PAEDIATRIC TRAUMA

Trauma results in *half of all deaths* in children aged 1 to 14 years...

The most common single organ system injury associated with death in injured children is *head trauma.* Multiple injuries are common in children.

Principles of Disease.

There are major anatomic & physiologic differences between paediatric & adult patients that play a significant role in evaluation and management of the paediatric trauma patient.

Table 35-1 Anatomic Differences in the Pediatric Airway—Implications in Pediatric Trauma Management

DIFFERENCES	IMPLICATIONS
Increased vagal response to laryngoscopy	Bradycardia during intubation; in infants and small children may be abated through the use of glycopyrrolate or atropine
Relatively larger tongue	Most common cause of airway obstruction in children May necessitate better head positioning or use of airway adjunct (oropharyngeal or nasopharyngeal airway)
Larger mass of adenoidal tissues may make nasotracheal intubation more difficult	Nasopharyngeal airways may also be more difficult to pass in infants
Epiglottis floppy and more U shaped	Necessitates use of a straight blade in young children
Larynx more cephalad and anterior	More difficult to visualize the cords; may need to get lower than the patient and look up at 45-degree angle or greater while intubating
Cricoid ring the narrowest portion of the airway	Allows for use of uncuffed tubes in children up to size 6 mm or approximately 8 years old Can use cuffed tube with or without balloon blown up; cuffed tube size typically (age/4) + 3
Narrow tracheal diameter and distance between the rings, making tracheostomy more difficult	Needle cricothyrotomy for the difficult airway versus a surgical cricothyrotomy for the same reason
Shorter tracheal length (4–5 cm in newborns and 7–8 cm in 18-month-olds)	Leads to intubation of right mainstem or dislodgment of the endotracheal tube Ensure tube position is checked before taping with head in neutral position or it can be driven into the right mainstem when the head is flexed or withdrawn when the head is extended to get to neutral
Large airways more narrow	Leads to greater airway resistance (R proportional to $1/\text{radius}^4$)

BOX 35-1 ANATOMIC DIFFERENCES IN ADULTS AND CHILDREN: IMPLICATIONS FOR PEDIATRIC TRAUMA MANAGEMENT

The child's body size allows for a greater distribution of traumatic injuries, so multiple trauma is common.
The child's greater relative body surface area causes greater heat loss.
The child's internal organs are more susceptible to injury based on more anterior placement of liver and spleen and less protective musculature and subcutaneous tissue mass.
The child's kidney is less well protected and more mobile, making it susceptible to deceleration injury.
Fifteen percent of pediatric patients presenting with hematuria after trauma have underlying congenital abnormalities.
Growth plates are not yet closed in pediatric patients, leading to Salter-type fractures with possible limb-length resultant abnormalities.
The child's head-to-body ratio is greater, the brain is less myelinated, and cranial bones are thinner, resulting in more serious head injury.

Any given force to a child is more widely distributed through the body of the child making multiple injuries significantly more likely to occur.

Oxygen extraction & consumption (as well as glucose utilisation) is higher per kg in infants & small children.

Children have a great capacity to maintain blood pressure despite significant acute blood losses (always pay attention to HR and RR, as a marker for shock).

Children are primarily diaphragmatic breathers.

Clinical Features.

The highest priority in the approach to the injured child is ruling out the presence of life-threatening or limb-threatening injury. This initial assessment (the primary survey) and necessary initial resuscitation efforts must occur simultaneously.

A - AIRWAY & C.SPINE STABILISATION.

There are multiple anatomic considerations (& implications) in the management of the paediatric airway (*see above)*.

Assess for possible airway obstructions including injury, bleeding, teeth, constriction or vomitus.

Whilst stabilising the C-spine, the airway is opened with jaw-thrust.

Any complaint of previous/current neurological deficit, neck pain or significant head/chest/abdo trauma or other spinal level should raise concern for a C-spine injury.

Table 35-2 Airway: Assessment and Treatment

ASSESSMENT PRIORITIES	INTERVENTIONS
Airway patency	Jaw thrust, suction, airway adjuncts Stabilize/remove loose teeth or other foreign bodies
Level of consciousness	Cervical spine immobilization
Maxillofacial injury	Apply 100% O_2 by mask Monitor patient closely for emesis
Stridor or cyanosis	Intubate for Glasgow Coma Scale ≤8 or absent gag reflex in a patient with a clinically concerning head injury or $Po_2 < 50$ mm Hg or $Pco_2 > 50$ mm Hg Needle cricothyrotomy if intubation impossible and cannot oxygenate and ventilate by bag-valve-mask until successful airway control by alternative method or provider

Table 35-3 Breathing: Assessment and Treatment

ASSESSMENT PRIORITIES	INTERVENTIONS
Respiratory rate	100% O_2 by nonrebreather mask or intubate if in respiratory failure; fast rates may indicate shock (fluid resuscitation) or pain (parenteral analgesics).
Chest wall movements	For significant pneumothorax or hemothorax: Place chest tube. Small pneumothorax in a patient spontaneously breathing may only require close monitoring and/or oxygen washout. Transfer to operating room if initial drainage >20 cc/kg or subsequent output >2 mL/kg/hr.
Percussion	Open pneumothorax: Seal with three-sided occlusive dressing (Vaseline gauze) followed by tube thoracostomy and then seal remaining side of occlusive dressing.
Paradoxical breathing	Contusion/flail chest: Intubate if tachypneic or $Po_2 < 50$ mm Hg or $Pco_2 > 50$ mm Hg.
Tracheal deviation	Tension pneumothorax: Needle decompression at second intercostal space, midclavicular line, followed by placement of chest tube unless chest tube incision can be immediately placed, negating the necessity of needle decompression.
Flail segments	O_2 by nonrebreather mask or intubate if in respiratory failure.
Open wounds	Compress bleeding sites and cover as indicated. Consider use of hemostatic dressing.

B - BREATHING & VENTILATION.

Assess for adequacy of chest rise (lower chest & upper abdomen, moving concordantly). Discordance suggests impending respiratory failure.

Careful assistance with BVM (avoidance of gastric insufflation). Placement of an NGT will be of benefit (use topical anaesthetics if conscious).

Indications for intubation include;
1. inability to ventilate w/ BVM or need for prolonged control of airway
2. GCS <9, avoidance of secondary brain injury and allowance of hyperventilation.
3. respiratory failure w/ hypoxaemia (flail chest or pulmonary contusion) or hypoventilation.
4. presence of decompensated shock

C - CIRCULATION & HAEMORRHAGE CONTROL.

Shock is a state of inadequate tissue perfusion. Maintenance of systolic BP does not ensure avoidance of shock.

The paediatric vasculature has incredible ability to increase SVR in attempt to maintain perfusion. Do not be reassured by 'normal' blood pressure.

Look for cool distal extremities, reduced peripheral cap refill.

Altered mental state can be a sign of either/or circulatory or respiratory failure.

Table 35-4 Circulation: Assessment and Treatment

ASSESSMENT PRIORITIES	INTERVENTIONS
Capillary refill	Oximeter and cardiac monitor, O_2 and fluid resuscitation 20 mL/kg. Consider intubation and ventilation to decrease workup breathing.
Heart rate	Monitor vital signs every 5 min.
Peripheral pulses	Two large-bore intravenous sites (above and below diaphragm when indicated).
Sensorium	Bolus with 20 mL/kg lactated Ringer's or normal saline solution (warm all intravenous fluids).
Pulse pressure increase	Repeat fluid bolus two times if necessary.
Skin condition/perfusion	Packed red blood cells, 10–20 mL/kg for decompensated shock secondary to blood loss.

D - DISABILITY ASSESSMENT.

Table 35-5 Disability: Assessment and Treatment

ASSESSMENT PRIORITIES	INTERVENTIONS
Level of consciousness	Maintain blood pressure and oxygenation and ventilation.
AVPU scale or GCS	If head injury with GCS <9: RSI and intubate; head computed tomography, neurosurgical consult. If normotensive, consider mannitol 0.25–0.5 g/kg. Maintain CO_2 at approximately 35 mm Hg. Maintain cerebral perfusion pressure of at least 50 mm Hg in children and 70 mm Hg in adults.
Pupil size and reactivity	Hyperventilate: P_{CO_2} to 30–35 mm Hg with signs of herniation. Consider alternative causes of pupillary dilatation, such as traumatic mydriasis or drug effect from atropine.
Extremity movement and tone	Stabilize spinal column. If blunt cord trauma, consider methylprednisolone sodium succinate (Solu-Medrol) 30 mg/kg IV bolus, then 5.4 mg/kg/hr for 23 hr IV.
Posturing	Hyperventilate: P_{CO_2} to 30–35 mm Hg.
Reflexes	Assess for signs of respiratory failure/ bulbocavernosus reflex or anal wink for spinal injury "completeness."

E - EXPOSURE & THOROUGH EXAMINATION.

Table 35-7 Exposure: Assessment and Treatment

ASSESSMENT PRIORITIES	INTERVENTIONS
Undress	Trauma examination, including rectal examination when indicated.
Look under collar and splints	
Log roll and examine back	Remove from board when not contraindicated.
Radiology	Consider cervical spine, chest, and pelvis radiographs.
Laboratory	Complete blood cell count, type and crossmatch, amylase, urinalysis, urine pregnancy test.
Interventions	Place urinary catheter and nasogastric or orogastric tube as indicated.
Immunization	Appropriate tetanus vaccine if indicated. Consider tetanus immune globulin in appropriate cases.
Pelvic fracture	Consider binding pelvis to decrease pelvic volume and improve hemostasis.

During the exposure and further examination, it is crucial to maintain normothermia & as soon as able; increase ambient temperature, apply warm blankets, humidified O_2, head wraps etc should be used.

F - FAMILY.

This includes rapidly informing the family of what has happened and what is going to happen next. If possible, dedicate one member of staff to be with the family to explain the process of resuscitation with them.

Family may also be helpful in 'playing' with the patient by distracting them to allow for further evaluation or procedures.

SECONDARY SURVEY.

An organised, complete assessment for detection of additional injuries which were not identified on the initial primary survey.

Features of the Hx can be obtained; ***"AMPLE"***.

Also consider tetanus immunisation, ABx (if indicated), ongoing monitoring of vital signs & assessment of urine output.

Management and Diagnostic Strategies.

General Principles.

All paediatric patients who have sustained major trauma should be placed on cardiac monitor, receive supplement O_2 and have constant reassessment of vital signs, oximetry, ET CO_2 and vascular access.

Failure to get peripheral IV access should lead to consideration of IO access, femoral CVC or vascular cutdown.

- Umbilical vein cannulation can be obtained in infants up to ~2 weeks of age.
  - 3-5 French lines can be used, as well as flexible peripheral IVCs.
  - If vasoactive agents are required, ensure a formal umbilical CVC is placed (above the liver) to avoid hepatic injury.

Hypovolaemic patients = 20mL/kg boluses of crystalloid.

- Following a total of 40mL/kg of fluid --> infusion of packed RBCs should be started @ 10mL/kg.
- Massive transfusion = >1 blood volume = 80mL/kg
  - Focal local guidelines
  - Avoid coagulopathy with 1:1:1 replacement ratios.
  - FFP = 15-25mL/kg.
  - PLTs = 10mL/kg. (Target PLT count > 50,000)
  - Cryoprecipitate (Target Fibrinogen level > 1-1.5 g/dL)

Any patient with shock, chest or abdominal trauma should receive a *FAST scan !!*

Recall your common types of shock (hypovolaemic, obstructive, neurogenic, cardiogenic).

- Always aim to exclude haemorrhagic/hypovolaemic shock even if there is another obvious cause (eg. spinal cord injury).

Examination of paediatric abdomen is most reliable when performed on a cooperative patient.

Consider urethral trauma in a patient with perineal or lower abdominal haematoma or blood from the urethral meatus.

- This would mandate a *retrograde urethrogram*.

Splint all possible fracture sites (or sites of suspected #'s).

Pain Control.

This includes not only medications, but techniques to change perception or draw attention away from noxious stimuli. Mainstay = *opiate analgesics*.

- **Fentanyl** has preferred haemodynamic profile and *intranasal route* is an option.
- Loading dose + PRN medication.

Immobilisation of fractures & extremities with soft tissue injuries.

Diagnostic Evaluation.

<u>Laboratory Studies.</u>
Standard trauma evaluation is required including G&H.
Older children / adolescents should be assessed for possible drug/alcohol intoxication.
Never forget GLUCOSE!! and repeat at 30 & 60mins.

<u>Radiology.</u>
The two most important radiographs for paediatric trauma = *Chest & Pelvis xrays.*
Generally, the pelvic film can be eliminated in stable/alert children without suggestion of sacral or pelvic trauma.

7 criteria are required to rule out pelvic fracture:

1. Age > 3 years
2. No impairment of consciousness
3. No major distracting injuries
4. No complaint of pelvic pain
5. No signs of fracture on inspection
6. No pain on iliac or pubic symphysis compression
7. No pain on hip rotation or flexion

Further radiographs are guided by physical examination on primary & secondary survey.

Consider *skeletal survey* in children of suspected child abuse / NAI.

Consider CT C-Spine in those with altered mental state and in those with significant trauma.

ECG (after electrical injury).
The majority of paediatric electrocutions are due to household current (< 240V).

Those who do not have ventricular dysrhythmias in the field, or water contact at the time of electrocution with household current and do not have ventricular dysrhythmias in the ED are at very low risk for significant arrhythmias.

Those with normal or non-specific ECGs remain at low risk.

ECGs and cardiac monitoring are indicated (minimum of 4 hours) in patients who experience high-voltage electrocution.

Specific Disorders / Injuries.

HEAD INJURY.

The leading cause of death amongst injured children (80% of all traumatic deaths).

In children, the cranial vault is larger & heavier in proportion to the total body mass, predisposing to high degrees of torque (along the C-spine axis). Their sutures are both protective & detrimental (more pliable therefore less skull #'s, but more likely to suffer parenchymal injury without skull #).

Clinical Features.

History requires details of height of fall, surface landed on, ?restraint used (in MVA) etc.

- ?LOC or altered mental state at scene.
- behavioural changes
- irritability / lethargy
- abnormal gait
- seizure / vomiting. *NB: an impact seizure alone is not an indication to scan !*

Physical examination includes strict attention to ABC's and consideration of cervical spine injury. Included mental state (AVPU or paediatric GCS can be used for assessment), cranial nerves, motor and sensory testing, cognition and memory testing.

- The most important aspect = motor and cranial nerve evaluation.

Maintenance of oxygenation, ventilation and normoglycaemia is paramount.

BOX 35-7 COMMON SYMPTOMS AND SIGNS OF INCREASED INTRACRANIAL PRESSURE IN INFANTS

- Full fontanel
- Split sutures
- Altered state of consciousness
- Paradoxical irritability
- Persistent emesis
- "Setting sun" sign (bilateral downward gaze of the eyes with apparent inability to elevate the eyes superiorly in a normal manner leading to an area of sclera being seen between the iris and the upper palpebra when the child attempts to look upward). This finding can be a normal finding when intermittent in infants younger than 7 months of age, especially with the withdrawal of a light stimulus.

BOX 35-8 COMMON SYMPTOMS AND SIGNS OF INCREASED INTRACRANIAL PRESSURE IN CHILDREN

- Headache
- Stiff neck
- Photophobia
- Altered state of consciousness
- Persistent emesis
- Cranial nerve involvement
- Papilledema
- Hypertension, bradycardia, and hypoventilation
- Decorticate or decerebrate posturing

Assess and management scalp haematomas & lacerations (including haemostasis).

- *Subgaleal haematomas* (above the periosteum) cross the suture lines.
- *Cephalohaematomas* (a collection of blood under the periosteum) do not cross the suture lines.

Skull fractures occur in different configurations...

- Linear #'s = most common and rarely require treatment.
- Diastatic #'s = extend through suture lines
- Basilar skull #'s = common also. Battle's sign / Raccoon eyes.

Epidural / Extradural haematomas;

- Triad of head injury / lucid interval / rapid deterioration.
- Can result from arterial & venous bleeding.
- High incidence of overlying skull #'s (60-80%)

Subdural haematomas;

- Usually from rupture of bridging veins.
- Most commonly in children <1 year of age.
- Chronic subdurals hint towards NAI / child abuse "Shaken Baby Syndrome".

Always send a child home with a sensible supervising adult and head-injury advice on when and why to return to ED for rapid assessment !!!

<u>Diagnostic Strategies & Management.</u>

Serial examination is the most reliable indicator of clinical deterioration. The presence of *focality* is a reliable indicator of a localised insult. In infants, signs of increased ICP usually develop later in the course. The *Cushing's* response is unreliable in children.

Recall the *Monroe-Kelly doctrine*.

- ICP can rapidly reach a level that is not conducive to localised brain survival.
- An ICP > 20-25 mmHg should be treated.
- *CPP = MAP - ICP*. (Target CPP = 50-65 mmHg)

The use of *anticonvulsants* following moderate-severe head injury in children is controversial, as early prophylaxis does not decrease incidence of late seizures.

- If seizures do occur, they require rapid and aggressive control.

Most clinicians favour early & controlled intubation for paediatric patients with GCS <9.

- An OGT should always subsequently be placed.

Herniation syndromes are very similar in children and adults.

- Uncal herniation
    - Unilateral dilated pupil (3rd nerve compression)
    - Contralateral hemiplegia (ipsilateral cerebral peduncle compression against the tentorium)
    - Spontaneous hyperventilation

Management of suspected herniation beings with immediate *controlled hyperventilation*. Aim for improved patient status, pupillary constriction or CO2 of 30-35 mmHg.

- Avoid excessive hyperventilation (can precipitate vasoconstriction).

Table 35-8 Emergent Management of Increased Intracranial Pressure

THERAPY	DOSE	MECHANISM OF ACTION
Head elevation (30 degrees)		Lowers intracranial venous pressure
Head in midline		Prevents jugular vein compression
Hyperventilation	Maintenance Pa_{CO_2} 38–42 mm Hg If acute increase in ICP then reduce Pa_{CO_2} to 30–35 mm Hg	Promptly but temporarily decreases cerebral blood volume and thus intracranial pressure Only recommended for short-term treatment of acute ICP elevation
Mannitol	0.25–0.5 g/kg IV	Both agents effect rapid osmotic diuresis.
Hypertonic saline (HTS)	0.1–1 mL/kg of 3% Titrate to effect	Diuresis may decrease BP and CPP. Mannitol should be given through filter. HTS may require central line. Effect from osmotic and rheologic effects Avoid dehydration
Pentobarbital	5–10 mg/kg over 30 minutes, then 5 mg/kg/hr for 3 hours, then 1 mg/kg/hr Rarely indicated or started in emergency department	Thought to lower cerebral metabolism; also may have some effect on free radical formation. Other barbiturates (phenobarbital) also have been used. May decrease BP and CPP
Decompressive craniotomy		Allows more space for swelling and decreases ICP Potential value in children
Mild hypothermia (35° C)		Thought to decrease cerebral blood flow and metabolic rate Can cause cardiac dysrhythmias Is currently under investiagtion
Maintain euvolemia	Clinically or invasive monitoring	Maintenance of mean arterial pressure
Pressors if needed to maintain CBF	Depends on agent used	Maintain CBF and CPP by increasing MAP
Neuromuscular blockade	Depends on agent used	Helps maintain lower ICP
Sedation	Depends on agent used	Do not assume they are completely incapable of response to noxious stimuli or situation.
Prevent fever	Acetaminophen 15 mg/kg OG	Fever raises ICP and cardiac work.
Treat seizure aggressively	Depends on agent used	Prophylactic treatment controversial. Treatment of seizure not controversial and must be aggressive to prevent increased ICP, hypoxia, hyperpyrexia, and hypercarbia.

<u>Radiology.</u>

Skull Radiographs.

- Indicated for skeletal survey (suspected NAI, abuse), ?functionality of VP-shunt, penetrating scalp wounds (?FB).

CT-Head.

- CHALICE & PECARN studies provide indications on who to scan.

- Kuppermann, N., Holmes, J., Dayan, P., Hoyle, J., Jr, Atabaki, S., Holubkov, R., Nadel, F., et al. (2009). Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. *The Lancet*, *374*(9696), 1160–1170. (**PECARN**)

- Dunning, J., Daly, J., Lomas, J., Lecky, F., Batchelor, J., & Mackway-Jones, K. (2006). Derivation of the children's head injury algorithm for the prediction of important clinical events decision rule for head injury in children. *Archives of disease in childhood*, *91*(11), 885. **(CHALICE)**

The children's head injury algorithm for the prediction of important clinical events rule

A computed tomography scan is required if any of the following criteria are present.

- *History*
  - Witnessed loss of consciousness of >5 min duration
  - History of amnesia (either antegrade or retrograde) of >5 min duration
  - Abnormal drowsiness (defined as drowsiness in excess of that expected by the examining doctor)
  - ⩾3 vomits after head injury (a vomit is defined as a single discrete episode of vomiting)
  - Suspicion of non-accidental injury (NAI, defined as any suspicion of NAI by the examining doctor)
  - Seizure after head injury in a patient who has no history of epilepsy
- *Examination*
  - Glasgow Coma Score (GCS)<14, or GCS<15 if <1 year old
  - Suspicion of penetrating or depressed skull injury or tense fontanelle
  - Signs of a basal skull fracture (defined as evidence of blood or cerebrospinal fluid from ear or nose, panda eyes, Battles sign, haemotympanum, facial crepitus or serious facial injury)
  - Positive focal neurology (defined as any focal neurology, including motor, sensory, coordination or reflex abnormality)
  - Presence of bruise, swelling or laceration >5 cm if <1 year old
- *Mechanism*
  - High-speed road traffic accident either as pedestrian, cyclist or occupant (defined as accident with speed >40 m/h)
  - Fall of >3 m in height
  - High-speed injury from a projectile or an object

If none of the above variables are present, the patient is at low risk of intracranial pathology.

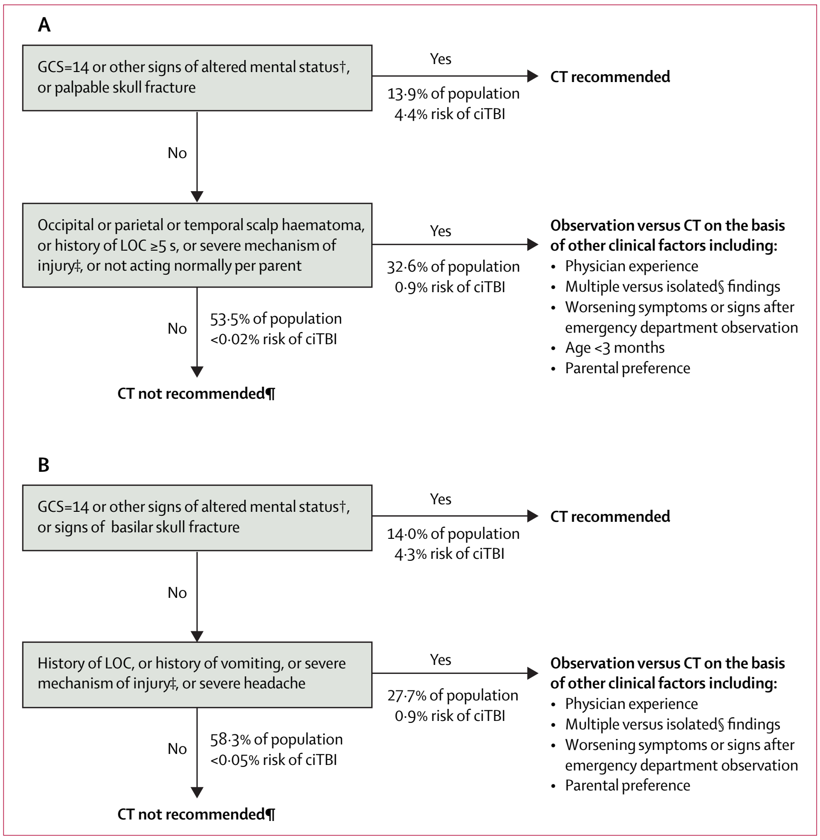


Figure 3: Suggested CT algorithm for children younger than 2 years (A) and for those aged 2 years and older (B) with GCS scores of 14–15 after head trauma*

↑ PECARN Study

← CHALICE Study

CERVICAL SPINE INJURY.

Cervical spine injury patterns vary with the age of the patient.

- #'s below C3 = ~ 30% in children younger than 8 years
- Differs dramatically from adult patterns.
- SCIWORA has been found in ~25-50% of SCI in the same age group.

Injury patterns identical to those of adults are not fully manifested until age 15 years.

BOX 35-9 ANATOMIC DIFFERENCES IN THE PEDIATRIC CERVICAL SPINE

Cervical spine fulcrum changes from C2–C3 in toddlers to C5–C6 by age 8–12 years.
Relatively larger head size, resulting in greater flexion and extension injuries.
Relatively large occiput in children younger than age 2 years leads to flexion of cervical spine if they are laid flat on standard backboard without support under their scapula and pelvis.
Smaller neck muscle mass with ligamentous injuries more common than fractures.
Anterior wedge appearance of cervical vertebral bodies is common.
Increased flexibility of interspinous ligaments.
Flatter facet joints with a more horizontal orientation.
- Upper 30→65 degrees and lower 55→70 degrees as one ages to adulthood.

Incomplete ossification, making interpretation of bony alignment difficult (synchondrosis).
- Uncinate processes do not calcify until approximately 7 years of age.
- Basilar odontoid synchondrosis fuses at 3–7 years of age.
- Apical odontoid epiphyses radiographically apparent at 7 years of age but may not fuse until approximately 12 years of age.
- Posterior arch of C1 fuses at 4 years of age.
- Anterior C1 arch may not be visible until one year of age and fuses at 7–10 years of age.
- More inferior cervical vertebral segments.
  - Neural arches fuse to body by approximately 7 years of age.
  - Posterior arches fuse by 3–5 years of age.

Epiphyses of spinous process tips may mimic fractures.
Preodontoid space 4–5 mm in those <8 years of age and <3 mm in those 8 years or older.
Pseudosubluxation of C2 on C3 seen in 40% of children <8–12 years of age.
Prevertebral space size varies with phase of respiration.

<u>Clinical Features.</u>

Any patient with severe multiple injuries should be considered to have an SCI until proved otherwise.

Like any multiple injured patient, the evaluation of a paediatric patient should begin with a *primary survey* with concomitant *stabilisation of the cervical spine.*

- *Palpation of the neck* for pain & bony deformity should be performed.
- Take all complaints of pain or tenderness seriously, due to high risk of *ligamentous injury* (which can sometimes be subtle).

A thorough neurological examination should be performed (a challenge in a small paediatric patient). Specific findings to search for & note are:

- paralysis
- perceived paraesthesia (including resolved symptoms).
- ptosis
- priapism

The rectal exam ('anal wink' test) or bulbocavernosus reflex is important in assessing for sacral level injury (and for resolution of spinal shock).

CENTRAL CORD SYNDROME.

- usu. extension injury
- arm findings > leg findings
- distal symptoms > proximal symptoms (eg. burning pain in fingers & hands).

ANTERIOR CORD SYNDROME.

- complete motor paralysis and loss of pain & temperature sensation
- preservation of proprioception & vibration sense

BROWN-SEQUARD SYNDROME.

- hemisection of the spinal cord (usu. from penetrating injury)
- ipsilateral loss of motor function & proprioception
- contralateral loss of pain & temperature sensation

<u>Radiology.</u>

The use of plain C-spine x-rays remains controversial in children, with some experts advocating for liberal use (as a sensitive screening tool), whilst the NEXUS study derived its criteria from only 3065 children (and only 30 paediatric C-spine injuries, none of which were SCIWORA & only 4 of these were in children < 9 years).

NEXUS:

- Sn of 100%
- NPV = 100% (however, < 1% of cases had an injury therefore less meaningful).

1- No posterior midline tenderness
2- No focal neurological deficit
3- Normal level of alertness
4- No evidence of intoxication
5- No clinically apparent, painful, distracting injury.

Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. (2000). Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. *New England Journal of Medicine*, *343*(2), 94–99.

All C-spine x-rays should consist of three views (cross-table lateral, AP view & open-mouth odontoid view), with complete visualisation of the entire C-spine vertebrae including the C7-T1 interface.

The interpretation of these films can be challenging due to anatomical changes with growth, as well as *pseudo-subluxation of C2 or C3* which occurs in up to 40% of patients.

- The *Line of Swischuk* can help distinguish pseudo-subluxation from true subluxation.

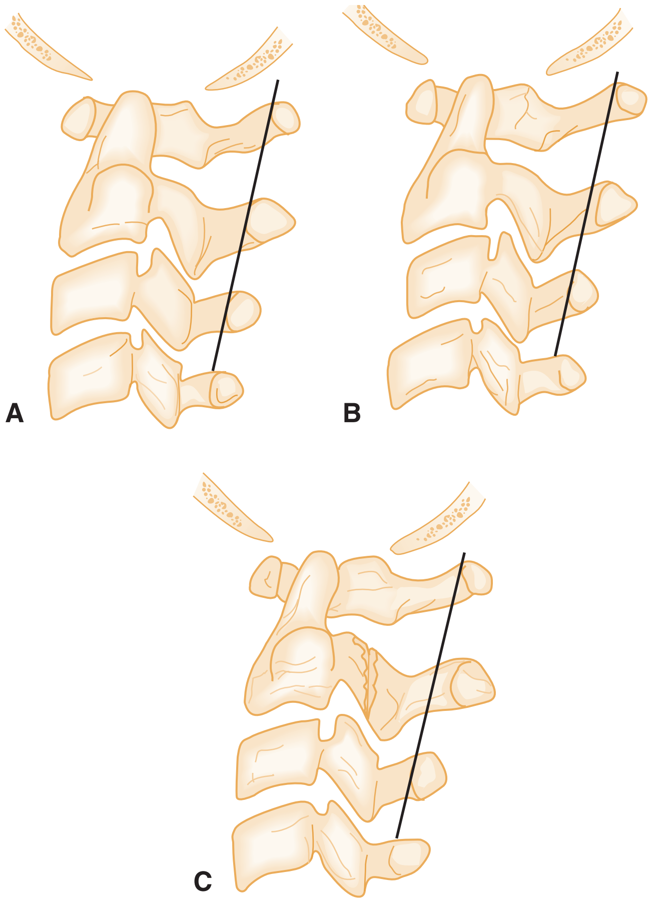
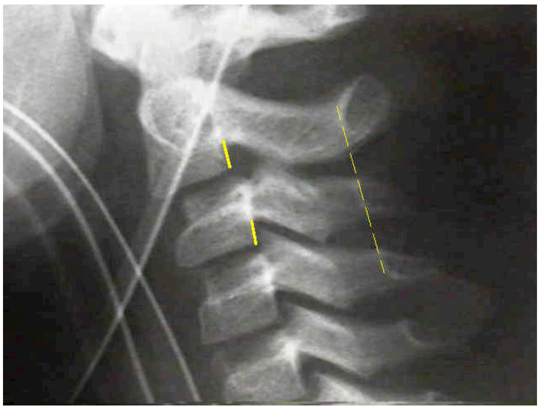


Figure 35-1. Spinolaminar line. Use only to access anterior displacement of C2 on C3. A line is drawn from the cortex of the spinous process of C1 to the cortex of the spinous process of C3, and the relationship of the spinous process of C2 is noted. **A,** Normal line passing through the cortex of C2. **B,** Normal line passing within 1.5 mm of the cortex of C2. **C,** Abnormal line passing greater than 2 mm anterior to the cortex of C2, suggesting underlying fracture of posterior elements of C2. (From American College of Emergency Physicians, American Academy of Pediatrics: APLS: The Pediatric Emergency Medicine Resource, 4th edition, Dallas, Elk Grove Village, Ill, 2004, the College and the Academy.)



* A case of pseudo-subluxation !

Other modalities that can be used include CT & MRI.

Classically, young children should be considered at greater risk for upper cervical spine injury

<u>Management.</u>

There are two phases of SCI

1. Direct, or initial phase: resulting in largely irreversible injury to the spinal cord
2. Indirect: from preventable or reversible injury to the spinal cord secondary to ischaemia, hypoxaemia or tissue toxicity.

Resuscitation of patients with SCI focuses on prevention or minimisation of indirect causes of injury.

Immobilisiation: hard collar, back board, external fixation, head tapes, head box.
- provide appropriate padding for avoidance of pressure-necrosis.

Breathing: assessed for hypoventilation (?diaphragmatic or intercostal paralysis).
- compounded by concomitant chest injury (contusion, rib #s, aspiration).
- apply supplemental O2 / intubation & mechanical ventilation.

Circulation: avoidance of hypotension and end-organ hypoperfusion.

- Assess for hypovolaemia & neurogenic shock (*above level of T6*).
- Never assume that a spinal-injured patient's hypotension is solely related to neurogenic shock (*always examine for & exclude haemorrhage).*

The use of IV steroids for blunt injury remains controversial.

CARDIOTHORACIC INJURY.

Most serious chest injuries in children result from *blunt trauma* (83%), most of which are MVAs. Sequelae of blunt chest trauma include *rib fractures, pulmonary contusion (50%), pneumothorax (20%) & haemothorax (10%).* Penetrating chest injuries in children should raise concerns for concomitant intraabdominal injuries.

Young children and infants are preferential diaphragmatic breathers & any impairment of diaphragmatic mobility compromises ventilation (especially gastric distention). The presence of adequate oxygenation in a paediatric patient does not always ensure adequate ventilation. Consider the use of ETCO2.

Infants & children are anatomically protected against blunt thoracic cage trauma due to the compliance of the rib cage, therefore allowing significant injury to occur with little apparent external signs of trauma. Multiple rib fractures are a marker of serious injury to children, with *NAI* being the most likely cause (especially if the #s are posterior and in various stages of healing).

<u>Pneumothorax:</u>

- Traumatic PTX commonly associated with significant pulmonary injury (& often assoc. with haemothorax).
- *Signs & Symptoms include:*
    - External evidence of chest trauma (contusion, abrasion, ecchymoses)
    - Tachypnoea & respiratory distress
    - Hypoxaemia
    - Chest pain.
- *Management* includes placement of an intercostal catheter.
    - ICC tube size = ~ 4x the ETT size.
    - Supplemental O2 for nitrogen washout.

<u>Open PTX:</u>

- Allows bidirectional flow of air through the wound.
- Inability to expand lung, due to equalisation of pressure b/ween atmosphere & pleural space.
- Ventilation & oxygenation are both severely impaired.
- *Management*:
    - Three sided occlusive dressing
    - ICC via a separate site/incision.
    - Conversion to PPV (mechanical ventilation).

Tension PTX:

- Created by a one-way valve with increasing air in the pleural space (leading to positive pleural pressure & eventual shifting of mediastinal structures and compromising cardiac output).
- Final common pathway = hypoxia, hypotension and refractory shock.
- Tension PTX in children may be quite subtle on presentation.
    - ie. *tachycardia, respiratory distress & shock.*
- *Management:*
    - Needle decompression (2nd IC space / MC line) & ICC insertion

Haemothorax:

- Significant bleeding can result from injury to intercostal vessels, internal mammary arteries or lung parenchyma.
- Can be difficult to detect on CXR (especially in supine films)
    - A slightly less radiolucent appearance of the affected side may be the only sign.
- Can present with early or late signs of shock (and shock should be managed simultaneously, with the insertion of ICC).
    - Crystalloid / O-Neg blood / Type-specific blood
    - Auto-transfusion is also an option.

INDICATIONS FOR THORACOTOMY:
- Immediate loss of 10-15mL / kg of blood.
- Persistent blood loss (2-4mL / kg / hour over 3 hours).
- Continued air leak.

- Contraindications to ED thoracotomy after out of hospital CPR include.
    - Blunt trauma with CPR > 5mins / no signs of life / no tamponade on USS.
    - Penetrating trauma with CPR > 15mins / asystole or no signs of life / no tamponade on USS.
- Penetrating injury with < 5 mins of CPR warrant a left-anterior thoracotomy.

Pulmonary Contusion.

- The compliance of the paediatric rib cage renders them susceptible to the development of pulmonary contusion (even without external evidence of trauma).
- May impair both oxygenation & ventilation.
- Management includes supplemental oxygen and close monitoring. Some may require positive pressure ventilation.

Traumatic Diaphragmatic Hernia.

- Children in MVAs, *wearing only lap-belts* are predisposed to diaphragmatic herniation (usually on the left side).
- Results from sudden increase in intra-abdominal pressure.
- Respiratory distress is directly proportional to the amount of abdominal contents in the pulmonary space.
- Commonly associated with *thoracolumbar spinal injuries & Chance fractures.*
- *Management* is NGT placement (stomach decompression) +/- intubation & PPV.
    - Surgical repair is the definitive cure.

<u>Cardiac & Vascular Injuries.</u>

- Very uncommon in children.
- *Myocardial contusions* are the most common traumatic cardiovascular injury.
    - Generally, no long term sequelae.
- *Tachycardia* is the most common finding.
- Elevated cardiac enzymes may be diagnostic (but not very specific).
- *Tamponade* is the most concerning life-threatening injury.
    - Usually relating to a penetrating injury.
    - Tachycardia, distant heart sounds, raised JVP, pulsus paradoxus & narrow pulse pressure.
    - Diagnosed with USS.
- Pericardiocentesis may be both diagnostic & therapeutic.
- Thoracotomy may be required.

<u>Commotio Cordis.</u>

- Results from sudden impact to the anterior chest wall, causing cessation of normal cardiac function.
    - Immediate dysrhythmia or VF, refractory to resuscitative attempts.

ABDOMINAL INJURY.

This is the 3rd leading cause of traumatic death in children & is the most common cause of unrecognised fatal injury in children (usually resulting from blunt injuries).

"Lap-belt" injuries, including small bowel injury or Chance fractures may occur in ~ 5-10% of restrained children in MVAs. Handle-bar injuries represent a serious cause of injury & subsequent hospitalisation.

All children with epigastric pain after blunt trauma, especially when concentrated force has been applied in this area, should be considered to have *duodenal haematoma* until proven otherwise. Pancreatic injury should be considered also.

Paediatric anatomy lands to some special protection from some injury patterns (& predisposes to others).

- Larger solid organs & less fat = more solid organ injury.
- Relatively larger kidneys = more renal injury.

<u>Clinical Features.</u>

History is often limited & traditional signs of decompensation are often not as evident. Physical examination can be difficult.
Attempt to distract the child with toys/lights/bubbles/keys.

Signs & symptoms include:

- Tachypnoea
- Abdominal tenderness / bruising
    - Ecchymoses = 1 in 9 have an intraabdominal injury.
- Signs of shock.

- Pain is often very difficult to localise & any form of tenderness should prompt further evaluation or observation.
- Vomiting is a late sign of duodenal haematoma or traumatic pancreatic injury.
- Rectal examination may need to be performed in selected cases of trauma.

Diagnostic Strategies & Management.

Distress & pain can make evaluation challenging. Children will distend there stomach considerably whilst ingesting air; therefore early decompression with NGT should be considered.

Early use of FAST examination will identify intraperitoneal bleeding.
Diagnostic peritoneal lavage may still be used in some circumstances.

- Positive DPL =
    - > 100,000 RBC / mL
    - > 500 White cells / mL
    - Gram-negative bacteria or vegetative matter on microscopy.

CT-scan may be used on stable patients, keeping in mind that CT is not very sensitive for bowel injury.

SPLEEN INJURY.

- The most common injury in paediatric abdominal trauma.
- LUQ pain, radiating to left shoulder.
- May be either haemodynamically stable or in profound haemorrhagic shock.
- Management is decided by surgical team.

LIVER INJURY.

- 2nd most common injury. Mortality of severe liver injury approaches 10-20%.
- RUQ tenderness +/- right shoulder pain.

RENAL INJURY.

- Signs & symptoms are less obvious due to the kidney's retroperitoneal location.
- Dull back pain, ecchymoses & haematuria.
- Renal USS or CT may be helpful.

PENETRATING INJURY.

- Usually require rapid evaluation by a surgeon & in some cases operative intervention.
- The role of DPL is controversial.

Radiology:

- CT provides high sensitivity (except for hollow viscous injury) & specificity for identifying splenic, hepatic, renal and GIT injuries.
    - *Oral contrast does not add to the accuracy of CT (and often delays evaluation).*
- USS/FAST

Disposition.

Do not let extensive radiologic evaluation hinder the transport to definitive care.
Under no circumstances should the child's likely outcome be downplayed to the parents.
The threshold to admit for observation should be very low in cases of suspected NAI or child abuse.

Cessation of Care.

Some injured children die.

Patients who lose their vital signs en route to *or* in the resuscitation room should receive maximal resuscitative efforts, potentially including thoracotomy.

Parental presence should be considered in all paediatric resuscitation cases, assigning a member of staff to the parent to provide them with explanations of what is going on.

Parents who witness what the team does for their children during resuscitation seem to better understand the ability and limitations of medicine. In the final analysis, most parents want to be there, and frankly, at the time of death, their presence is more important than the presence of the medical team.