The issues...
Outline

Evaluation of polytrauma
Scoring systems
Ortho urgencies and emergencies
MOF, ARDS, physiologic response
*Damage Control Orthopaedics* (DCO), evidence and modes
Occult Hypoperfusion and Resuscitation
*Early Appropriate Care*
Timing of definitive fixation in DCO

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Evaluation of the polytrauma patient

ATLS
Primary Survey
- Airway
- Breathing
- Circulation
- Disability
- Exposure/Environmental Control

Secondary Survey

Tertiary Survey

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Evaluation of the polytrauma patient

ATLS
Primary Survey
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Secondary Survey

Tertiary Survey

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Evaluation of the polytrauma patient

Primary Survey

– Circulation

• Clinical + radiographic (Pelvic X-Ray)
• Sheet / binder if needed
• Direct pressure to areas of obvious hemorrhage
• Initiation of resuscitation
Evaluation of the polytrauma patient

Primary Survey

- **Disability**
  - Neuro evaluation
  - Open Fx
  - Displaced Fx
  - Pelvis/Tab
Evaluation of the polytrauma patient

Tertiary Survey

- Repeat physical exam
- Review of any additional labs and radiographs
- 12% injuries in polytrauma missed in first 24 hours
- Standardized tertiary survey has shown to decrease missed injuries by 36%


Evaluation of the polytrauma patient

• **Tertiary Survey**
  - Repeat physical exam
  - Review of any additional labs and radiographs
  - 12% injuries in polytrauma missed in first 24 hours
  - Standardized tertiary survey has shown to decrease missed injuries by 36%

Scoring Systems

Glasgow Coma Scale
Abbreviated Injury Scale
Injury Severity Score
New Injury Severity Score
Scoring Systems

Glasgow Coma Scale
Abbreviated Injury Scale
Injury Severity Score
New Injury Severity Score
Abbreviated Injury Scale (AIS)

9 anatomic areas:
- Head
- Face
- Neck
- Thorax
- Abdomen
- Spine
- Upper Extremity
- Lower Extremity
- External
Abbreviated Injury Scale (AIS)

Each area scored from 0 to 6
Values consensus driven
Values found in “dictionary”

0 None
1 Minor
2 Moderate
3 Serious
4 Severe
5 Critical
6 Not survivable
Abbreviated Injury Scale

Examples:
- Femur fracture → serious, AIS=3
- Pulmonary contusion → serious, AIS=3
- Flail chest → severe, AIS=4
Injury Severity Score (ISS)

Calculated from AIS

Highest AIS value from each individual anatomic area (6)
- Head/ neck
- Face
- Chest
- Abdomen
- Extremities including pelvis
- External

Three highest AIS values (from different anatomic areas)
- → squared
- → summed

\[ \text{AIS}^2 + \text{AIS}^2 + \text{AIS}^2 \]
Injury Severity Score (ISS)

Highest Score: 75 (not survivable)
- AIS of 5 in three anatomic areas
- AIS of 6 in any anatomic area
Injury Severity Score (ISS)

Defines polytrauma
  – ISS ≥ 18

Correlates with:
  – Morbidity
  – Mortality
  – Length of hospital stay
Injury Severity Score (ISS)

A problem with ISS…
Injury Severity Score (ISS)

A problem with ISS… injuries within the same anatomic system are only counted once!
ISS and Bilateral Femur Fractures
Bilateral Femur Fractures

- Independent risk factor for ARDS
- Historical mortality rates ~40%, recent 5.6%
- Treated with IMN at same setting


Life > Limb

- Orthopaedic urgencies and emergencies must be treated within overall context of polytraumatized pt’s condition
- Care of orthopaedic injuries impacts mortality
- Early orthopaedic trauma involvement is essential

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Orthopaedic Urgencies and Emergencies

- Unstable pelvic fractures
- Fractures or dislocations with associated vascular injuries, neurologic injuries, soft tissue compromise
- Compartment syndrome
- Spine injury with deficit
- Joint dislocations associated with avascular necrosis
- Open fractures
Unstable Pelvic Fractures

Associated with significant transfusion requirements

Initial Treatment:

- Mechanical stabilization
- Assessment of response to resuscitation
  - Angiography
  - Pelvic Packing

Fractures w/Vascular Injury

Control Hemorrhage (pressure)
Realign limb / Splint
  – Will often resolve issue
Further eval (arteriogram)
Ex-fix + vascular repair
  – Ortho first

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Compartment Syndrome

Elevated tissue pressure within a closed fascial space

Reduces tissue perfusion → ischemia

Results in cell death → necrosis

8 hrs - irreversible changes

True Orthopaedic Emergency
Compartment Syndrome

Fractures
Compartment Syndrome

Fractures
- closed and open
- 2-10% tibia, 48% segmental, 53% medial knee fx dislocation
Compartment Syndrome

Fractures

closed and open
2-10% tibia, 48%
  segmental, 53% medial
  knee fx dislocation

Blunt trauma
Compartment Syndrome

Fractures
- closed and open
- 2-10% tibia, 48%
  - segmental, 53% medial
  - knee fx dislocation

Blunt trauma
Temp vascular occlusion
Compartment Syndrome

Fractures
- closed and open
- 2-10% tibia, 48%
  - segmental, 53% medial
  - knee fx dislocation

Blunt trauma
Temp vascular occlusion
Cast/dressing

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Compartment Syndrome

Fractures
- closed and open
- 2-10% tibia, 48% segmental, 53% medial knee fx dislocation

Blunt trauma
Temp vascular occlusion
Cast/dressing
Closure of fascial defects

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Compartment Syndrome

Fractures
closed and open
2-10% tibia, 48%
  segmental, 53%
  medial knee fx dislocation
Blunt trauma
Temp vascular occlusion
Cast/dressing
Closure of fascial defects

Burns/Electrical
Exertional states
GSW
IV/A-lines
Hemophiliac/coag
Intraosseous IV(infant)
Snake bite
Arterial injury

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Compartment Syndrome

Initial Treatment
- Remove splint/dressing
- Elevate
- Check pressures
  - \( \text{Delta P} = \text{SBP} - \text{CP} \)
  - \(<30 \rightarrow \text{bad} \)
  - Obtunded
- Fasciotomy
Dislocations

Urgency depends on joint
Knee, elbow, hip > ankle, shoulder

Potential neurologic/vascular sequelae

Initial treatment:
– Emergent Reduction
– Assessment of vascularity
  • Physical Exam
  • Ankle Brachial Index (ABI)
  • Arteriogram prn
Dislocations

Can be associated with avascular necrosis

- Emergent Reduction
- Do this in the OR for a native hip! (risk FN fx)
Dislocations

Associated with soft tissue compromise

- Emergent Reduction
- Still get Xrays first!

Why?
Open Fractures

Break in skin and underlying soft tissues leads directly into and communicates with the fracture and its hematoma

Wound in same limb segment as fracture

Prognosis depends on contamination, associated injuries and…
Open Fractures

Break in skin and underlying soft tissues leads directly into and communicates with the fracture and its hematoma

Wound in same limb segment as fracture

Prognosis depends on contamination, associated injuries and...

Classification: Gustilo and Anderson
Open Fx: Type I

Low energy injury
<1 cm long (only one aspect of the classification)
Bone piercing from inside out
Typically low level of bacterial contamination
Minimal/no muscle damage
Open Fx: Type II

>1 to <10cm in length
Moderate soft tissue damage
(higher energy injury)
Outside to inside pattern
Some necrotic muscle,
minimal/moderate debridement required
None/minimal stripping, coverage without grafts / flaps
Open Fx: Type III

High energy, outside to inside pattern

>10cm w/ extensive muscle devitalization

Fracture widely displaced or comminuted

Extensive wound contamination

Subtypes

– IIIA- can be covered primarily
– IIIB- needs flap coverage
– IIIC- vascular injury requiring repair
Open Fx: Type III

Additional factors

- Close range shotgun, high velocity (>2000ft/s) gunshot
- Segmental fx
- Diaphyseal segmental loss
- Farmyard / other highly contaminated environment
- Associated compartment syndrome
Open Fractures

The “Six Hour Rule”

– Timing of debridement generally has NOT been associated with infection

– OR ASAP after life threatening conditions treated and stabilized

– Early administration of antibiotics ➞ decreased rates of infection


What are we trying to avoid?
What are we trying to avoid?

• MOF
• ARDS
What are we trying to avoid?

- MOF
- ARDS
Acute Respiratory Distress Syndrome (ARDS)

B/L infiltrates on CXR
PaO2/FiO2 < 200
High mortality
May be related to imbalance between proinflammatory and antiinflammatory mediators
Physiologic Response

First hit → severe response → MODS/ARDS

Reaction ? nature → Surgical procedure

Resolution → MODS/ARDS

Second hit

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Physiologic Response

Systemic Inflammatory Response (SIRS)
- Proinflammatory cytokine response (IL-6, IL-8, etc.)
- “Primed” PMNs
- Secondary tissue (lung) injury
- Predictive of ARDS

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Physiologic Response

Systemic Inflammatory Response (SIRS)

- Components
  - Fever: $T < 34$ or $> 38$ (100.4 F)
  - Tachycardia: HR >90
  - Hyperventilation: RR > 20 (or PaCO2<33mmHg)
  - Leukocytosis: WBC <4,000 or >12,000
Physiologic Response

First hit → severe response → MODS/ARDS

Reaction → ? nature → Surgical procedure

Resolution → MODS/ARDS
Damage Control Orthopaedics (DCO)

- Approach to treating polytrauma pts
- Goal: minimize impact of “second hit”
Damage Control Orthopaedics

Priorities
- Hemorrhage control
- Soft tissue management
- Provisional fracture stabilization

Definitive fixation
delayed until physiology improved

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Bone et al. JBJS 1989

Early Total Care

Prospective randomized study:

- Femur fractures treated < 24 hours
  VS
- Femur fractures treated > 48 hours

Early fixation in patients with an

\textit{ISS} \geq 18 \rightarrow \text{decreased}:

\begin{itemize}
  \item Pulmonary complications
  \item ICU LOS
  \item Hospital LOS
\end{itemize}
History of DCO

Early 1990’s: complications associated with ETC begin to be described

- ARDS
- MOF
History of DCO

Pape et al: ETC may not be appropriate in some pts

Alternative treatment strategy → “Damage Control Orthopaedics”

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Do some patients not tolerate ETC?

Pape et al, 1993: retrospective study
Polytrauma patients with femur fracture treated with IMN
Analyzed patients based upon
  – chest injury (AIS thorax ≤2 versus AIS thorax ≥2)
  – timing of fixation (<24hrs vs >24hrs)
**Trend** towards higher ARDS (33% vs 7.7%) in patients with severe chest injury managed acutely with IMN (not stat sig)
Intramedullary Nailing has physiologic effects...

- Blood loss
- Fluid loss
- Fat embolization
- Cytokine production
- Activation of coagulation system

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DCO: Does it work?

Pape et al, J Trauma 2002

– Reduction in rates of ARDS and MOF over time with increased usage of DCO

Modes of DCO

Retrospective review; sub-analysis of pts undergoing DCO

- 60 pts → skeletal traction
- 19 pts → external fixation

Modes of DCO

Results:

– No difference between external fixation and skeletal traction in:

• ARDS
• MOF
• Pneumonia

Modes of DCO

Problem with study:
- Small number of pts, particularly in external fixation group → possibility of Type II error
Modes of DCO

Concern with traction:

- Difficulty with pulmonary toilet?
- Increased narcotic requirements
- Increased risk FES (fat embolism)?

Potential issues with overutilization of DCO

- Unnecessary delay in definitive treatment
- Longer ICU stays
- Longer time on ventilator
- Longer LOS
- Increased cost
ETC vs DCO: When?
# Patient Risk Stratification

## Classification Systems for Clinical Patient Assessment

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Stable (Grade I)</th>
<th>Unstable (Grade II)</th>
<th>Unstable (Grade III)</th>
<th>In Extremis (Grade IV)</th>
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</thead>
<tbody>
<tr>
<td><strong>Shock</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Blood pressure (mm Hg)</td>
<td>100 or more</td>
<td>80–100</td>
<td>60–90</td>
<td>&lt;50–60</td>
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<tr>
<td>Blood units (2 h)</td>
<td>0–2</td>
<td>2–8</td>
<td>5–15</td>
<td>&gt;15</td>
</tr>
<tr>
<td>Lactate levels</td>
<td>Normal range</td>
<td>Around 2.5</td>
<td>&gt;2.5</td>
<td>Severe acidosis</td>
</tr>
<tr>
<td>Base deficit (mmol/L)</td>
<td>Normal range</td>
<td>No data</td>
<td>No data</td>
<td>&gt;6–8</td>
</tr>
<tr>
<td>ATLS classification</td>
<td>I</td>
<td>II–III</td>
<td>III–IV</td>
<td>IV</td>
</tr>
<tr>
<td><strong>Coagulation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platelet count (µg/mL)</td>
<td>&gt;110</td>
<td>90–110</td>
<td>&lt;70–90</td>
<td>&lt;70</td>
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<tr>
<td>Factor II and V (%)</td>
<td>90–100</td>
<td>70–80</td>
<td>50–70</td>
<td>&lt;50</td>
</tr>
<tr>
<td>Fibrinogen (g/dL)</td>
<td>1</td>
<td>Around 1</td>
<td>&lt;1</td>
<td>DIC</td>
</tr>
<tr>
<td>D-dimer</td>
<td>Normal range</td>
<td>Abnormal</td>
<td>Abnormal</td>
<td>DIC</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lung function; PaO₂/FiO₂</td>
<td>&lt;33°C</td>
<td>33–35°C</td>
<td>30–32°C</td>
<td>30°C or less</td>
</tr>
<tr>
<td>Chest trauma scores; AIS</td>
<td>AIS 1 or 2</td>
<td>AIS 2 or more</td>
<td>AIS 2 or more</td>
<td>AIS 3 or more</td>
</tr>
<tr>
<td>Chest trauma score; TTS</td>
<td>0</td>
<td>I–II</td>
<td>II–III</td>
<td>IV</td>
</tr>
<tr>
<td>Abdominal trauma (Moore)</td>
<td>&lt; or = II</td>
<td>&lt; or = III</td>
<td>III</td>
<td>III or &gt; III</td>
</tr>
<tr>
<td>Pelvic trauma (AO class.)</td>
<td>A type (AO)</td>
<td>B or C</td>
<td>C</td>
<td>C (crush, rollover abd.)</td>
</tr>
</tbody>
</table>

Borderline Patients

- Severe abdominal injury
  (AIS abdomen ≥ 3)

  Retrospective review of 3069 polytrauma patients treated for femur fracture with internal fixation

  ~50% relative risk reduction in mortality in patients treated after 12 hours

  → Benefited from delay

Level I Data?

- RCT comparing IMN (ETC) vs DCO in stable and borderline patients

Level I Data?

- Stable Patients
- → acute IMN associated with decreased ventilator time
Level I Data?

Impact of the Method of Initial Stabilization for Femoral Shaft Fractures in Patients With Multiple Injuries at Risk for Complications (Borderline Patients)

Hans-Christoph Pape, MD, FACS,* Dieter Rixen, MD,† John Morley, MD,‡ Elisabeth Ellingsen Husebye, MD,§ Michael Mueller, MD,¶ Clemens Dumont, MD,¶¶ Andreas Gruner, MD,¶ Hans Joerg Oestern, MD,** Michael Bayeff-Filloff, MD,**️ Christina Garving,**️ Dustin Pardini, PhD,**️ Martijn van Griensven, PhD,**️ Christian Krettek, MD, FRACS,**️ Peter Giannoudis, MD,**️ and the EPOFF study group

Borderline Patients

→ acute IMN associated with increased

acute lung injury (ALI)

– 6.69x greater chance of developing ALI, s/p acute IMN (CI = 1.01-44.08)
Reamed vs. Unreamed?

Reamed Versus Unreamed Intramedullary Nailing of the Femur: Comparison of the Rate of ARDS in Multiple Injured Patients

By The Canadian Orthopaedic Trauma Society

- RCT
- 322 femur fractures
- IMN within 24 hours
Reamed vs. Unreamed?

Reamed Versus Unreamed Intramedullary Nailing of the Femur: Comparison of the Rate of ARDS in Multiple Injured Patients

By The Canadian Orthopaedic Trauma Society

- Reamed IMN → 3/63 ARDS
- Unreamed IMN → 2/46 ARDS
- 2 deaths in each group
- No statistically significant difference
- 39,817 patients would be needed to appropriately power study

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Now what?

Is there another way of looking at orthopaedic trauma resuscitation?
Evaluating Response to Resuscitation

Compensated Shock

- Brain and heart perfused at expense of other organs
- Occult hypoperfusion exists
Occult Hypoperfusion

Patients with ISS $\geq 18$ + femur fracture stabilized within 24h

No patients had clinical signs of shock:

- Normotensive
- Not Tachycardic
- Adequate urine output
Occult Hypoperfusion

Retrospectively divided into 2 groups based on lactate levels (normal and abnormal)

Group with lactate $> 2.5$ had higher pulmonary and infectious complication rates

Resuscitation and *Early Appropriate Care*

When is patient’s physiology appropriate for definitive care?

- pH $\geq 7.25$
- Base excess $\geq -5.5$
- Lactate $< 4.0$

Definitive care proceeds when any of these has been achieved.


Resuscitation and *Early Appropriate Care*

Included femur fractures, axially unstable injuries (pelvis, acetabulum, spine)

Compared to historical cohort

Patients treated with EAC within 36 hours:

- 1.5% ARDS
- 0.37% MOF
- 1.5% Mortality
- Shorter ICU and total LOS, ventilation time

“Normalizing lactate”

- Retrospective review of protocol for treatment of femur fractures in polytrauma patients
- N=229; ISS $\geq$ 17
- 88% patients treated with reamed IM nailing and 12% treated with DCO (External fixation)
- “Normalizing lactate” to $<$2.5 → parameter used to demonstrate adequate resuscitation

“Normalizing lactate”

Results:

- ARDS (overall): 1.5%
- ARDS (pulmonary injured patients): 2.0%
- ARDS (pulm. injured patients with ISS>28): 3.3%

Compare extremely favorably to published series by Pape, Brundage, Bosse, Charash, Bone

Measures of Resuscitation

Stable hemodynamics
No hypoxemia

Lactate
- < 2.5 mmol/L (Crowl et al)
- < 4.0 mmol/L (Vallier et al)
  - “normalizing,” toward 2.5 mmol/L (O’Toole)

Base Deficit
- <5.5 (Vallier et al), <5, <6

Serum Bicarbonate
- SB>24.7; SB>26.4 (Morshed et al)

pH > 7.25 (Vallier et al)
Normal coags
Normothermia
Normal U/O (>1cc/kg/hr)
Algorithm: ETC vs DCO

Timing of definitive treatment in DCO

- Polytrauma pts managed with DCO followed by later definitive fixation
- Patients who converted @2-4 days were compared to those @5-8 days
- MODS 46% in early group versus 16% in late group

Timing of definitive treatment in DCO

Alterations in the Systemic Inflammatory Response after Early Total Care and Damage Control Procedures for Femoral Shaft Fracture in Severely Injured Patients

Paul John Harwood, MB, ChB, Peter V. Giannoudis, MD, Martijn van Griensven, MD, Christian Krettek, MD, and Hans-Christoph Pape, MD

- Retrospective review: ISS>20 + femur fx
- N=174, initial ex-fix vs early IMN
- Ex fix group more severely injured
- SIRS score, modified Marshall multi-organ dysfunction score

Timing of definitive treatment in DCO

Alterations in the Systemic Inflammatory Response after Early Total Care and Damage Control Procedures for Femoral Shaft Fracture in Severely Injured Patients

Paul John Harwood, MB, ChB, Peter V. Giannoudis, MD, Martijn van Griensven, MD, Christian Krettek, MD, and Hans-Christoph Pape, MD

- DCO patients converted from external fixator while SIRS score still elevated → most pronounced post op inflammatory response and organ failure rate

Timing of definitive treatment in DCO

Majority of pts treated with DCO should probably wait until at least post injury day 5 before definitive treatment.
Summary

• Evaluation of polytrauma patient guided by ATLS.
• Identifying and treating orthopaedic urgencies and emergencies in the initial evaluation is critical in minimizing M&M.
• Knowledge of scoring systems necessary in managing polytrauma.
Summary

Identifying patients w/ occult hypoperfusion necessary to minimize M&M.

Knowledge of *Damage Control Orthopaedics* and when to implement methods of DCO is critical.

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Summary

- Majority of polytrauma pts with femur fx benefit from treatment within the first 36 hrs
- Further research will help clarify which patients can tolerate acute IMN and which patients should be treated with DCO
Thank You

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