EMST Immediate Management

- ***Priority Plan***

1. primary survey
2. resuscitation phase
3. secondary survey
4. definitive treatment & re-evaluation
5. transfer if appropriate

- ***Primary Survey***

1. ***Airway and Cervical spine***
   - assess for patency ± removal of foreign material, chin lift, jaw thrust
   - assume Cx spine injury in all patients with multisystem trauma
   - lateral Cx spine XRay ***does not*** exclue all cervical injuries
2. ***Breathing***
   - exposure of the chest
   - high F_IO_2 > 0.85
   - three commonest traumatic causes of embarrassed ventilation,

   i. tension pneumothorax
   ii. open pneumothorax
   iii. flail chest with pulmonary contusion
3. ***Circulation***

   i. blood-volume & CO
      - conscious state
      - skin colour & perfusion
      - pulse rate & character

   ii. bleeding
      - esanguinating external haemorrhage should be immediately controlled
      - occult internal haemorrhage may be difficult to detect / control
      - MAST suit may be appropriate for abdominal/lower limb bleeding
4. ***Disability*** - overt neurological status

   i. level of consciousness
      - A - alert
      - V - responds to verbal stimuli
      - P - responds to painful stimuli
      - U - unresponsive

   ii. pupillary size & response to light
5. ***Exposure*** - complete exposure of the patient

- ***Resuscitation***

1. supplemental O_2
2. IV access
   i. minimum of 2x 16G cannulae
   ii. blood drawn for X-match, FBE, Coags, MBA
   iii. commence fluid replacement
      - initially with either balanced salt solution or synthetic colloid
      - use blood if > 2-3 litres in adult with no improvement
      - ***type-specific*** unmatched, or ***O-negative*** blood acceptable
      - adequacy of resuscitation judged by physiological parameters
3. ECG monitoring
   - HR, dysrhythmias
   - EMD → hypovolaemia, tamponade, tension pneumothorax, massive embolism: air, fat, AFE, PTE, massive MI, profound metabolic disturbance
4. urinary catheter
   - CUD insertion generally contraindicated when,
   i. blood at the external meatus
   ii. blood in the scrotum
   iii. impalpable, or high riding prostate
5. naso/oro-gastric tube

- ***Secondary Survey***

Def'n: "head-to-toe & front-to-back" examination of patient

1. ***Head***
   i. eyes - pupillary size, response, EOM's, conjunctival haemorrhage
      - visual acuity, lens dislocation, fundi/optic disc changes
   ii. ears - TM patency, haemorrhage, CSF leak
   iii. scalp - lacerations, haematoma
2. ***Maxillo-facial trauma***
   - when ***not*** associated with airway compromise, shold be deferred to definitive management
   - mid-face fractures may have fractures of the ***cribriform plate***
3. ***Cervical Spine / Neck***
   - presume in all patients with blunt maxillo-facial trauma & multisystem trauma
   - absence of neurological deficit, pain or tenderness ***does not*** exclude significant injury
   - helmets should be removed with manual in-line stabilisation
   - penetrating wounds through the platysma require surgical exploration in theatre

4. ***Chest***
   - anterior, posterior, rib-cage, thoracic spine
   - bone injury, soft-tissue injury, penetrating injury
   - diminished apical breath sounds may be only sign of pneumothorax
   - soft heart sounds / narrow pulse pressure in tamponade

5. ***Abdomen***
   - anterior, posterior, lumbar spine
   - obvious swelling, penetrating injury
   - consider peritoneal lavage vs CT scan
   - many centres now trialling emergency ultrasound in assessment

6. ***Rectum***
   - anal sphincter tone
   - integrity of rectal wall, presence of fractures
   - position of prostate
   - presence of blood

7. ***Fractures***
   - long bones, joints, digits
   - pelvis, thoracic cage
   - spine, cranium

8. ***Neurological***
   - CNS status - AVPU
   - GCS, pupillary responses
   - motor & sensory evaluation of extremities
   - vasomotor stability, HR, sphincter tone

9. ***Investigations***
   i. blood - X match, FBE, MBA, Coags
   ii. XRays - CXR, AXR, Cx spine
   - pelvis, Tx/Lm spine, long bones
   ± contrast studies
   iii. DPL
   iv. U/Sound
   v. CT scan
   vi. laparotomy

Haemorrhage

1. ***class 1*** < 15% blood volume
   - minimal tachycardia, no measurable changes in BP, pulse pressure, RR, perfusion
2. ***class 2*** ~ 15-30% ~ 800-1500 ml in 70kg adult
   - ↑ HR > 100 bpm, ↓ pulse pressure and peripheral perfusion
   - ↑ RR
   - SAP changes little, DAP increases due to ↑ SNS tone
   - ↓ urine output
   - many in this group will eventually require blood replacement, however this can follow colloid/crystalloid resuscitation
3. ***class 3*** ~ 30-40% ~ 2000 ml
   - clinically shocked, ↑ RR, ↑ HR, ↓ BP, CNS changes
4. ***class 4*** > 40%
   - life-threatening shock & CVS collapse
   - require immediate volume resuscitation & blood ASAP

NB: compensation generally prevents a fall in systolic BP until **> 30%** BV loss

haematocrit/Hb is an unreliable guide to volume loss

- ***Exceptions***

1. elderly
2. athletes
3. medications - β-blockers
4. hypothermia
5. pacemakers

- ***Emergency Transfusion***

1. ***full crossmatch***
   - preferrable where possible
   - takes ~ 45-60/60 in most laboratories
   - compatability ~ **99.95%**
2. ***type specific*** - "saline crossmatched" blood
   - ABO-Rh typing plus immediate phase X-match ~ 5-10 minutes
   - compatability ~ **99.8%**
   - only **1:1000** patients has an unexpected Ab found in full X-match
   - greater risk in previously transfused patients ~ 1:100 unexpected Ab
   - first choice for life-threatening shock states
3. ***type O Rh-negative***
   - universal donor, uncrossmatched blood
   - some type O donors produce high titres of anti-A,B immunoglobulins

     → ***packed cells*** better than whole blood
   - transfusion of > 2 units of whole type O requires continued use until the blood bank determines levels of anti-A/B have declined (theoretically !)
   - continued use of type O results in minor haemolysis & hyperbilirubinaemia
4. ***fluid warmers***
   - iatrogenic hypothermia associated with,

   i. shivering & ↑ VO_2

   ii. platelet dysfunction and coagulopathy
5. ***coagulopathy***
   - rare problem in the first hour & with less than 10 units Tx
   - clotting factor deficiency less comon than,

   i. surgical bleeding

   ii. hypothermia

   iii. thrombocytopaenia
   - administer FFP according to APTT/INR
6. ***MAST trousers*** - see over

MAST Suit

NB: improves early haemodynamics
no evidence of improved survival

- ***Indications***

1. splinting and control of pelvic fractures with continued haemorrhage / hypotension
2. intra-abdominal trauma with severe hypovolaemia in patients being transported to definitive care

- ***Contraindications***

1. absolute
   i. pulmonary oedema
   ii. myocardial dysfunction
   iii. ruptured diaphragm
2. relative - uncontrolled haemorrhage outside of confines of suit
   i. intrathoracic haemorrhage
   ii. severe head injury / raised ICP

- ***Complications***

a. lower limb ischaemia
b. compartment syndrome
c. pulmonary oedema
d. increased haemorrhage from thoracic injuries
e. raised ICP
f. post-deflation
   i. hypotension
   ii. acidaemia
   iii. reperfusion injury

CHEST TRAUMA

- ***Acute Life Threatening Injuries***

  a. airway obstruction
  b. tension pneumothorax
  c. open pneumothorax
  d. haemothorax ≥ 1500 ml
  e. flail chest
  f. cardiac tamponade
  g. aortic rupture
  h. air embolism - broncho-pulmonary venous fistula

  NB: chest injuries result in ~ 1/4 trauma deaths,
  only ~ 15% of such injuries require operative intervention

- ***Indications for Intercosal Tube Drainage***

  1. pneumothorax
  2. haemothorax
  3. empyema
  4. bronchial rupture
  5. oesophageal rupture
  6. prior to transport in high risk patients

Tension Pneumothorax - Causes

NB: results from "one-way-valve" air leak,
either from the lung or through the chest wall

a. IPPV & barotrauma
b. spontaneous pneumothorax / ruptured bullae
c. blunt chest trauma - rib fractures
d. penetrating chest trauma - less often
e. bronchial rupture
f. iatrogenic
   i. CVC cannulation
   ii. pleural aspirate/biopsy
   iii. non-functioning chest tube

• ***clinical diagnosis*** for which radiology is used for confirmation,

a. respiratory distress
b. tracheal deviation
c. unilateral diminshed breath sounds
d. tympanic percussion note
e. pulse paradoxus ± hypotension
f. distended neck veins
g. cyanosis

• management,

1. 14G IV cannula insertion 2nd interspace MCL
2. intercostal catheter

Open Pneumothoax

• if the opening defect is > 2/3 the tracheal diameter, effective ventilation is impaired
• management options,

1. apply sterile occlusive dressing with 3/4 sides taped forming valve
2. use totally occlusive dressing & insert remote intercostal catheter

Massive Haemothorax

- usually the result of > **1500 ml** blood in the thoracic cavity
    1. shock
    2. stony dull percussion note
    3. neck veins → ***flat***, due to severe hypovolaemia, or
       distended, due to impaired venous return
    4. confirmed by CXR

- management,
    1. simultaneous drainage & volume replacement
    2. ***autotransfusion*** if device available
    3. ***thoracotomy***
        i. initial drainage > 1500 ml
        ii. continued loss > 200 ml/hr

    NB: thoracotomy more often required for penetrating wounds medial to the nipple line

Flail Chest

- usually 2° multiple rib fractures as a result of blunt trauma
- if large enough may result in lung pump failure,
    1. ***dominant lesion*** is injury to underlying lung
    2. rarely does flail alone result in respiratory failure
    3. hypoventilation 2° to pain

- CXR may show multiple fractured ribs, but may miss costo-chondral separation
- paradoxical movement may be hidden by splinting in acute setting
- AGA's required for assessment
- management,
    1. supplemental O_2 - humidified
    2. volume resuscitation
        - contused lung is sensitive to both under/over resuscitation
    3. pain relief
        i. oral narcotics, mild analgesics
        ii. systemic opioids
        iii. interpleural catheter - local anaesthetics ± opioids
        iv. thoracic epidural / spinal opioids
    4. intubation / IPPV

Cardiac Tamponade

- Beck's triad,
    1. hypotension
    2. elevated JVP
    3. silent heart

- elevated CVP may be absent with hypovolaemia
- distended neck veins may be obscured by a cervical collar
- initial IV resuscitation will elevate CVP and improve CO initially
- ***Kussmaul's sign***, a rise in CVP with inspiration, is a true paradoxical venous pressure abnormality associated with tamponade
- performance of pericardiocentesis pre/post-echocardiography depends upon,
    1. the level of suspicion that tamponade exists
    2. the degree of decompensation of the patient

    NB: ***all*** patients having a positive pericardiocentesis require a thoracotomy

Chest Trauma - Delayed Major Injuries

1.	pulmonary contusion	- without flail chest
2.	myocardial contusion	- arrhythmias
3.	aortic rupture / haemorrhage	
4.	ruptured diaphragm	- respiratory failure
5.	ruptured bronchus	- bronchopleural fistula - pneumothorax
6.	ruptured oesophagus	- mediastinitis

Pulmonary Contusion

- most common potentially lethal chest injury seen
- may be managed with or without intubation, but require observation due to progression over the first 24-48 hrs
- factors indicating a need for ***early intubation***,

1. impaired level of consciousness
2. pre-existing cardiopulmonary disease
3. any injury dictating anaesthesia/operation
   i. associated abdominal injury requiring laparotomy
   ii. skeletal injuries requiring immobilization
   iii. craniotomy - ICH, raised ICP and monitor insertion
4. renal failure

Myocardial Contusion

- incidence **~ 65%** of major blunt chest trauma
- site affected,

a. RV ~ 65%
b. LV ~ 15%
c. both ~ 20%

- clinical presentation,

a. unexplained hypotension
b. unexplained elevation of CVP/JVP
c. acute cardiac failure
d. arrhythmias
e. new murmur - VSD, MV rupture
f. tamponade

- investigations,

a. ECG changes - ischaemic changes in RV leads
   - multiple ectopics, sinus tachycardia, AF
   - RBBB, ST/T wave changes
   ± myocardial infarction
b. high CK/CK_{MB} * poor correlation
c. troponin I ? sensitivity / specificity
d. gated nucleotide scans = "gold standard"

Traumatic Aortic Rupture

- most common major vessel injured following blunt chest trauma
- common cause of immediate death in MVA, ~ **90%** fatal at the scene of accident
- 50% of surviving patients die per left untreated

a. 60% rupture just distal to the origin of the left subclavian artery
   - at the level of the ***ligamentum arteriosum***

b. 25% rupture at the ascending aorta
   - just proximal to the origin of the brachiocephalic artery

c. characteristic pathophysiology of ***contained haematoma***
   i. initial BP fall associated with loss of 1000-1500 ml
   ii. hypotension responds to IV volume replacement

NB: ∴require high index of suspicion & radiological exclusion

- ***Diagnosis***

1. CXR * may be essentially ***normal***
   * no single finding reliably predicts or excludes significant injury
   i. widening of the superior mediastinum
   ii. fractures of the 1st & 2nd ribs
   iii. blurring of the left margin of the aortic knuckle
   iv. tracheal shift → right
   v. left pleural cap | effusion
   vi. elevation & right-shift of the RMB
   vii. depression of the LMB
   viii. obliteration of the space between PA and aorta
   ix. oesophageal deviation (NGT)
2. angiography
   - "gold-standard" for diagnosis
   - high index of suspicion, ∴high false negative rate
   - LIGW, "if negative angiography rate < 50%, then not doing enough angiograms"
3. CT scan
4. TEE
   - NEJM 1995, completed studies in 93/101 within 29 ± 12 min
   - 11 positives → sensitivity = 100%
     specificity ~ 98%
   - additional information - LV function, valvular competence
     - tamponade
   - ***but*** operator dependent & blind spots in ascending aorta & other arteries
   - transthoracic echo of ***no use*** in diagnosis

- ***Management***

1. surgical repair
2. post-operative paraplegia ~ 5%

Diaphragmatic Rupture

NB: high index of suspicion in the patient with major abdominal injuries, modes of ***presentation***,

i. acute respiratory failure
ii. bowel sounds in left hemithorax
iii. peritoneal lavage fluid "disappears", or drains from chest tube
iv. bowel / NGT in hemithorax on CXR
v. failure to wean from mechanical ventilation

- ***CXR***

a. loops of bowel in ***left hemithorax***
b. "pseudo-haemopneomothorax" = air/fluid level of stomach
c. persistent elevated left hemidiaphragm
d. NG tube in left hemithorax

NB: may be ***mimmicked*** by (misinterpreted as),

i. elevated left hemidiaphragm
ii. acute gastric dilatation
iii. loculated pneumothorax
iv. subpulmonic haematoma

Tracheobronchial Tree Injuries

- ***Laryngeal Injury***

  a. history of injury
  b. may be minimal external tissue damage
  c. hoarseness
  d. subcutaneous emphysema
  e. crepitus

  NB: in the presence of ***acute obstruction*** oral intubation should be attenpted, failing this ***surgical tracheostomy*** is the procedure of choice, ***not*** cricothyroidotomy

- ***Bronchial Rupture***

  a. sites
     i. lower trachea ~ 80% transverse
     ii. major bronchus - spiral
     iii. post. tracheal wall - vertical
  b. presentation
     - may be insidious
     - high suspicion in major chest trauma

     i. haemoptysis - major or minor
     ii. subcutaneous emphysema
     iii. tension pneumothorax
     iv. acute bronchopleural fistula
     v. persistent lobal collapse

  NB: majority of patients with this injury die at the scene, of those who survive to hospital, ***mortality*** **~ 30%**, usually due to associated injuries

- diagnosis may be confirmed by bronchoscopy
- large leaks may require insertion of a second intercostal catheter
- management may be conservative or by operative repair

Oesophageal Rupture

- clinical presentation,
    a. penetrating, most common, or severe closed chest trauma
    b. retrosternal pain
    c. dysphagia
    d. haematemesis
    e. cervical emphysema
    f. CXR:
        - left pleural effusion, haemothorax
        - widened mediastinum
        - mediastinal emphysema, air/fluid level
        - cervical emphysema
        - hydropneumothorax / pneumothorax
    g. pleural aspirate
        - pH < 6.0
        - bloody fluid, high WCC
        - high amylase
    h. late events
        - fever, shock, septicaemia

- confirmatory diagnosis is by gastrograffin swallow or endoscopy
- there is a high associated mortality ~ 2% / hr left untreated
- aetiology,
    a. traumatic
        - external
        - internal / vomiting
    b. iatrogenic
    c. FB
    d. carcinoma

Coma: Causes of Respiratory Failure

a. airway obstruction
b. aspiration
c. acute neurogenic pulmonary oedema
d. post-obstructive pulmonary oedema
e. thoracic injuries
    i. tracheobronchial disruption
    ii. pulmonary contusion
    iii. haemothorax / pneumothorax
    iv. flail chest
    v. diaphragmatic disruption
f. acute gastric dilatation
g. cervical cord trauma
h. central hypoventilation

ABDOMINAL TRAUMA

Peritoneal Lavage

a. sensitivity ~ 95-98%

b. specificity ~ 85%

c. positive result

i. ***aspiration***

- fresh blood ≥ 10 ml prior to lavage
- faecal soiling or vegetable material

ii. ***lavage***

- fluid exits via intercostal or urinary catheter

iii. ***analysis***

- RBC count > 100,000/µl
  > 50,000/µl ≡[t] eqivocal
  > 5,000/µl for penetrating injuries
- WCC > 500/µl

- causes of ***false positives*** ~ 15%

a. traumatic lavage

b. retroperitoneal haemorrhage

c. pelvic haematoma - 2° fractures

- causes of ***false negatives*** ~ 2-5%

a. incorrectly performed

b. diaphragmatic rupture

c. retroperitoneal injuries - haemorrhage
- duodenum
- pancreas
- renal injury

d. isolated hollow viscus perforation - small bowel
- bladder

- ***Indications***

a. multiple trauma patient in whom abdominal examination is,
   i. equivocal
   ii. unreliable - CHI, intoxication, cord injury
   iii. impractical - prolonged XRays, angiography
   - requiring GA

b. unexplained fluid requirements in resuscitation

c. penetrating injuries - including lower thoracic

d. gunshot wounds

- ***Contraindications***

a. full bladder

b. pregnancy

c. recent abdominal surgery

d. obvious signs of intraperitoneal haemorrhage/infection

NB: the only ***absolute contraindication*** is an existing indication for laparotomy

- ***Compications***

a. haemorrhage

b. intestinal perforation

c. bladder perforation

d. infection

- ***Peritoneal Lavage - Technique***

a. empty bladder, sterile technique, IV access

b. dialysis catheter introduced into pelvis via sub-umbilical incision

c. aspiration for frank blood

d. 1000 ml of normal saline introduced over 5 minutes + ballotment

e. fluid drained sent for,
   i. red & white blood cell counts
   ii. urgent gram stain & culture
   iii. amylase
   iv. ? cytology

Abdominal CT Scanning

- suggested as a substitute for DPL in haemodynamically stable patients
- criticism of DPL is indication for laparotomy in cases of minor liver laceration
- several clinical studies suggest double contrast CT may miss life-threatening intra-abdominal injuries

a. diaphragmatic tears
   - most commonly 5-10 cm length, involving posterolateral left hemidiaphragm
   - initial CXR is usually non-specific
   - high association with wedge #L1, (b) and (c)

b. duodenal rupture

c. pancreatic injury
   - normal serum amylase ***does not*** exclude pancreatic fracture
   - conversely, may be elevated from non-pancreatic sources

Penetrating Trauma

NB: an aggressive policy for exploratory laparotomy is justified, due to the high incidence of hollow visceral injury & vascular involvement

1. gunshot wounds
   - entry of the peritoneum mandates laparotomy
   - in the absence of an exit wound, AXR required to establish trajectory
   - broard spectrum antibiotic therapy early
2. stab wounds
   - selective laparotomy procedure - wound exploration
     - DPL
   - < 50% of such injuries will require urgent laparotomy
3. lower thoracic wounds
   - defined as - line from 4^{th} ICS anteriorly to 7^{th} ICS posteriorly
     - nipple line to inferior border of scapula
   - incidence of significant abdominal injury with penetrating injury,
   i. stab wound ~ 15-25%
   ii. gunshot wound ~ 45-60%
   - $\therefore$ laparotomy for all gunshots & sleective for stab wounds
4. flank & back wounds
   - risk of significant visceral injury following panetrating,
   i. back wounds ~ 5-15%
   ii. flank wounds ~ 20-30%
   - routine laparotomy is the safest policy, as there are no reliable tests

Genitourinary Tract

Blunt Trauma

- increased incidence of injury with,
    1. renal
        i. back / flank haematomas, ecchymoses
        ii. fractures of lower ribs
        iii. fractures of spinal transverse processes
    b. bladder/urethra
        i. perineal haematomas
        ii. anterior pelvic fractures
    c. overt signs of lower tract injury
        i. blood at the urethral meatus
        ii. inability to void

- urethral disruptions are divided into,
    a. posterior - above the urogenital diaphragm
        - usually multisystem trauma. pelvic fractures
    b. anterior - below the urogenital diaphragm
        - usually starddle injuries & isolated

- imaging techniques,
    1. IVP
        - unilateral non-function - congenital absence, previous nephrectomy
            - massive parenchymal shattering
            - vascular pedical disruption
    2. urethrography
        - should be performed prior to CUD in all suspected urethral tears
    3. cystography
    4. CT scan

Pelvic Fractures

- open pelvic fractures → ***mortality* > 50%**
- rectal & genital injuries should be suspected in all major fractures
- DPL should be performed, preferrably from ***above*** the umbilicus, due to extension of haematoma
    a. negative DPL - reliably excludes major intraperitoneal bleeding
    b. positive DPL ~ 15% FP, due to leaking into the peritoneum

- a MAST suit may be used if there is haemodynamic instability
- continued bleeding then become a therapeutic dilemma,
    a. if DPL is grossly positive, then laparotomy indicted to exclude co-existent abdominal pathology
    b. ***arteriography* | *embolization*** may be life-saving for uncontrolled haemorrhage

HEAD TRAUMA

• head injury is associated with,

a. ~ 50% of all trauma deaths

b. ~ 60% of MVA deaths

Def'n: ***coma*** is defined as,

1. no eye opening = 1
2. not obeying command = 1-5
3. no word verbalisation = 1-2

virtually all patients with GCS < 8 and
most with GCS = 8 are comatose

Def'n: head injury is arbitrarily divided according to GCS as,

1. severe HI GCS < 9
2. moderate HI GCS = 9-12
3. minor HI GCS > 12

• other factors considered as severe HI, despite GCS,

a. unequal pupils > 1 mm difference

b. unequal motor response

c. open HI - CSF leak, exposed brain tissue

d. neurological deterioration

e. depressed skull fracture

• a change in GCS ≥ 2 represents clear deterioration, ≥ 3 major deterioration requiring immediate assessment & therapy

• other factors of concern,

a. increased severity, or unusually severe headache

b. unilateral increase in pupil size

c. unilateral onset of weakness

- ***Imaging Techniques***

a. CT scan
   - examination of first choice in all but trivial injuries

b. SXR
   - limited value in early management, except in penetrating injuries

c. examination with limited/no role in acute head injury
   i. LP
   ii. EEG
   iii. isotope scanning

- ***Skull Fractures***

a. linear, non-depressed
   - across vascular arterial grooves or suture lines increases the risk of ***extradural haematoma***

b. depressed
   - increased risk of sequelae (eg seizures) in depressed > thickness of skull

c. open
   - early operative intervention, elevation & removal of fragments & closure of the dura

d. basal skull fractures
   - internally compound, and loss of CSF may be occult into sinuses
   - factors suggestive of diagnosis,
   i. Battle's sign - mastoid ecchymoses
   ii. raccoon eyes - bilateral periorbital ecchymoses
   - associated with cribiriform plate fracture
   iii. CSF leak - rhinorrhoea, otorrhoea
   iv. haemotympanum

- ***Diffuse Brain Injury***

  a. ***concussion***
     - is a brain injury accompanied by brief loss of neurological function
     - various neurological abnormalities may be described, however, these have usually resolve by the time a tertiary institution is reached
     - ∴***any*** neurological abnormality observed in a patient ***should not*** be attributed to concussion
     - rule of thumb is that if the patient has been unconscious for > 5 minutes then they should be observed for 24 hrs

  b. ***diffuse axonal injury***
     - characterised by prolonged coma, lasting days to weeks
     - overall mortality ~ 30%
     - autonomic dysfunction, fever, hypertension, sweating etc is common

- ***Focal Injuries***

  a. contusions

  b. haemorrhages

  c. haematomas

  NB: operative intervention usually only required for mass effect

- ***Meningeal Haemorrhage***

1. extradural haemorrhage
   - most commonly middle meningeal artery, rarely dural sinus
   - usually 2° linear fracture of parietal/temporal bones
   - relatively rare ~ 0.5% of unselected HI
     ~ 0.9% of HI resulting in coma
   - classical description of progress,
   i. LOC followed by lucid interval
   ii. secondary depression of conscious state
   iii. development of contralateral hemiparesis
   iv. ipsilateral dilated pupil
   - outcome is directly related to the condition of the patient prior to surgery
   i. light coma → ~ 9% mortality
   ii. deep coma → ~ 20% mortality
2. subdural haemorrhage
   - much more common than extradural ~ 30% of severe HI
   - most commonly rupture of ***bridging veins***, less often cortical arteries or brain
   - underlying primary brain injury is often severe
   - poor prognosis → mortality ~ 60%
   - recent studies suggest some improvement of outcome with early evacuation
3. subarachnoid haemorrhage
   - blood in CSF → meningeal irritation, headache, photophobia, etc.
   - LP not required → CT scan

- ***Parenchymal Haemorrhage***

1. intracerebral haematomas
2. impalement injuries
3. bullet wounds

SPINAL TRAUMA

- ***Demographics***

a. age ~ 70-80% are between **11-30 yrs**

b. sex ~ 2/3 are ***males***

c. ***mortality*** ~ 30% die before reaching hospital
~ 10% during the first year
~ normal for age thereafter

• although semi-rigid cervical collars are useful, securing the ehad to a spianl board is equally, or more effective
• a conscious patient with paralysis is usually able to identify pain at the site of injury due to sensory loss below the level

NB: paralysis/sensory loss may mask abdominal or lower extremity injury

• in unconscious patients 2° MVA or a fall, chance of Cx spine injury **~ 5-10%**
• risk of Cx spine injury in unconscious patients increases with,

1. flaccid areflexia
2. flaccid rectal sphincter
3. ability to flex, but ***not extend*** the elbow
4. grimaces to pain above, but not below the clavicle
5. hypotension with bradycardia & dilated veins
6. priapism

- ***Vertebral Assessment***

  a. usually associated with pain & tenderness
  b. less often palpable step-deformity
  c. oedema / ecchymoses
  d. tracheal tenderness / deviation - retropharyngeal haematoma
  e. muscle spasm ± head tilt

- ***Neurological Assessment***

  a. motor power
  b. tone
  c. reflexes
  d. sensory deficit
     - light touch is conveyed in both lateral and posterior columns & may be the only modality preserved in incomplete injuries
     - sparing of sensation in the ***sacral dermatomes*** may be the only sign of incomplete injury
     - evaluation of sacral sparing should include sensory perception and voluntary contraction of the anus
  e. autonomic dysfunction - bladder / rectal control, priapism

- ***Neurogenic & Spinal Shock***

1. ***neurogenic shock***
   - hypotension associated with high thoracic & cervical injuries
   - hypotension, bradycardia & dilated veins → "relative hypovolaemia"
   - atropine may be used to Rx bradycardia
2. ***spinal shock***
   - refers to neurological function of the spinal cord following injury
   - "shock" may result in almost total non-function despite viability of the cord
   - produces flaccid paralysis, cf. normal spasticity, brisk reflexes & ↑ plantars

- ***Fractures / Dislocations***

1. ***C1 Atlas***
   - usually involves a blow-out of the ring → ***Jefferson*** fracture
   - asociated with axial load
   - 30% have associated C2 fracture
   - usually ***not*** associated with cord injury
   - they are unstable & require immediate immobilization
2. ***C2 Axis***

   i. dislocation
      - odontoid may be displaced posteriorly into the spinal canal
      - injury to the transverse ligament, between odontoid & anterior arch of C1
      - consider whenever C1-arch to odontoid distance > **5 mm**
      - displacement can occur without injury → Steel's rule: "1/3 of the area in the atlas is occupied by odontoid, 1/3 by spinal cord"

   ii. odontoid fractures
      - ***type I***: above the base & stable
      - ***type II***: through the base & usually unstable
      - ***type III***: extends into the vertebral body
      - NB: in children under 6 yrs the epiphysis may appear as a fracture line cf. type II fractures

   iii. posterior element fractures → ***"hangman's*** fracture"
      - posterior elements damaged by flexion & distraction
      - unstable

3. ***C3-C7***
   - assess distance from anterior aspect of C3 to pharyngeal shadow
     → prevertebral thickness < 5 mm
   - increased thickness "without" fracture classically seen with minimally displaced C2 fracture
   - "rule-of-thumb" for prevertebral haematoma is the distance to the air-shadow should be < ½ the vertebral body thickness
   - radiological evidence identifying an unstable fracture,

   i. ***disruption*** of all of either anterior or posterior elements

   ii. ***over-riding*** of a superior vertebral body > **3.5 mm**

   iii. ***angulation*** between vertebral bodies > **11°**

4. ***facet dislocations***
   - unilateral facet injury→ vertebral displacement ~ 25% of body width
   - bilateral facet injury → vertebral displacement > 50% of body width
   - malalignment of spinous processes on AP film
   - bilateral dislocations frequently unstable

Pathophysiology

- injury results from both primary and secondary injury
- the anatomic and histological findings associated with ***primary injury***,
    a. direct neurilemmal & neuronal disruption ± destruction
    b. petechial haemorrhages
    c. gross haematomyelia
    d. total cord transection * a rare event
- subsequent ***secondary injury*** involves,
    a. progressive haemorrhagic necrosis
    b. oedema
    c. inflammatory response

    NB: → proportional to the extent of the 1° injury
- the proposed mechanism of the ***2° injury*** includes,
    a. activation of ***phospholipase*** $\mathbf{A_2}$, due to release of
        i. Ca^{++}
        ii. bradykinin
        iii. thrombin
    b. formation of arachidonic acid & other FFA's from cell membrane
    c. metabolism of arachidonic acid to,
        i. prostaglandins * mainly ***thromboxane***
        ii. leukotrienes → microcirculatory thrombosis & stasis
            vasogenic oedema
            tissue ischaemia
            chemotaxis of inflammatory cells
    d. free radical formation & hydrolysis of membrane lipid fragments
        → ***lipid fragment peroxides***
    e. lipid hydrolysis and peroxidation of fragment membrane phospholipids
        → further release of Ca^{++} & positive feedback
    f. increased $PGF_{2\alpha}$ and thrombin augment phospholipase activity
    g. raised intracellular Ca^{++} leads to disordered energy metabolism and maintenance of cell integrity (Na^+/K^+-ATP'ase)
    h. increased endogenous kappa opioid agonist ***dynorphin***, plus an increase in receptor binding capacity following experimental SCI in rats

- ***Effects on Spinal Cord Blood Flow***

• immediately following SCI there is a marked ***reduction*** in SCBF, resulting in ischaemia and biochemical changes as above
• these changes may not commence for up to 1-4 hrs post SCI
• therefore postulated that interruption of the above cascade may protect against ischaemia
• the normal mean ***SCBF ~ 40-50 ml/100g/min***
• this is partitioned between grey & white matter ~ 3:1
• SCBF normally ***autoregulates*** between ~ 60-150 mmHg MAP in rats
• SCBF has been shown to vary with P_{aCO2} ~ 1:1 ratio (1 ml/mmHg)
• most of the decrease in SCBF following SCI is in the central cord region
• work with cats has shown that autoregulation is ***abolished*** following SCI

Management of Acute SCI

a. pharmacological
   i. ***steroids***
      • given before, or shortly after decrease 2° injury in animals
      • Braken (1990) showed high dose methylprednisolone improved motor and sensory function at 6 weeks & 6 months
      • benefit is statistically significant only when administered £ ***8 hrs*** of SCI
      • there was no increased incidence of septic complications
      • subsequent RCT's have not suported this finding and use currently controversial
   ii. mannitol
      • effective in reducing parenchymal volume
      • also causes a vigorous osmotic diuresis
      • intravascular volume must be maintained to ensure SCB

b. spinal cord perfusion
   • following experimental SCI ***autoregulation*** is lost → ***pressure passive***
   • hypotension leads to cord hypoperfusion & ischaemia
   • hypertension leads to increased oedema and haemorrhage
   • therefore the aim is to maintain ***MAP ~ normal***

c. experimental*
   • hypothermia
   • hyperbaric oxygen
   • catecholamine antagonists
   • dimethyl sulphoxide
   • naloxone (opioid antagonism)

NB: *none of these has consistently demonstrated a benefit in human clinical trials

Associated Problems

- ***Airway Management***

NB: any patient with a significant ***closed head injury*** potentially has a fractured ***cervical spine***

• ***neutral position*** must be maintained during intubation
• non-incremental traction without radiological control ***does not*** protect against further injury
• blind nasal & fibreoptic intubation may be attempted only if base of skull fracture can be excluded, however both tend to produce coughing & bucking which may be deleterious

NB: RSI & oral intubation are indicated in the presence of,

i. complete apnoea
ii. associated head injury with GCS < 9
iii. an uncontrollable patient

- ***Respiratory Complications***

1. ***anoxia/hypoxia*** is the most common cause of death in acute SCI
2. ***pneumonia*** is the 2nd most common cause of death

• the degree of respiratory embarrassment depends upon SCI level
• ***phrenic paralysis*** ($C_{3,4,5}$) arises with ***lesions*** ³ $\mathbf{C_4}$, leaving only the accessory muscles

→ severe hypoventilation

• intercostal & abdominal paralysis results in significant reduction in pulmonary function ³ $\mathbf{T_7}$
• pulmonary oedema, ***DVT & PTE***, also contribute significantly to early mortality
• ***pulmonary oedema*** has been seen in up to 44% of patients following resuscitation from spinal shock
• this most likely results from over-enthusiastic volume resuscitation, and attempts to maintain a "normal" arterial BP

- ***Cardiovascular Complications***

1. ***acute changes***
   - in experimental SCI there is an abrupt, brief (2-3 min) increase in MAP, ? due to sympathoadrenal outflow
   - this is associated with significant increases in CBF/ICP, BBB permeability, extravascular lung water, CVP, PAP, PAOP, and CO
   - this supports the tendency for these patients to develop ***cerebral & pulmonary oedema*** early in resuscitation
   - rarely seen by the time of admission to a 3° centre

2. ***hypotension*** ≡ᵗ "neurogenic shock"
   - varying degrees of hypotension, bradycardia, decreased TPR, low-normal CVP and a normal or slightly elevated CO
   - decreased myocardial function, with ↓ LVSWI (~ 26%) and CI (~ 18%) in response to volume loading in patients for spinal stabilisation surgery
   - loss of the cardioaccelerator fibres (T_{1-4}) produces ***bradycardia***
   - ? the Bainbridge reflex (decreased RAP) may contribute as bradycardia is seen in below T_4 SCI
   - lesions ³ $\mathbf{T_1}$ leave only the Frank-Starling mechanism to increase contractility, and may produce a MAP < 40 mmHg
   - the b-***endorphin*** surge with SCI may also depress contractility by either a direct action on the heart, or by centrally mediated increases in parasympathetic tone
   - ***orthostatic reflexes*** are absent & positioning important
   - severe hypotension is observed above a ***critical level ~*** $\mathbf{T_{6-7}}$
   - this phase may last days to weeks but is usually ***less than*** the period of flaccid muscle paralysis
   - cautious addition of fluid is recommended in view of the decreased CVS reserve and tendency to ***oedema formation***
   - monitoring by PAOP is frequently indicated as the venous compliance curve is abrupt in the absence of resting tone

3. ***autonomic hyperreflexia***
   - this follows the phase of hypotension/flaccid paralysis in patients with ***lesions*** ³ $\mathbf{T_{6-7}}$, usually at 1-3 weeks
   - MAP returns to ~ normal or below, with episodes of severe hypertension in **~ 85%** of patients
   - triggered by common noxious stimuli, bladder or rectal distension, labour or surgical pain
   - this generalised response begins ***below*** the level of the lesion, due to the loss of control from the higher centres
   - it may spread above the lesion due to ***sympathetic divergence***
   - symptoms include nasal congestion, severe headache, dyspnoea and nausea
   - signs include pallor, sweating, intense somatic & visceral muscle contraction, & piloerection below the lesion
   - above the lesion there is flushing & severe hypertension with reflex bradycardia
   - SAH & retinal haemorrhages have been observed, with syncope, convulsions and death if unabated
   - management has included ganglionic blockers, catecholamine storage depletion, α-adrenergic blockade, and direct vasodilators
   - however the studies have been small & lacked controls
   - the main aim is to ***avoid*** known stimuli

4. ***arrhythmias & ECG abnormalities***
   - mid thoracic SCI results in sinus or nodal bradycardia ± PAC's, PVC's, AV dissociation, or ventricular tachyarrhythmias
   - ***atropine*** is usually effective for bradyarrhythmias, which are frequently seen with airway manipulations
   - b-***blockers*** may be useful for ventricular tachyarrhythmias
   - the ECG frequently shows LV strain ± subendocardial ischaemia
   - similar arrhythmias are seen in ~ 75% of autonomic hyperreflexic episodes

- ***Other Systems***

1. ***genitourinary***
   - ARF may occur 2° to hypotension, dehydration, sepsis, nephrotoxic drugs, acute obstruction, associated renal trauma, or other factors
   - in the chronic phase of SCI, renal failure accounts for ~ **20-75%** of mortality
2. ***disordered thermoregulation***
   - afferent information to the hypothalamus may be interrupted
   - sympathetic denervation causes heat loss
   - inability to shiver reduces heat production
   - general tendency to become ***poikilothermic***
3. ***fluid & electrolytes***
   - chronic SCI patients tend to be ***hypovolaemic & anaemic***
   - hypercalcaemia and hypercalcuria follow immobilisation, especially in young male patients (peak ~ 10/52 post-SCI)
4. ***gastrointestinal complications***
   - ~ 20% of SCI patients develop ***GIT bleeding*** acutely
   - nonspecific liver dysfunction with a normal bilirubin occurs commonly
   - gastric distension & ileus are common
   - increased risk of regurgitation / ***aspiration***
5. ***suxamethonium hyperkalaemia***
   - may be seen as early as **3 days**
   - the magnitude of the rise is more a function of the muscle mass affected than the amount of drug given
   - the underlying overgrowth of receptors may occur well ***before*** spasticity replaces flaccid paralysis
   - pretreatment with a nondepolarising agent ***does not*** reliably prevent the occurrence of significant hyperkalaemia

Management

• between **25-65%** of SCI patients have associated problems, most commonly,

1. head injury
2. thoracic trauma
3. abdominal trauma
4. major skeletal trauma

• these may compromise respiratory or circulatory function coincident with spinal shock and require a high index of suspicion
• during the acute phase, maintenance of "normal" acid-base & blood gas parameters and adequate cord perfusion are paramount
• experimental animal work has shown ***no advantage*** in either hypercapnia or hypocapnia in neurological recovery or histological tissue damage
• although not statistically significant, there is some date to suggest hypercapnia is more harmful than hypocapnia
• therefore, should aim for a P_{aCO2} ~ 35-40 mmHg and ***hypoxaemia*** should be avoided at all costs
• ***contributing factors*** such must be suspected and managed accordingly,

1. pulmonary contusion
2. pneumothorax, haemothorax
3. pulmonary embolism (fat or thrombus)
4. foreign body
5. gastric aspiration
6. non-cardiogenic pulmonary oedema

• similar to the findings for CNS ischaemia, an elevated ***plasma glucose*** has been shown to be deleterious upon neurological outcome
• mild to moderate increases of BSL ≤ 2.5 mmol/l, tripled the incidence of paraplegia in rabbits following aortic occlusion
• notably there was a ***lack of correlation*** between the degree of BSL rise and the extent of neurological injury
• therefore, as for head injury, the administration of dextrose containing fluids should be restricted to proven hypoglycaemia
• the present data are insufficient to recommend active reduction of an elevated plasma glucose

• Cole (1989) looked at various anaesthetic techniques following SCI in the rat
• of the techniques studied, halothane, fentanyl, N_2O, and SA lignocaine, ***all*** increased the duration of ischaemia required to produce SCI
• no one technique was superior in terms of final ***neurological outcome***

THERMAL INJURIES

- ***Management***

1. airway compromise
   - clinical indications of inhalation injury,
   i. facial & neck burns
   ii. singeing of the eyebrows, eyelashes or nasal hair
   iii. carbon deposits /inflammatory changes in oropharynx
   iv. carbonaceous sputum
   v. history of impaired mentation
   vi. fire in an enclosed environment
   vii. arterial COHb level
   - any suggestion of significant airway injury supports early intubation & ventilation
2. ongoing burning
   - remove all clothing
   - cool burnt area with body temperature saline
3. estimate surface area & depth of burn
4. IV access
   - upper limbs preferrable due to high incidence of saphenous phlebitis
   - Brook → Hartmann's @ 4 ml/kg/%burn in first 24 hrs
     give half in first 8 hrs, remainder over 16 hrs
     in addition to usual fluid requirements
     *starting from the time of injury, not assessment
   - all patients with > 20% burn require immediate IV access & IVT replacement
   - formulas are ***guides***, ∴ regular assessment of patient essential
   - hourly urine output probably best guide in otherwise healthy patients
5. baseline investigation
   i. blood - FBE, XMatch, AGA's/COHb, EC&U
   ii. CXR
6. analgesia
7. wound care
   - do not open blisters to apply antiseptic
   - avoid extensive use of cold soaks
   - apply clean dressings to painful second degree burns
8. antibiotics
   - ***not indicated*** in the early post-burn period
9. tetanus prophylaxis
10. oral fluids
    - no contraindication with small burns < 10%

Circumferential Burns

- the salient point in maintenance of the ***peripheral circulation***

1. remove rings & bracelets
2. assess status of peripheral circulation
   - cyanosis, impeired capillary refill
   - progressive neurological signs
   - doppler ultrasound
3. escharotomy
   - theoretically can be done in ED without anaesthesia, but there would seem little justification for this
   - incision must be entire length of eschar
   - consider bilateral midaxillary escharotomy for circumferential thoracic burns
   - fasciotomy is seldom required unless complicated injury or electrical burn

Chemical Burns

- alkali burns are generally more serious as alkalis penetrate tissue more deeply
- factors determining severity include,

1. duration of contact
2. concentration of agent
3. amount of agent / area of contact

- main principal of management is copious irrigation

Electrical Burns

1. high tension / lightning injuries
   - tissue thermal injury/necrosis $\propto$ ***Joule's Law***: Heat $\propto I^2 \times W$
   - electrical flash burns and flame burns 2° to clothing ignition
2. electrocution
   - disruption of normal physiological function
   - tissue thermal injury

- frequently more serious than appear externally
- muscle, nerve & blood vessels may be destroyed with sparing of the skin due to its high resistance
- ***rhabdomyolysis*** may be severe enough to result in acute renal failure, ∴ require aggressive fluid resuscitation of evidence of pigmenturia
- ***fasciotomy*** may be required for compartmental syndrome

- ***Burns Unit Transfer Criteria***

1. partial thickness burns > 20%
2. partial thickness burns > 10%
   + ages > 50 yrs or < 10 yrs
3. full thickness burns > 5%
4. partial / full thickness burns involving,
   i. face, eyes, ears
   ii. hands, feet, major joint
   iii. genitalia, perineum
5. electrical burns / lightening burns
6. chemical burns
7. complicated injuries, ie. fractures, where the major risk of morbidity is from the burn
8. inhalational burns
9. lesser burns in patients with significant pre-existing disease

Cold Injury

- ***Classification***

1. frostbite
   i. first degree - hyperaemia & skin oedema without necrosis
   ii. second degree - partial thickness necrosis with vesicle formation
   iii. third degree - full thickness skin, plus some underlying tissue necrosis
   iv. fourth degree - full thickness skin, muscle & bone with gangrene
2. nonfreezing injury
   - due to microvascular endothelial injury, with stasis & vascular occlusion
     eg., "trench foot", "immersion foot"
3. hypothermia
   - states with a core temperature < 35°C
   - see notes on hypothermia

HYPOTHERMIA

Def'n: ***core temperature* < 35°C**
homeotherms and regulate core temperature ~ 36-37.5°C (T.Oh)
~ 37 ± 0.4°C (RDM)

1. mild > 33°C
2. severe < 33°C

NB: demarcation is arbitrary, but effects more pronounced & ***loss of compensation***

- ***Aetiology***

a. extremes of ***age***

b. debilitating ***illness***
   - i. CNS - CVA, head injury, neoplasm
     - progressive mental deterioration
   - ii. CVS - CCF, MI, PVD, PTE
   - iii. infections - septicaemia, pneumonia
   - iv. renal - uraemia

c. ***exposure*** - environment
   - IV fluids
   - irrigating fluids

d. ***drugs*** - alcohol, GA, vasodilators
   - antipyretics
   - chlorpromazine

e. ***endocrine*** - hypothyroidism
   - panhypopituitarism
   - Addisonian crisis, hypoglycaemia
   - diabetes, hyperosmolar coma, ketoacidosis (~ 20%)
   - protein / calorie malnutrition

f. ***spinal cord trauma***

g. ***skin diseases*** - psoriasis, icthyosis, erythroderma

h. ***iatrogenic*** - induced hypothermia & inadequate rewarming

Clinical Effects

- ***Cardiovascular***

1. ↑ sympathetic tone - ↑ plasma NA/AD and FFA's
2. initially → vasoconstriction, tachycardia & increased CO
   later → bradycardia, hypotension & decreased CO
3. cardiac output - ↓ CO ~ 30-40% at 30°C ∝ ↓ VO_2
   - mainly 2° to ***bradycardia***, SV well preserved
   - coronary perfusion well maintained
4. ECG changes - exacerbated by ***acidosis & hyperkalaemia***
   i. bradycardia
   ii. prolonged PR, QRS, QT duration
   iii. J point elevation ~ 33°C
   iv. AF ~ 25-34°C (commonest arrhythmia)
   v. AV block 1° ~ 30°C
   3° ~ 25°
   vi. VF ~ **28°C**
   vii. asystole ~ 20°C
5. CPK & LDH levels are elevated
   - ? leakage from cells or microinfarction

- ***Central Nervous System***

- reasonably well preserved to 33°C, below this function deteriorates progressively,

1. initial confusion → coma ≤ 30°C with pupillary ***dilatation***
2. ↓ CBF ∝ ↓ $CMRO_2$ ~ **6-7% / °C**
   ~ similar change cf. whole body VO_2
3. progressive brainstem depression → ↓ HR & ↓ RR
4. ↓ ***temperature regulation*** →
   - ↓ shivering ≤ 33°C
   - loss of T control ≤ 28°C
5. cerebral protection
   - over and above metabolic depression
   - deep circulatory arrest
   - recovery from near drowning

- ***Pulmonary Changes***

1. central depression → ↓ RR ≤ 33°C
   ~ 4 bpm ± respiratory arrest at 25°C
2. impaired cough & gag reflexes → ***aspiration risk***
3. reduced CO_2 drive
4. ***no change*** in hypoxic drive
5. impaired hypoxic pulmonary vasoconstriction
6. ↓ FRC, increased atelectasis
7. ↓ gaseous diffusion capacity
8. ↑ VO_2 with ***shivering*** → ↓ VO_2 ≤ 33°C
9. ↓ O_2 availability ∝ ↑ HbO_2 affinity
10. increased ***gas solubility***
    i. ↑ αCO_2 / ↓ P_{aCO2} → ↑ pH
    ii. anaesthetic gases → ↓ rate of rise of F_A/F_I & elimination
    - halothane $MAC_{27°C}$ ~ 50% $MAC_{37°C}$

- ***Metabolic***

1. ↓ VO_2 ~ 6-7% / °C
2. severe ***acidosis*** → HbO_2 curve shifts to the ***right***
   i. respiratory ↓ CO_2 elimination due to hypoventilation
   ii. metabolic ↓ tissue perfusion
   ↓ hepatic lactate clearance
   ↓ renal tubular H^+ excretion
   iii. temperature correction of blood gas values offer ***no advantage*** in management
   → δ pH ~ -0.0147/°C
3. ***hyperkalaemia / hypokalaemia***
   • causes for expected rise in K^+
   i. decreased activity Na^+/K^+-ATPase → ↓Na^+ / ↑K^+
   ii. cellular hypoxia, membrane damage & acidosis
   • however, hypokalaemia more commonly observed
   i. ? 2° diuresis
   ii. ICF shift
4. ***hyperglycaemia*** - ↓ insulin secretion & ↓ peripheral glucose utilisation
   - ? mild pancreatitis
   - hypoglycaemia may ensue in longstanding hypothermia
5. ↑ drug $t_{½\beta}$ ∝ ↓ hepatic blood flow & enzyme reaction rates
   → ***heparin, citrate & lactate***

- ***Renal***

1. ↓ GFR ∝ ↓ renal blood flow ~ 50% at 30°C
   → ↓ drug clearance
2. ↓ tubular function
   i. cold diuresis - volume of urine initially increased or the same
   ii. hypoosmolar urine
   iii. glycosuria, kaluria → additional diuresis

- ***Neuromuscular Junction***

1. shivering occurs ~ 33-36°C
2. increased muscle tone → ***myoclonus*** ~ 26°C
3. increased sensitivity to ***both*** depolarising & nondepolarising with mild hypothermia

- ***Haematological***

1. ***coagulopathy***
   i. ↓ coagulation ↓ enzyme activity
   ii. thrombocytopaenia ↑ portal platelet sequestration
   ↑ bleeding time
2. increased blood ***viscosity*** - haemoconcentration
   - ↓ microcirculatory blood flow
3. ***immunoparesis*** - ↓ WCC & function
4. marrow hypoplasia

- ***Immunological***

1. ↓ neutrophils, phagocytes, migration, bactericidal activity
2. organ hypoperfusion & increased infection risk
3. diminished gag/cough reflexes
4. atelectasis

Regulation of Body Temperature

NB: balance between heat production and heat loss

a. heat production / gain
   i. basal VO_2
   ii. SDA of food
   iii. muscular activity
   iv. non-shivering thermogenesis
   v. gain from the environment

b. heat loss
   i. radiation ~ 40%
   ii. convection ~ 30%
   iii. evaporation ~ 29%
   iv. conduction, feces/urine ~ 1%

NB: respiratory losses ~ 10%

   i. humidification ~ 8%
   ii. convection ~ 2%

- ***Sensory Systems***

a. cutaneous thermoreceptors ~ 15% of input
   i. cold receptors < 24°C
   ii. heat receptors > 44°C

b. deep/core thermoreceptors **~ 85%** of input
   i. anterior hypothalamus
   ii. spinal cord
   iii. hollow viscera

- ***Central Integration***

• some processing in the spinal cord, majority in the ***posterior hypothalamus***
• "central thermostat" regulated by,

1. diurnal rhythm, age, sex, hormones
2. endogenous pyrogens
3. drugs
4. neurotransmitters (? 5HT)
5. exercise

- ***Effector Systems***

1. higher control centres
   - i. posture, avoidance behaviour
   - ii. apetite/hunger
   - iii. clothing
   - iv. level of activity → voluntary muscle metabolism
     ↑ VO_2 ≤ 10x with exercise
2. ***cutaneous blood flow***
   - first line of defence activated against heat loss
   - especially the extremities, cf. normal may decrease
   - i. skin blood flow ~ 5%
   - ii. heat loss to ~ **12%**
3. ***shivering thermogenesis***
   - involuntary incoordinate muscular activity ~ 50 Hz
   - may ↑ VO_2 ~ 2-5x
   - may ↑ core temperature ~ 2-3°C/hr
   - requires ↑ VO_2 ~ 100% / ↑1°C
4. ***nonshivering thermogenesis***
   - increased combustion of FFA's and glucose, regulated by,
   - i. sympathoadrenal outflow → fast response - noradrenaline
   - ii. thyroid function → slow response - adrenaline & T_4
   - liver and skeletal muscles in adults ~ 25% ↑ VO_2
   - ***brown fat*** in neonates ~ 100% ↑ VO_2
     ~ 25% of total CO
5. ***sweating***
   - direct or reflex stimulation of the spinal cord, medulla, hypothalamus or cortex
   - provides only coarse control of temperature
6. horripilation / piloerection - minimal effects in man cf. animals

NB: usually order of activation,

- i. behavioural modification
- ii. vasoconstriction
- iii. nonshivering thermogenesis
- iv. shivering thermogenesis

Effects of Anaesthesia

- ***Unintentional Hypothermia***

1. ↓ heat ***production***
   - i. ↓ VO_2 ~ 25-30%
     ~ 1 kcal/kg/hr
   - ii. ↓ muscular activity & shivering
2. ↑ heat ***losses***
   - i. ↑ radiation / convection - undressed in cold theatre
     - large surgical incisions
   - ii. ↑ evaporation - cold preparation solutions
     - from the wound
     - cold/dry anaesthetic gases
     - bypassing of upper airway
   - iii. ↑ conduction
     - cold IV solutions - 1 kcal/°C/l → ~ 17 kcal / 1000ml / 20-37°C
       ~ 1% of BMR
     - cold table (minimal) & wet drapes
3. inhibition of ***thermoregulation***
   - i. ↓ hypothalamic set point
   - ii. inhibition of effector responses
     - vasoconstriction & NST only means of heat gain available
     - GA → vasodilatation & redistribution of heat
       decreased core-shell gradient
       responsible for the initial rapid fall ~ 0.5-1.5°C
     - RA → similar initial loss of core-peripheral gradient
       central regulation preserved
       this ***is*** the origin of ***shivering*** with epidural blockade (?? not spinal)
4. ***at risk*** groups
   - i. neonates - high SA:V ratio, immature thermoregulation, no shivering
   - ii. elderly - low BMR, ↓ body mass
   - iii. prolonged procedures
   - iv. large central incisions
   - v. burns
   - vi. trauma patients, large volume transfusions/blood loss
   - vii. ↓ metabolism - adrenal insufficiency, hypothyroidism, hypopituitarism

- ***Perioperative Effects***

1. protection against CNS ischaemia, even with mild hypothermia (*Sano et al.* 1992)
2. metabolic
   - acidosis, hyperkalaemia
   - decreased drug metabolism
3. haematological
   - ↑ viscosity, ↓ O_2 delivery & tissue hypoxaemia
   - impaired coagulation
4. CVS
   - ↓ CO & arrhythmias (*AF)
5. postoperative problems
   i. shivering
      - ↑ VO_2 & hypoxia if borderline lung function
   ii. marked vasoconstriction
      - decreased microvascular flow
      ? graft survival & wound infection
      - haemodynamic instability on rewarming
   iii. impaired drug clearance
   iv. impaired immune function
      - predisposes to ***wound infection***
   v. impaired conscious level

- ***Intraoperative Management***

1. ↑ ambient temperature
   i. adults under cover ~ 21°C
   ii. neonates ≤ 26°C
2. radiant warmers
   - mainly useful in children (higher SA:V ratio)
   - limited by access
   - potential for burns
3. drapes / coverings
   ↓ radiant & convective losses
   - ***area*** more important than type, but must remain ***dry***
   - losses from the head important in neonates/bald adults
   * forced air convective warmers most effective means
4. warming blankets
   - most effective ***above*** patient, minimal losses to table
   - useful when patient < 10 kg
5. respiratory losses
   < 10% losses through the respiratory tract
   i. heat & moisture exchangers prevent most of this loss
   ii. heater humidifiers will prevent all of this loss
      - however, in adults are ***unable*** to significantly raise body heat content
      - studies showing otherwise actually looking at oesophageal probe changes
   iii. heater humidifiers rarely, if ever, indicated in adults
6. blood / IV warmers
   - especially large volumes given rapidly

- ***Monitoring During Anaesthesia***

  a. central - lower oesophageal & PA → heart
     - tympanic membrane → brain

  b. rectal - intermediate
     - changes lag behind core/shell during cooling & warming

  c. shell - skin/peripheral
     - may estimate vasoconstrictor/vasodilator responses

  NB: useful to measure both core & shell,
  core-shell gradient → better assessment of overall body temperature
  → adequacy of rewarming & predicts "afterdrop"

Deliberate Hypothermia

- ***Surface Cooling***

• principally historical interest, main use currently is in the management of ***malignant hyperthermia***, or severe hyperthermia in septic ICU patients
• cold environment, ice bathing, especially groins & axillae
• problems of slow & uneven effects both during cooling and rewarming,

  a. 2-6°C ***afterdrop*** when cooling / rewarming

  b. ***uneven*** effects mean some tissues are still "at risk" for ischaemia

- ***Cardiopulmonary Bypass***

  a. more rapid & even cooling / rewarming

  b. more precise temperature regulation

  c. maintenance of ***tissue perfusion*** despite ↓ CO / arrest

  d. combined with ***haemodilution***
     i. offsets the effects on viscosity
     ii. "optimal Hct." ~ 18-22%

- ***Deep Hypothermia & Total Circulatory Arrest***

  a. allows operation on still & bloodless heart

  b. principally for correction of complex CHD

  c. current operative times ~ 50-60 minutes at 18-20°C

  d. need for more thorough longterm outcome studies on CNS effects

PAEDIATRIC TRAUMA

- ratio of blunt:penetrating trauma highest for paediatric group
- MVA's and falls account for ~ 80% of trauma
- ***multisystem*** injury is the rule, rather than the exception

Unique Characteristics

1. smaller size - greater force per unit area
2. skeletal immaturity
   - soft bones with active growth centres can absorb large amount of energy without fracture
   - higher incidence of internal organ damage without overlying fracture
   - includes spinal column → SCIWORA
   - open sutures < 18 months
3. surface area
   - thermal energy loss higher
   - absorption of toxins higher
   - systemic effects of burns greater
4. GCS modified for age
5. higher incidence of
   i. seizure activity
   ii. mass lesions
   iii. white matter tears - frontal and temporal lobes
   - especially infants < 6 months
   iv. subdural haematomas - especially NAI
6. major blood loss with ***hypotension*** may be ***concealed***
7. IV access often more difficult
8. acute gastric distension → NG tube
9. psychological immatuirty
10. long-term effects
    - growth & deformity
11. equipment
    - specific equipment required → size for age
    - ***not*** small adults

Shock

a. normal blood volume ~ 80 ml/kg

b. estimated weight
   i. < 9 years ~ (2 x age) + 9
   ii. > 9 years ~ 3 x age

c. systolic arterial pressure ~ 80 + (2 x age)
   • cuff width 2/3 upper arm

Vital Signs			
	HR	SAP	RR
Infant	160	80	40
Preschool	140	90	30
Adolescent	120	100	20

Response to Blood-Loss			
	BL < 25%	BL 25-40%	BL > 40%
CVS	• ↑ HR • weak pulse	• ↑ HR • BP drop with tilting	• frank hypotension • ↑ or ↓ HR
CNS	• lethargic, irritable • confused, combative	• ↓ LOC • diminshed response to pain	• comatose
Skin	• cold, clammy • mottled	• cyanotic • ↓ capillary refill	• pale, cold
Renal	• ↓ urine output • high SG	• minimal urine output	• no urine

• initial fluid challenge ~ **20 ml/kg**, or 25% blood volume, for colloid, 3x for crystalloid
• if remain unstable, then give 10 ml/kg P-RBCs
• most common acid-base abnormality is ***respiratory acidosis***, correctable by adequate ventilation
• sites for emergency IV acces,

1. intra-osseus tibial needle
2. median antecubital vein
3. long saphenous at ankle
4. CVC - IJV or subclavian

- ***Chest Trauma***

a. majority blunt

b. underlying ***pulmonary contusion*** / haemorrhage most common significant injury

c. tension pneumothorax / haemothorax are less common cf adults, but may be rapidly lethal if unrecognised

d. injuries relatively rare in paaediatric group,
   i. fractures ribs
   ii. diaphragmatic rupture
   iii. injury to great vessels

- ***Abdominal Trauma***

NB: all should have stomach decompressed by oro/nasograstric tube

a. high incidence of visceral injury

b. more difficult to assess cf adults

c. limited role for DPL → ***CT scan***
   - CT must be - immediately available
     - not delay diagnostic algorithm
     - suit must have resuscitation facitlity

d. majority of solid visceral injuries are managed ***conservatively***
   - but require adequate observation

e. indications for operating on spleen/liver trauma,
   i. failure to respond to resuscitation
   ii. continued major haemorrhage > 40 ml/kg/24 hrs
   iii. suspicion of associated hollow visceral injury
   iv. severe concomitant HI, where haemodynamic instability is deleterious

f. many liver/spleen injuries can be repaired, rarely perform ***splenectomy***

- ***Extremity Trauma***

a. presence of growth plates makes assessment difficult
   - XRay of the opposite limb often useful

b. blood-loss associated with long-bone & pelvic fractures is proportionately more significant

c. ***physeal*** fractures classified by Salter-Harris
   i. type I - linear through growth plate
   ii. type II - cf. type I, plus small chip of metaphysis
   iii. type III - through growth plate & epiphysis
   iv. type IV - through both metaphysis & epiphysis
   v. type V - compression fractures
   - types I & II have best prognosis for normal growth
   - type V has worst prognosis & difficult to spot on XRay

d. greenstick fracture - fracture of cortex only
   - most require reduction

e. buckle fracture - angulation without cortical fracture

f. supracondylar fracture
   - high propensity for neurovascular injury
   - high incidence of growth deformity

- ***Head Trauma***

a. children < 3 years have worse outcomes following severe HI
   - cf. older children who generally recover better than adults

b. small children may develop hypovolaemic shock 2° head injury alone, or associated scalp laceration

c. children < 18 months with open sutures have increased tolerance of expanding intracranial masses
   - check for fontanelle bulging and suture diastasis

d. vomiting is a common response to injury and may, or may not, equal raised ICP

e. seizures occurring shortly after injury are usually self-limiting
   - recurrent seizures require Ix & Rx

f. focal lesions are less common

g. generalised oedema and raised ICP is more common

h. GCS, verbal score modified for age,

i.	appropriate words social smile fixes and follows	=	5
ii.	cries but consolable	=	4
iii.	persistently irritable	=	3
iv.	restless, agitated	=	2
v.	none	=	1

i. indications for ICP monitoring in children

i. GCS < 5, or motor scores < 3

ii. where raised ICP is known, or likely to develop, and signs are masked by neuromuscular paralysis

iii. multiple associated injuries, where CT scanning delayed

- ICP monitoring/management ***does not*** improve outcome in global ischaemic events
- near-drowning victims with ↑ ICP / ↓ CPP have poor prognosis, and maintenance of 'normal' ICP does not correlate with outcome

j. child drug doses

i.	diazepam	~ 0.25 mk/kg
ii.	phenytoin	~ 15-20 mg/kg
iii.	mannitol	~ 0.5-1.0 g/kg

▪ ***Spinal Trauma***

- paediatric spinal trauma is relatively rare → ~ 5% of all spinal injuries
- of children with severe trauma ~ 5% will have a cervical spine injury
- injuries will occur at more than one spinal level in ~ 16% of cases
- the commonest causes are,

a. road trauma - MVA, pedestrian, cyclist

b. falls - especially diving

- anatomical differences include,

a. interspinous ligaments & joint capsules are more flexible

b. uncinate articulations are poorly developed & slide forward

c. the facet joints are flat

d. the vertebral bodies are wedged anteriorly & slide forward with flexion

e. the head is relatively large
→ greater angular momentum can be generated with flexion / extension

• normal radiological variations include,

a. anterior displacement of C_2 on C_3 →
   i. ~ 40% of children < 7 yrs
   ii. ~ 20% of children ≤ 16 yrs
   iii. ± ≥ 3mm movement on flexion/extension
b. increased distance between the dens and anterior arch of C_1 ~ 20% of children
c. skeletal ***growth centres*** may resemble fractures
d. basilar ***odontoid synchondrosis*** appears as a radiolucent line at the base of the dens (especially ≤ 5 years)

• spinal cord injury without radiographic abnormality, ***SCIWORA*** is almost unique to the paediatric age group

~ **20-60%** of all SCI
~ 30-50% of these the lesion is complete

• SCI in the first decade of life is,

a. almost exclusively at $C_{1/2}$
b. either subluxation or SCIWORA and severe cord injury
c. rarely associated with fractures

• a high proportion of children who die in MVA's, or suffer cardiorespiratory arrest prior to reaching hospital have cord trauma above C_3, particularly at the ***cervico-medullary junction***
• this is difficult to diagnose in the unconscious patient, signs including,

a. flaccid immobility & areflexia
b. hypoventilation with paradoxical chest movement
c. apnoea and rhythmic flaring of the alae nasi (above C_3)
d. hypotension with - inappropriate bradycardia
   - peripheral vasodilatation
   ± priapism

▪ ***Spinal Shock***

• the syndrome of spinal shock occurs more commonly in children,

a. SCI lesion resolves after 2-3 days
b. progressive return of reflexes - bulbocavernous & anal first
c. incomplete lesions may then become apparent
   i. Brown-Sequard hemisection
   ii. anterior cord lesion
   iii. central cord lesion

Non-Accidental Injury

a. physical
b. sexual and emotional abuse
c. deprivation of medical care and nutrition

- children are also intentionally poisoned, and endure the consequences of inadequate supervision
- diagnosis of children who suffer from abuse or neglect is difficult
- NAI should be suspected where,

a. an injury is unexplained
b. the history is not consistent with the type of injury
c. it is alleged that the injury was self-inflicted
d. relatives delay in seeking medical aid
e. there are repeated suspicious injuries

- the history is rarely volunteered by the child
- the pattern of physical findings can be helpful,

a. head injury - skull fractures
- subdural haematomas
b. ***retinal haemorrhages*** occur with head shaking, but also have other causes
c. bruises and scars on the back and buttocks in different stages of development and of unusual shapes
d. burns from cigarettes or forced immersion in hot water
e. overt bone fractures or ***healing fractures***
f. long-bone fractures in children < 3 years
g. injury to genital or perianal areas

- when non-accidental injury is suspected, referral to a specialised child protection unit to enable appropriate counselling and intervention is helpful
- safety of siblings must be considered