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

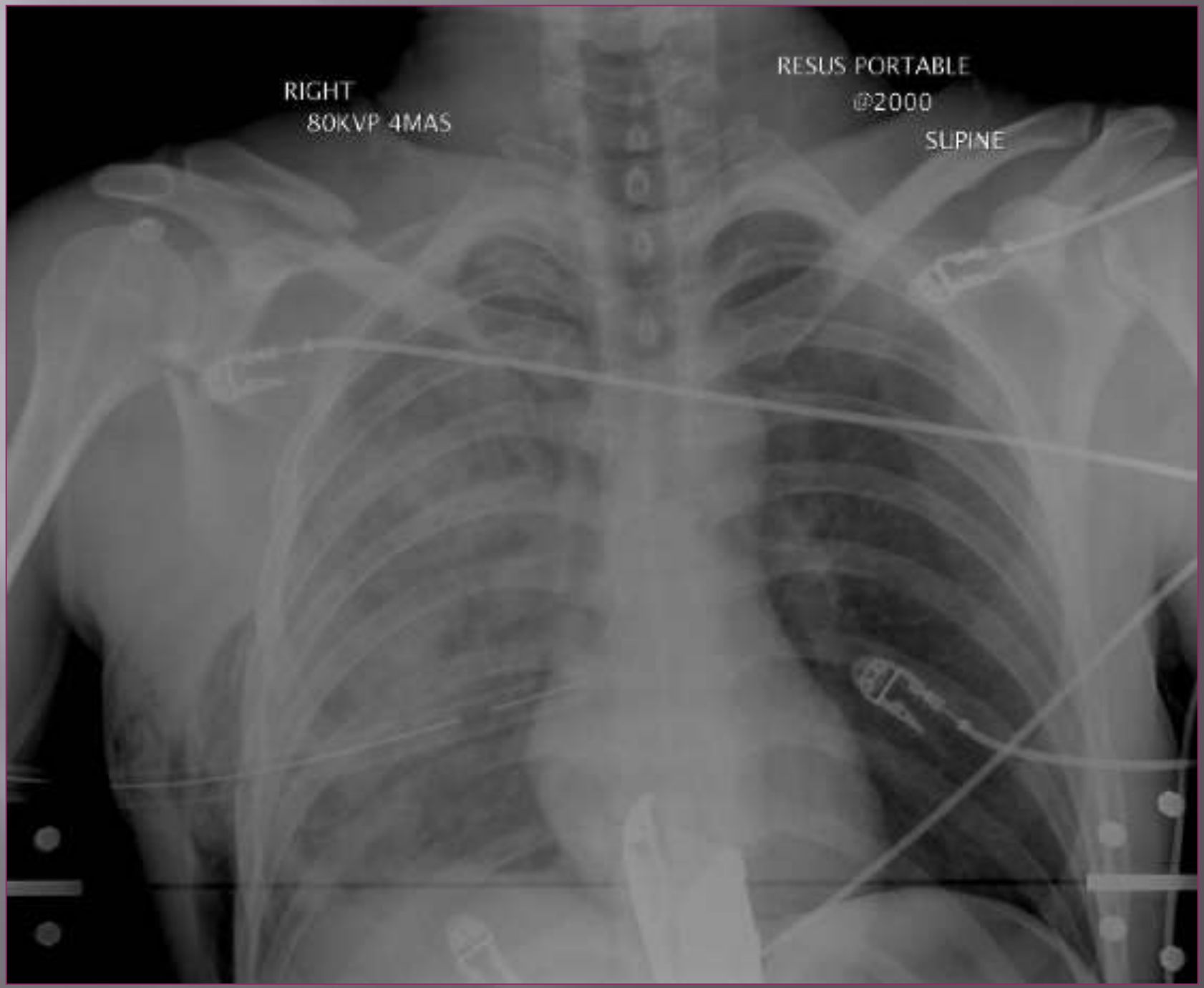
Disability - GCS 15

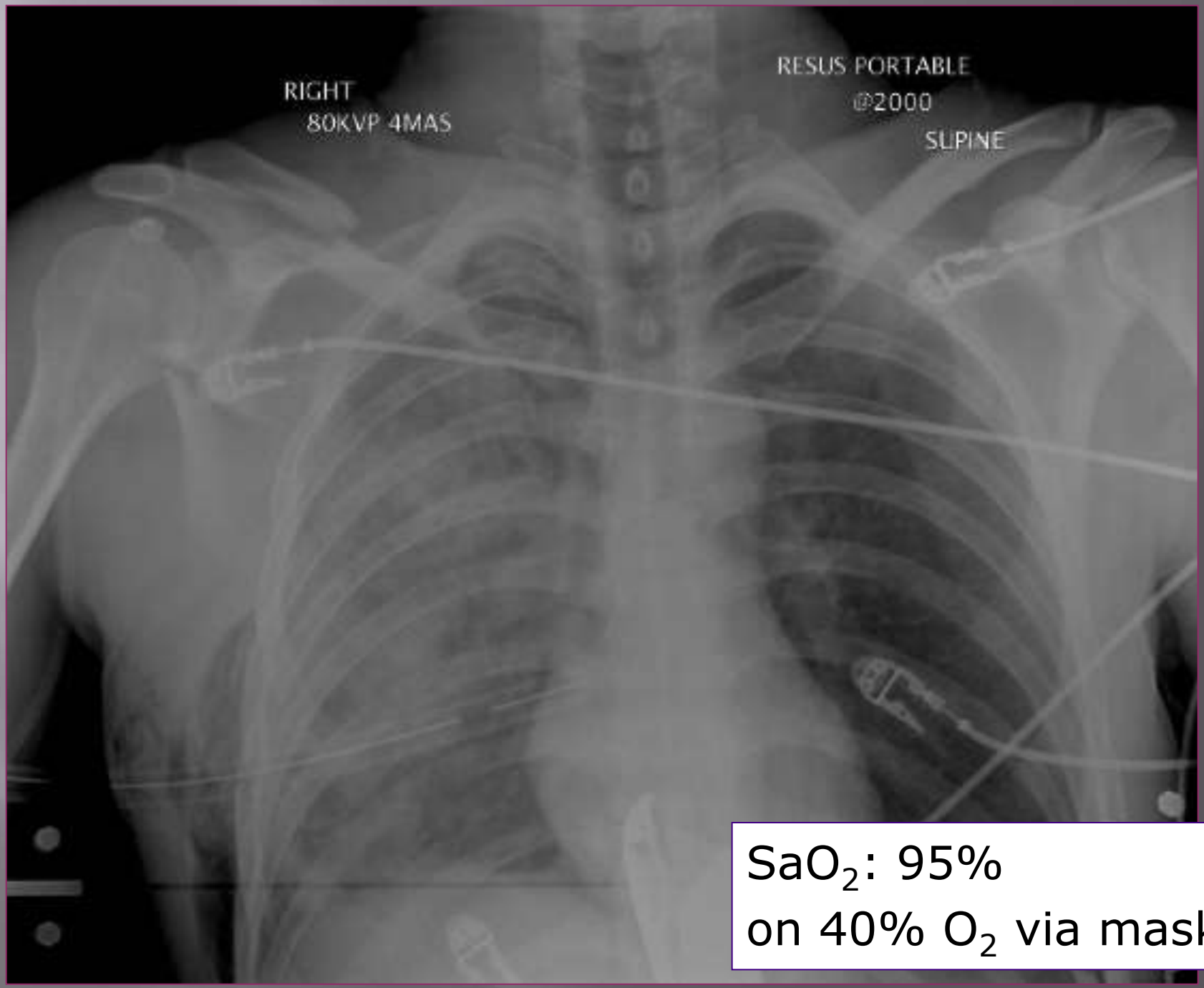
Exposure - temp 34^{C}

Male, 19 years
Motorcycle accident

chest drain → RR 30
SaO_2 95%

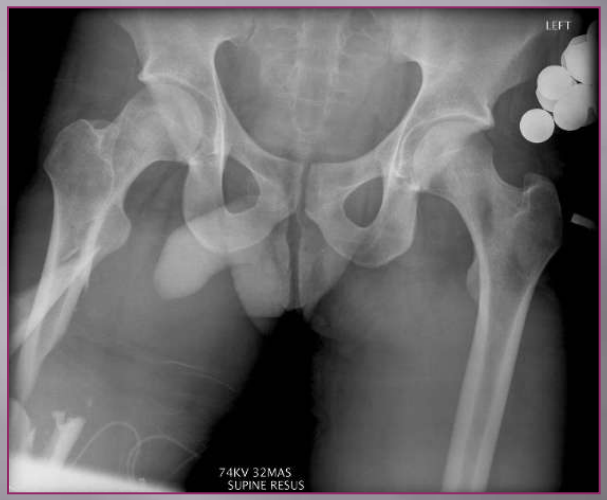
IV fluids → Pulse 100
BP 110/80

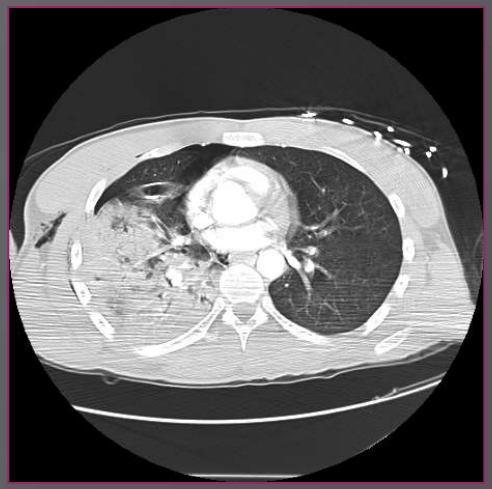

RIGHT
80KVP 4MAS
RESUS PORTABLE
@2000
SUPINE



SaO_2: 95%
on 40% O_2 via mask

Secondary survey (including CT)





Neck & spine

Male, 19 years
Motorcycle accident

normal
- *spine cleared*

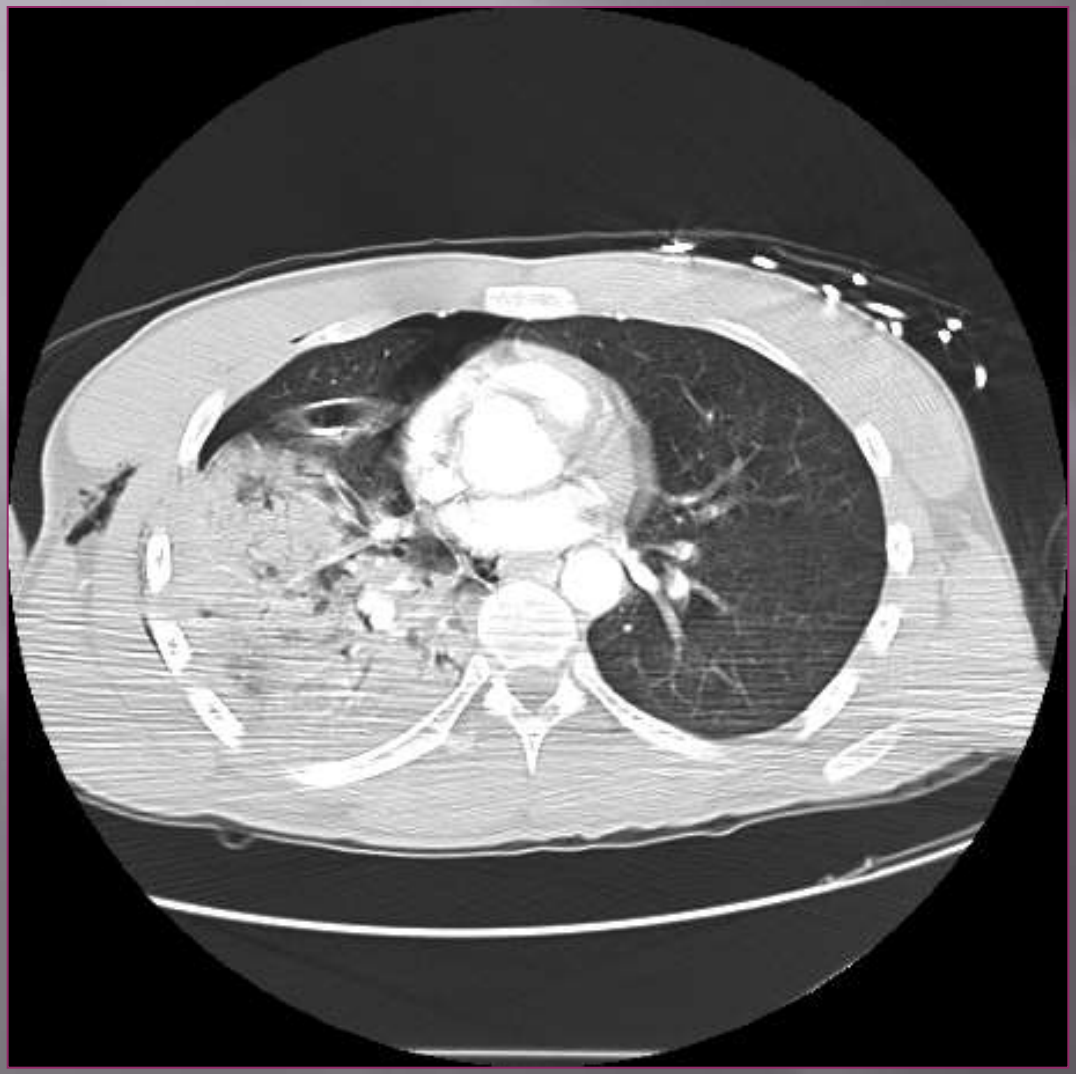
Pelvis

Male, 19 years
Motorcycle accident

normal
- *pelvis cleared*

Chest

Male, 19 years
Motorcycle accident



2 hours
since accident

Intubated
Ventilated 50% O_2

PaO_2: 13.1
$PaCO_2$: 4.5

pH: 7.21
base excess: -7.4

Right femur

Male, 19 years
Motorcycle accident

Closed
Neurovascular normal

Thomas' splint applied

Severe swelling thigh
- compartment pressure
= 67mmHg

Right tibia

Male, 19 years
Motorcycle accident

Open – IIIa
Neurovascular normal

No compartment syndrome

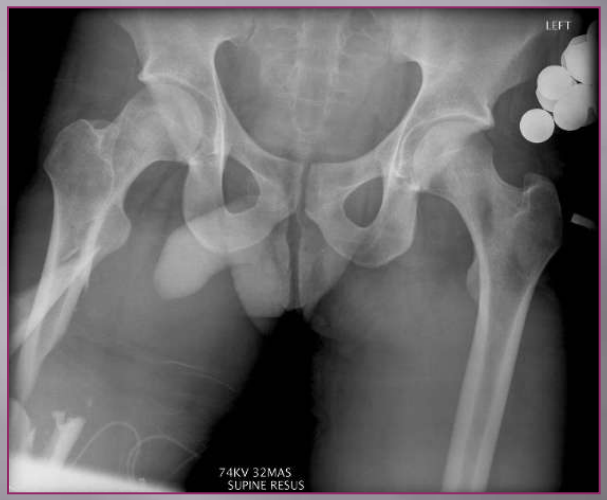
Right shoulder

Male, 19 years
Motorcycle accident

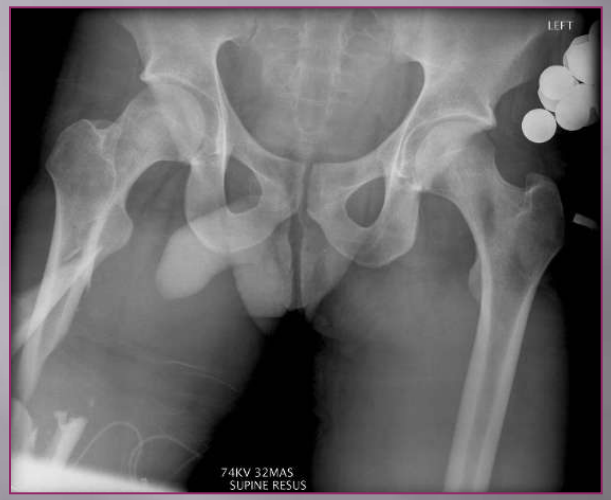
Closed
Brachial plexus ok
No vascular problem

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**

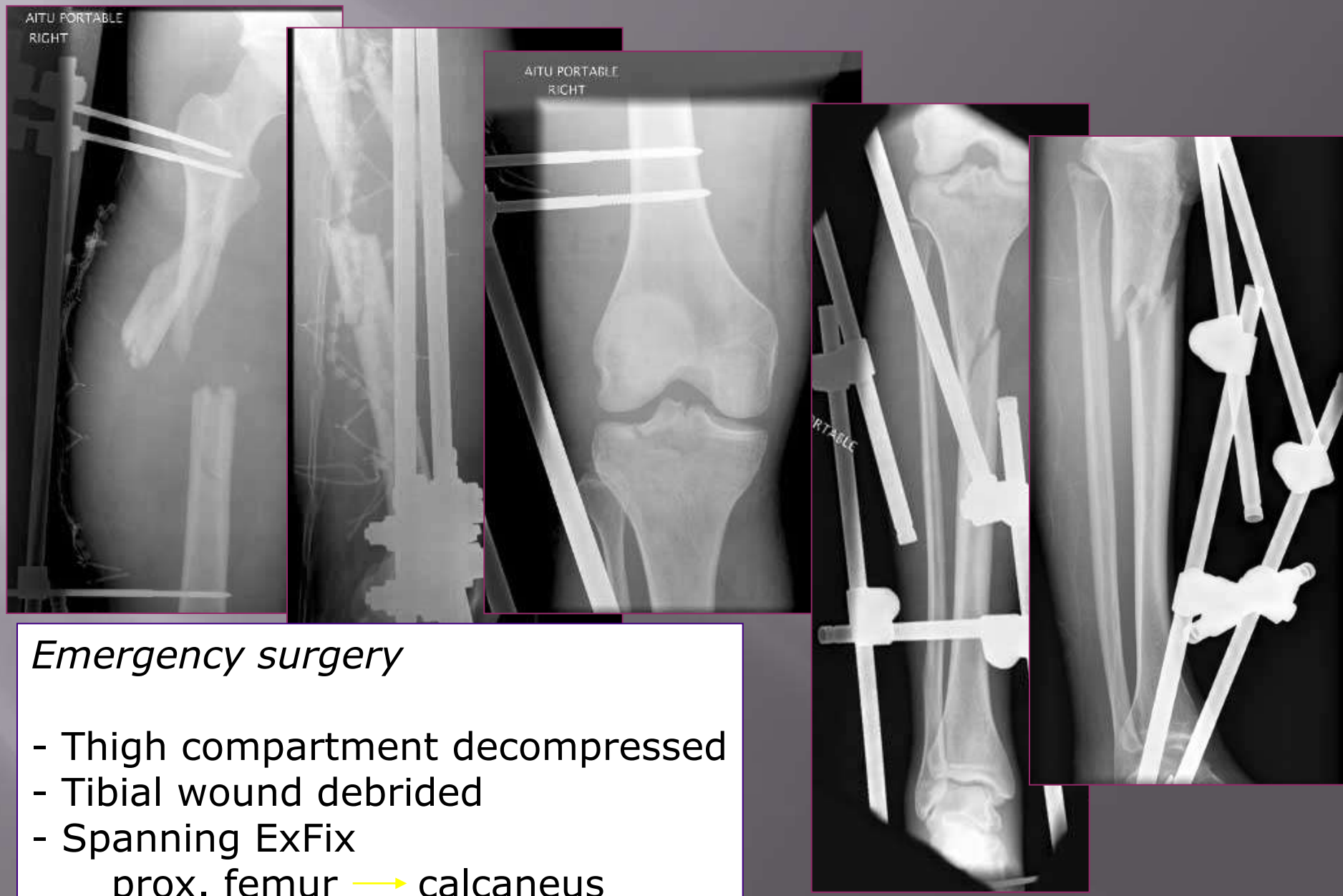
PaO_2 13 on 50% O_2

pH 7.21

Base excess -7.4

Case 1

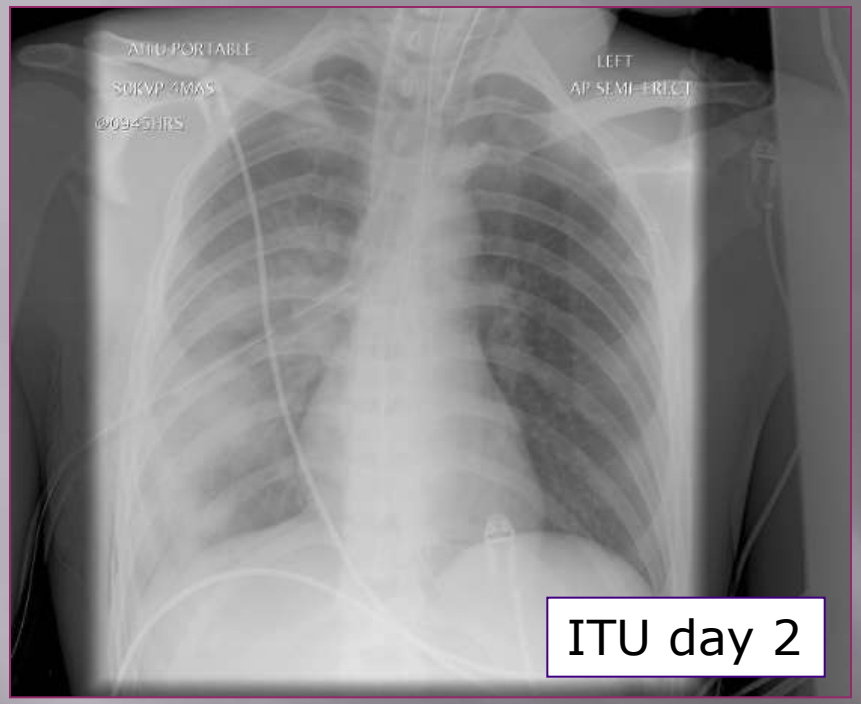
What happened.....



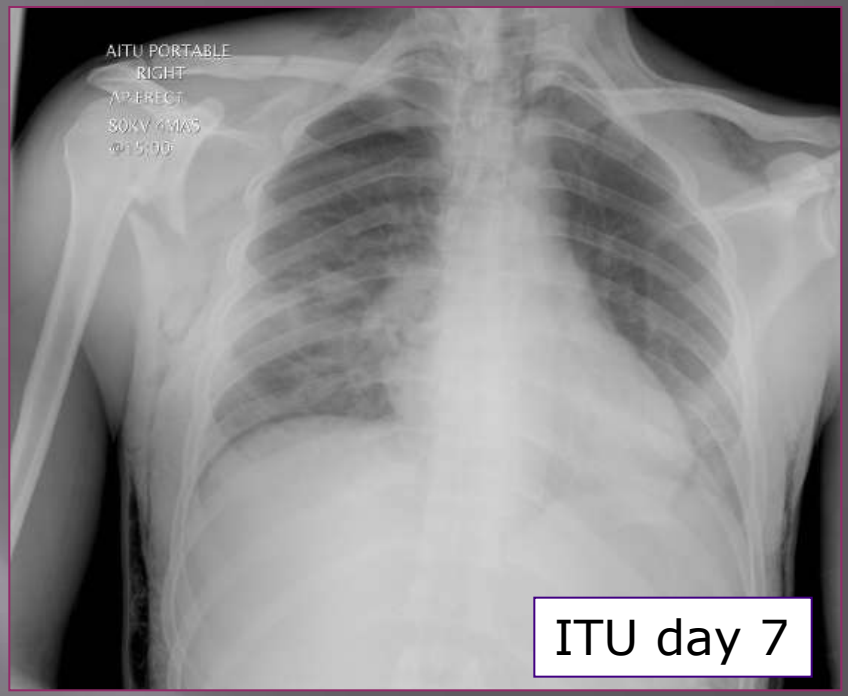
Emergency surgery

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

to ITU as quickly as possible

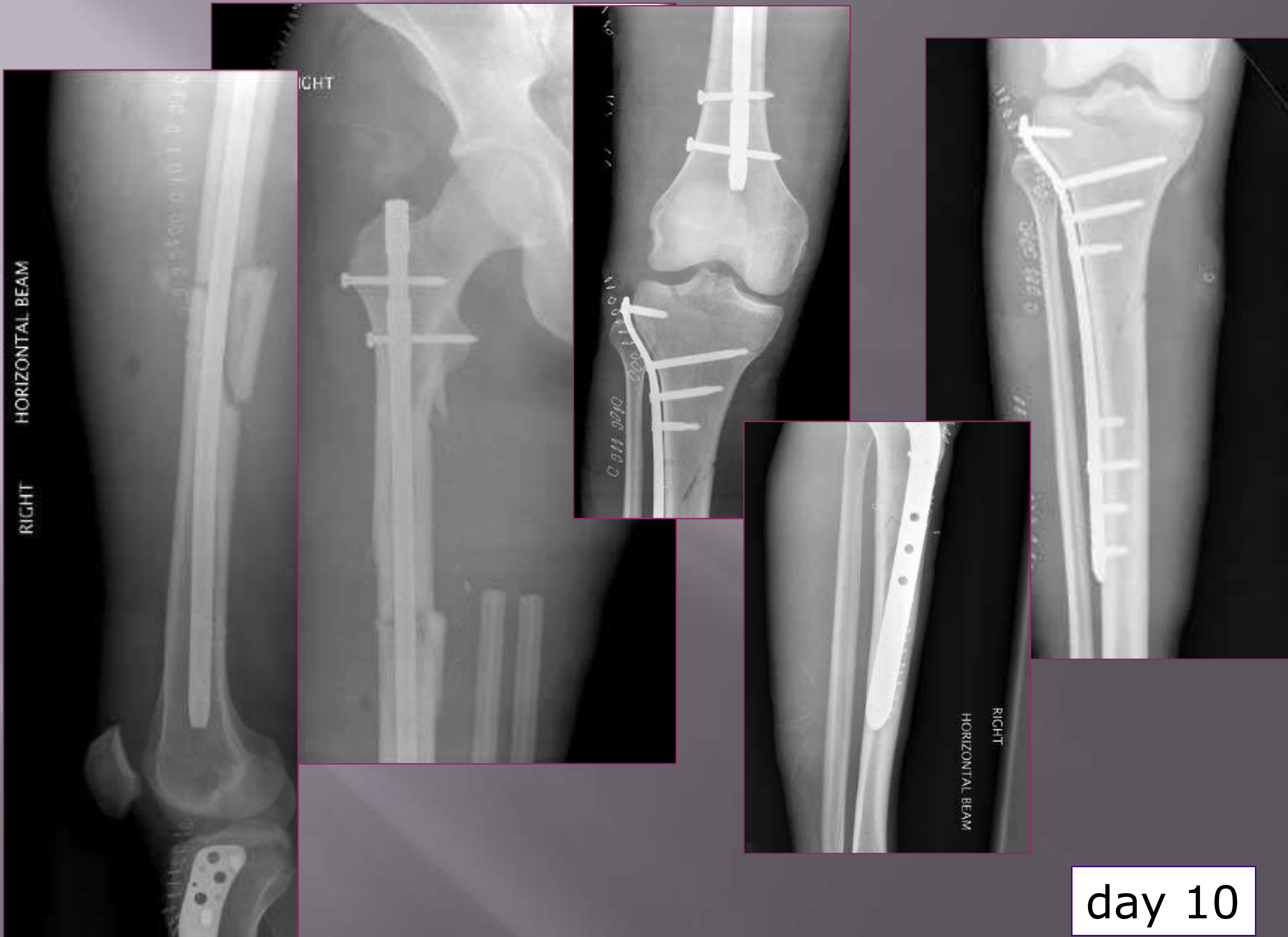


ITU day 2



ITU day 7

Timing of definitive care?



day 10

day 14

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 unstablised 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% (*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

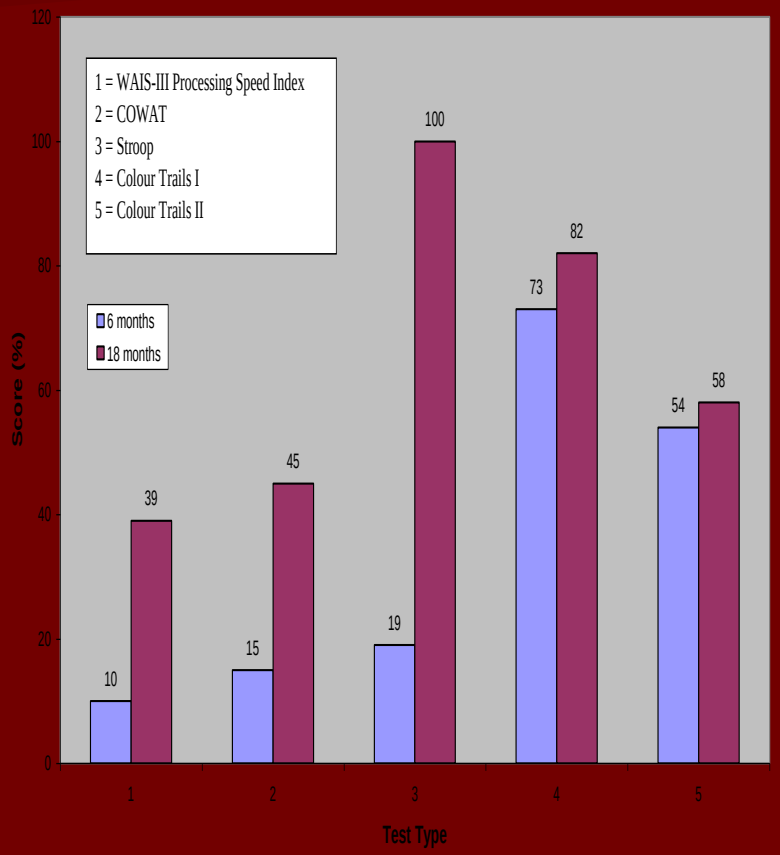
- Hypoxaemic
  - Pao_2/Fio_2 ratio = 8.6/0.6 = **14.3****
  - ALI < **40** ARDS < **26.7**

- CXR – bilateral lung infiltrates on AP view
- Pulmonary Artery occlusion pressure < 18mmHg

Cognitive Testing – 6 weeks

Tests	Description	Results
Weschler Test of Adult Reading (WTAR)	Predicted Full Scale Intelligence Quotient – PFSIQ (%)	**> 75%**
Colour Trails Tests 1 and 2	Visual processing speed. Sensitive measure of cerebral injury.	**12% (I)** **1% (II)**
Controlled Oral Word Association Test	Measures verbal fluency	**1%**
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

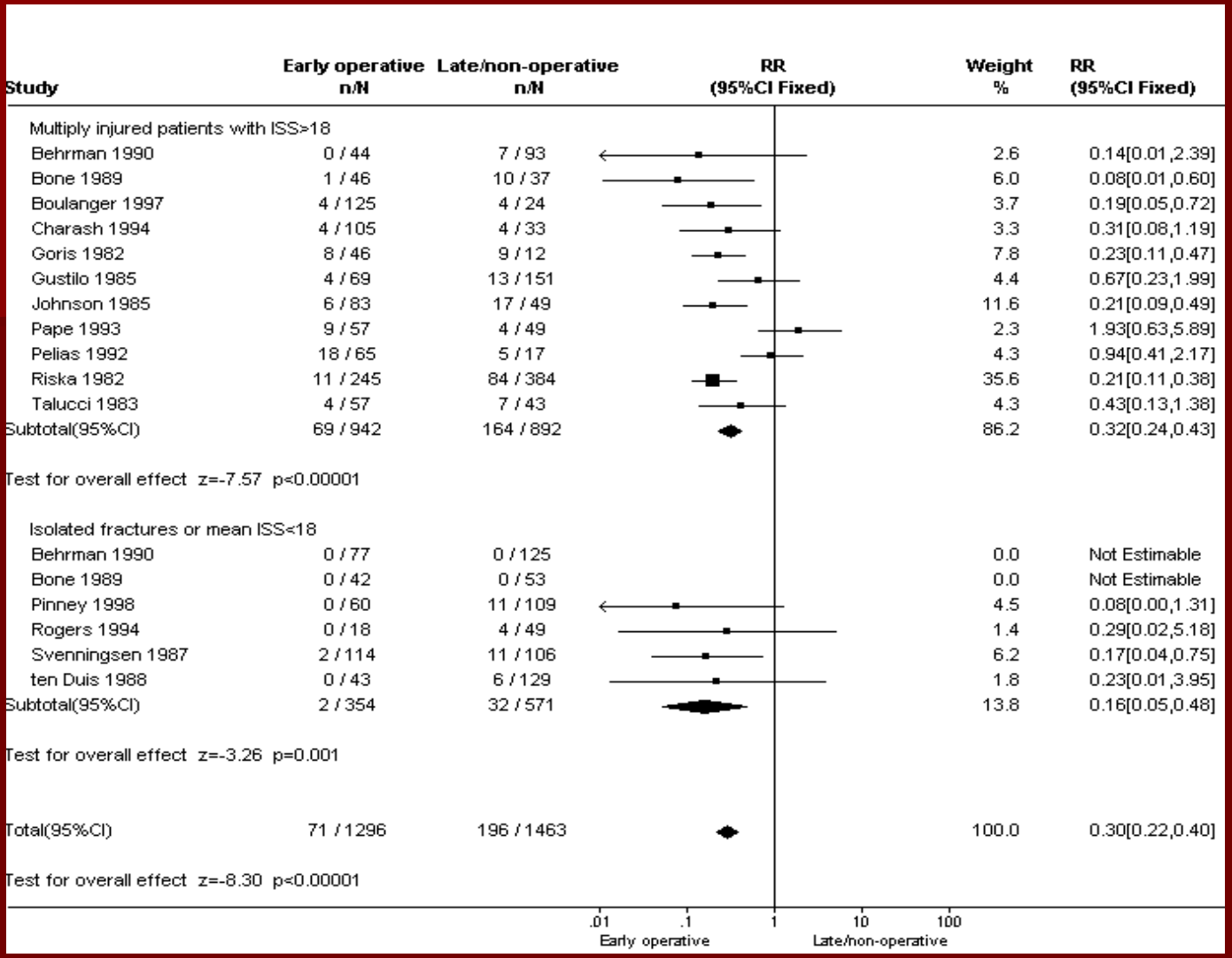


- Normal MRI – 6 mth.
- Gradual improvement
- Significant long term impairment persisted
- Rehabilitation issue
- ? Cognitive effects of injury

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

Conclusion

- 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 understimated 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

Giannoudis 2009

- 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)

Practical Application for DCO

- 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