injury Severity Score > 40 with no chest injury
- Polytrauma + systolic BP < 90mmHg
- X-ray evidence of bilateral lung contusions
- Mean Pulmonary Arterial Pressure > 24mmHg (i.e. hypoxaemia)
Poor prognosis

- inadequate resuscitation
- metabolic acidosis (pH<7.24)
- Coagulopathy++
- hypothermia
- multiple blood transfusions
- multiple long bone fractures
- excessive surgical time (> 6 hours)
- Exaggerated inflammatory response [IL-6]
Key publications

- Christie et al 1995 (JBJS)
  - IM nailing – large pulmonary emboli detected using TOE

- Forteza 1999 / Gray 2009 (Injury)
  - IM Nailing – Cerebral emboli detected using transcranial doppler
Key Points

- Adequately resuscitate patient
- Degree of initial trauma main determinant of outcome rather than type of surgery
- Don’t delay long bone fracture stabilisation
- Avoid aggressive fluid management (replace blood with blood)
- Can convert ex fix to IM nail within 7 days (no increase in infection rate). Notowotarski 2002 (1.5% incidence of infection at a mean of 7 days)
Clinical indicators used by the Hanover group are:

- Injury Severity Score > 20 with an associated chest injury
- Polytrauma with abdominal / pelvic trauma with hypovolaemia (systolic BP < 90mmHg)
- Injury Severity Score > 40 with no chest injury
- X-ray evidence of bilateral lung contusions
- Mean Pulmonary Arterial Pressure > 24mmHg
- Increase of > 6mmHg in pulmonary arterial pressure after intramedullary reaming
Thank-You