07
Paediatrics

07

07 • Paediatric trauma

Management of paediatric trauma will follow the same pathways as adults (section 3). This chapter details the variations in care where expected. **This guideline is applicable to children involved in trauma from the neonatal age group up to 16th birthday.**

The paediatric section of TEMPO provides a template for the management of major trauma in children. The paediatric emergency folder should be used in conjunction with TEMPO to help clinicians guide management and should be available in all resuscitation departments.

Children account for nearly 25% of the UK population. Major trauma remains the leading cause of death in children over one year of age, and the Confidential Enquiry into Maternal and Child Health found that 47% of all non-natural deaths in children were due to road traffic collisions. Approximately 300–500 children are involved in major trauma per annum in the UK. In the east of England, Cambridge University Hospitals (CUH) has the only paediatric major trauma centre (MTC).

Children have a higher proportion of *head injuries* and *burns*. Traumatic brain injury is the leading cause of morbidity and mortality. The need for urgent neurosurgical decompression is less common than in adults, however there is an equivalent urgency to access intracranial pressure monitoring.

At every stage of the trauma pathway, the importance of *safeguarding children* is paramount. Vulnerable children or those from an area of high social deprivation are over-represented as a group.

Children and young people are usually part of a *family unit* and they need their families to be involved in their care. Families should have information, encouragement and support to enable them to share in decisions about the child's care and to remain informed about their condition and management. Children must be informed about, and have active involvement in decisions related to their own ongoing care.

Particular attention needs to be paid to full documentation of decisions, interventions and times. The role of the scribe as part of the trauma team is pivotal to good documentation and their importance is often underestimated. Following admission, the requirement for accurate, concise and legible documentation of ongoing care does not diminish.

07.a • Pre-hospital care

The pre-hospital care of injured children should follow the same pathways as for adults (Section 4). Please use the JRCALC guidelines (and the paediatric physiological values printed on the back of the triage tool) for all paediatric patients.

07.a.i Triage tool

a. Apply within 10 mins of arrival (same as in the adult).
b. Call for help. NCS can give advice and guide the stabilisation and transfer.

07.a.ii Monitoring standards and initial management

Children involved in trauma should have the same multi-modality monitoring as applied to adults.

07.a.iii Tranexamic acid

Early use of tranexamic acid is to be considered for all paediatric patients with trauma and significant haemorrhage. Use within 3 hours of injury is recommended. See formulary for dose.

07.a.iv Pain

Analgesia should be provided to all major trauma children as per the patient requirement and the training of the crew members. The East of England Ambulance Service currently allows the following:

a. Critical care paramedics only:
Ketamine (under PGD) > 6yrs titrated to weight
IV paracetamol – from birth titrated to weight

b. Paramedics:
Oral – Morphine suphate – vials 10mg in 5ml – as per JRCALC guidelines 2013
IV Morphine sulphate – 10mg in 1ml – as per JRCALC guidelines 2013
Entonox – if capable of taking instruction
Co-codamol 30/500 > 12yrs
Oral paracetamol as per JRCALC guidelines 2013

c. Enchanced care teams:
can use any available methods of analgesia

07.a.v Pre-alert

There should be an early pre-alert through NCS to the receiving hospital ED about an injured child (less than 16 years of age) so that the specialists required in stabilisation are available as the child reaches the Emergency Department. Please clearly state ATMISTER, the age of the child and request for the Paediatric Trauma team. The trauma units will decide the composition of the paediatric trauma team in their set-up based on the resources; for children less than 6 years of age, it's preferable to have relevant speciality consultants involved in the resuscitation and stabilisation on arrival to the ED.

07.b • Acute care

Certain considerations regarding the management of paediatric trauma patients are often overlooked:

- **Equipment:** There should be appropriately sized equipment available in the resuscitation area where the child will be received. As well as consumables, the instruments to perform the same range of procedures that are expected in an adult should also be available for children.
- **Temperature control:** There should be measures in place to ensure that the child is kept warm, eg. ambient heaters, Bair Hugger available. As children have large body surface area, they lose heat at a fast rate. Therefore when a child is exposed during the resuscitation, active measures should be initiated / considered in order to ensure that the child does not become hypothermic.

  Measures include:
  - keeping child covered when not being examined
  - keeping room warm
  - use of ambient heater
  - use of Bair Hugger (active warming device)
  - use of warmed fluids

07.b.i • Trauma team roles (additional)

The trauma team roles and the time targets are the same as in the adult section. In addition to the trauma team roles defined in the adult section, a paediatric trauma team should also include:

Paediatric StR

- Assists Doctor 2 in obtaining vascular or intra-osseous access
- Calculates initial drug and fluid boluses according to estimated weight (Section 5: additional information or use the paediatric emergency folder)
- Takes AMPLE history from parents if available
- Liaises with the trauma team leader at all times
- Considers safeguarding

Surgical team involvement (paediatric surgical team where available):

Each hospital will have local guidelines for the surgical team involvement.

If a patient has been deemed to require immediate resuscitative laparotomy on arrival, the trauma team leader should contact the on-call surgical consultant to request their attendance at the trauma call. The trauma network co-ordination service (NCS) should be contacted and relevant paediatric specialists can then be conferenced in for appropriate advice.

07.b.ii Airway and anaesthesia

The airway specialist could be either a registrar or consultant anaesthetist or emergency medicine specialist. The on-call anaesthetic consultant could seek the help of another consultant anaesthetist with paediatric expertise or trauma consultant/PICU consultant in Cambridge University Hospitals through NCS if required.

Pre-anaesthetic induction checklist

Is pre-oxygenation in progress?

Monitoring

- What is the heart rate? Can it be improved?
- What is the blood pressure? Can it be improved?
- What are the oxygen saturations? Can they be improved?

Equipment

- Which laryngoscope blade size and type will be used?
- Which tracheal tube size and lengths will be used?
- Is bougie size appropriate for tube chosen?
- Are all equipment items checked?
- Is $ETCO_2$ connected?
- Is suction turned on and pre-positioned?
- Are the BVM and ventilator ready for use?
- Is there any additional rescue airway equipment needed?
- Is there an adequate sized orogastric tube?

Drugs

- What induction agent?
- Is dose appropriate for age, weight and BP?
- What muscle relaxant?
- Are any other emergency drugs needed?
- Are there two points of adequate vascular access?
- Are fluids connected and running easily?

Staff

- Who is giving the drugs? Have they been briefed?
- Who is the operator? Has their position been optimised?
- Who is providing cricoid pressure? Have they been briefed?
- Who is the assistant? Is the team and equipment in the right position?
- Who is providing cervical stabilisation? Is the collar open?

Checks complete

Note time and mark induction on the monitor. Give induction drugs.

Post intubation, maintain sedation and muscle relaxation with drug infusions (see drug monograph in additional information for doses).

Suggested protocol for induction of anaesthesia

Induction agents

It is recommended that the airway specialist should use induction drugs that they are familiar with and alter the dosage according to clinical circumstances.

It is also suggested opioids should be used (even in head injured patients) as analgesic and also as an adjuvant to induction drugs (to reduce the dose of anaesthetic drug needed for induction of general anaesthesia). Fentanyl at a dose of 0.5 to 2mcg/kg is a popular choice of opioid.

In relatively normovolemic children

- Propofol 2–4mg/kg
- Ketamine 2–3mg/kg (good evidence suggesting no increase in ICP with ketamine and hence its use in trauma patients including children with head injuries). If unfamiliar with use of ketamine for induction of general anaesthesia, please use the induction drug familiar to you.

In hypovolemic children

- Ketamine 1–2mg/kg
- Etomidate 0.2–0.3mg/kg
- Propofol 1–2mg/kg (slow titrated injection)

Muscle relaxants

- Suxamethonium 2mg/kg (avoid suxamethonium in children with chronic neuromuscular conditions, renal failure, burns more than 12 hours old, and high spinal cord injuries more than 12 hours old).
- Rocuronium 1mg/kg (caution to be exercised if difficult airway or difficult intubation is anticipated, and sugammadex not available).

Maintenance of anaesthesia

- Anaesthesia maintained with midazolam infusion at 50–300 mcg/kg/hr and morphine 20–50 mcg/kg/hr. (If more familiar, propofol infusion can be used in haemodynamically stable children for transport purposes, for no more than 12 hours.)
- Bolus muscle relaxant with Atracurium 0.5mg/kg or Rocuronium 1mg/kg.

Difficult airway algorithm

The following three guidelines relate to the management of the unanticipated difficult airway in children aged 1 to 8 years.

They are:

- difficult mask ventilation during routine induction of anaesthesia in a child aged 1 to 8 years
- unanticipated difficult tracheal intubation during routine induction of anaesthesia in a child aged 1 to 8 years
- cannot intubate and cannot ventilate (CICV) in a paralysed anaesthetised child aged 1 to 8 years

Paediatric patients are looked after in many hospitals and specialist paediatric services are neither necessary nor appropriate in all settings. The target audience for these guidelines is for the non-specialist anaesthetist who wishes to learn or maintain paediatric airway skills, rehearse unexpected difficult airway scenarios and teach good practice.

These guidelines are clinical, but are backed by a robust process. A formal paper giving all the background data used to develop these guidelines will be published in the near future.

Internationally it was clear that most units are using airway management guidelines for children which have been expanded from adult practice. We have therefore specifically developed these guidelines following an exhaustive process which involved a Delphi analysis (which ensured careful reflection of each step of the pathway, and a grading of how confident an expert group was in endorsing each step), and an extensive literature review. Following this we had further external reviews, and placed the guideline on the APA website requesting comments; all views were considered. There is very little grade 1 (randomised control trial) evidence to support good practice in the management of the difficult paediatric airway, and guidance must therefore be essentially a clinical issue.

The Guidelines Group, supported by the Association of Paediatric Anaesthetists, the Difficult Airway Society and liaising with the RCoA, have taken a careful and thorough approach to review current practice. We hope these guidelines will be used widely, and would encourage feedback. We trust that, long term, they will be of use to all anaesthetists who manage children in day-to-day clinical practice, and those who teach safe airway techniques.

07.b.iii Child maltreatment

Child maltreatment includes physical, emotional and sexual abuse, neglect, and fabricated or induced illness. A consideration of child maltreatment should be made in all cases and if necessary discussed with a senior clinician. Please follow the local child protection/safeguarding policies.

The following injuries should prompt you to **suspect** child maltreatment

- Bruising in the shape of a hand, ligature, stick, teeth mark, grip or an implement
- Bruising or petechiae not caused by a medical condition with an unsuitable explanation, including:
  - in a child who is not independently mobile
  - that are multiple or in clusters
  - of similar shape and size
  - on non-bony parts of the body, including the eyes, ears and buttocks
  - on the neck/ankles.
- Human bite mark thought unlikely to be caused by a small child.
- Lacerations, abrasions or scars on a child that have an unsuitable explanation, including:
  - on a child who is not independently mobile
  - that are multiple or have a symmetrical distribution
  - on the areas usually protected by clothing, or the eyes, ears and sides of face
  - on the neck, ankles and wrists that look like ligature marks.
- Burn or scald injuries on a child:
  - with an absent or unsuitable explanation or
  - who is not independently mobile or
  - on soft tissue areas not expected to accidently come into contact with a hot object (for example, backs of hands, soles of feet, buttocks, back) or
  - in the shape of an implement (for example, cigarette or iron) or
  - that indicate forced immersion.
- One or more fractures in a child if there is no medical condition that predisposes to fragile bones or if the explanation is absent unsuitable, including:
  - fractures of different ages
  - X-ray evidence of occult fractures.
- Intracranial injury in a child if there is no major confirmed accidental trauma or known medical cause in one or more of the following circumstances:
  - there is an absent or unsuitable explanation
  - the child is under 3 years
  - other inflicted injuries, retinal haemorrhages, or rib or long bone fractures
  - there are multiple subdural haemorrhages with or without subarachnoid haemorrhage with or without hypoxic ischaemic damage to the brain.
- Retinal haemorrhages or injury to the eye in a child if there is no major confirmed accidental trauma or medical explanation
- Signs of spinal injury in a child if there is no major confirmed accidental trauma
- Intra-abdominal or intrathoracic injury in a child if there is no major confirmed accidental trauma, with an absent or unsuitable explanation, or with delay in presentation. There may be no external bruising or other injury.

Please refer to NICE guideline 89.

If a child with suspected inflicted injury needs transferring to MTC, please call NCS to facilitate referral and transfer.

07.c • Emergency treatment guidelines

07.c.i Paediatric massive blood transfusion

Definitions

Massive blood loss in children may be defined as:

1. loss of one blood volume in 24 hours (approximately >80ml/kg in those <40kg) or
2. loss of 50% blood volume in three hours (approximately 40ml/kg in those <40kg) or
3. loss of >3ml/kg/min.

The chart below offers volume estimates for children.

Age / weight based estimates of massive blood loss in children				
Age	Approximate weight	Total blood volume (80ml/kg in 3hrs)	50% blood volume (40ml/kg in 3hrs)	Rate of loss >3ml/kg/min
Term	3.5kg	280ml	140ml	10ml/min
6 months	7kg	560ml	280ml	20ml/min
1 year	10kg	800ml	400ml	30ml/min
5 years	20kg	1600ml	800ml	60ml/min
10 years	30kg	2400ml	1200ml	90ml/min
12 years	40kg	2800ml*	1400ml*	100ml/min*
16 years (adult)	60kg	4200ml*	2100ml*	150ml/min*

* Based on blood volume 70ml/kg in over 12 year old

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Massive blood loss in children

>80 ml/kg 24 hours >40 ml/kg in 3 hours >3 ml/kg/min

*Please see guideline for age/weight blood loss estimates

Get help

Contact senior member of clinical team. Contact senior ward nurses.
Contact portering services

Contact transfusion

Contact transfusion

Ask transfusion to **'Initiate children's massive blood loss (C-MBL) protocol'**
Give the weight, age and location of the child

Assess ABC

Stop overt bleeding where possible

Suspect 40% blood loss if significant source of bleeding suspected and clinical parameters as follows:

Age	Heart rate	Systolic BP
<1 year	>160	<70
1–2 years	>150	<80
3–5 years	>140	<80
6–12 years	>120	<90
>12 years	>100	<100
Tachypnoea or increased work of breathing		
Urine output <0.5ml/kg/hour		

IV access

2 cannula (largest possible)
Send blood samples – crossmatch, FBC, PT / APTT / Fibrinogen,
Biochemistry (U&E, LFT, ionised Ca, phosphate)
Arterial / venous blood gas measurement

In trauma or surgical bleeding consider **Tranexamic Acid**
Initial bolus 15mg/kg (max 1g) followed by maintenance infusion

Resuscitate

IV fluids – crystalloid or colloid – 10–20ml/kg
Give oxygen

Therapeutic aims

Hb	>80g/L
Platelets	>75 x 10^9/L
Fibrinogen	>1g/L
APTT/PT	<1.5x midpoint of normal range
Ionised calcium (on ABG)	>1mmol/L
pH	>7.2
Core temperature	>35°C

Give blood

Blood loss >40% blood volume (ie. >30ml/kg) is immediately life-threatening
Give 20ml/kg red cells (up to four units). Aim for Hb>80g/L
Give Group O RhD negative if immediate need
and/or blood group unknown

Blood transfusion lab will provide group specific/
crossmatched red cells as required

Before transfusion
- Check patient ID
- Use wristbands
- Ask parent if present

Prevent coagulopathy

Anticipate need for platelets and FFP after 20–30ml/kg blood replacement and continuing bleeding
Give Primary Children's Massive Blood Loss (C-MBL) Pack
Order Secondary Children's Massive Blood Loss (C-MBL) Pack
(Secondary pack to be given if bleeding continues)
Correct hypothermia and use fluid warmer
Correct hypocalcaemia (keep ionised Ca>1 mmol/L)
Contact Haematologist

Primary C-MBL pack
- Blood 30ml/kg (up to 5 units)
- FFP 20ml/kg FFP (up to 4 units)

Secondary C-MBL pack
- Blood 30ml/kg (up to 5 units)
- FFP 20ml/kg (up to 4 units)
- Platelets 15ml/kg (up to 1 unit)
- Cryoprecipitate 5ml/kg (up to 300ml)

Maintain stability

Repeat blood gas (including Hb,
ionised Ca, Na, K, glucose) every 30 minutes
Repeat FBC, coagulation after every 40ml/kg blood components given
Monitor HR, BP, capillary refill, saturation, temperature, urine output

Reassess
- Re-assess ABC and clinical parameters regularly
- Document status

Get more help to stop bleeding

Contact paediatric surgeons, paediatric gastroenterologists,
PICU, radiology as appropriate

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Massive blood loss (C-MBL) packs for children

Red cells	Use O RhD negative until group is known – then use ABO and RhD suitable Move to crossmatch compatible as soon as all investigations are complete Consider age of patient to inform component specification (eg. paediatric red cells)
Platelets	Use group A HTN until group is known – then use ABO suitable (A HTN for AB patients) Use apheresis if possible
Fresh frozen plasma	Use group AB until group is known – then use ABO suitable **Order of preference:** 1. Non-UK methylene blue treated (MB-FFP) 2. Octaplas (SD-FFP) 3. Standard FFP
Cryoprecipitate	Use group A until group is known – then use ABO suitable (A for AB patients) **Order of preference:** 1. Non-UK methylene blue treated cryoprecipitate 2. Standard cryoprecipitate

Avoid group O for non-O patients where possible
(for platelets, FFP and cryoprecipitate)

	Weight		
	< 10kg	< 10–40kg	> 40kg
Primary pack	2 x Red cells 2 x FFP (~400ml)	4 x Red cells 4 x FFP (~800ml)	5 x Red cells 4 x FFP
Secondary pack	2 x Red cells 2 x FFP (~400ml) 1 x Adult platelet dose 3 x MB Cryoprecipitate (~50ml) or 1 adult pool	4 x Red cells 4 x FFP (~800ml) 1 x Adult platelet dose 10 x MB Cryoprecipitate (~160ml) or 2 adult pools	5 x Red cells 4 x FFP 1 x Adult platelet dose 10 x MB Cryoprecipitate (~160ml) or 2 adult pools

07.c.ii C-spine immobilisation

Traumatic injuries of the cervical spine are uncommon in children. They are primarily seen in 1 to 2 percent of children who sustain blunt trauma. However, it is essential to assume cervical spine injury in every injured child until examination and / or radiological investigation prove otherwise. Injury may involve bones, ligaments, blood vessels, and/or the spinal cord, and must be rapidly recognised and treated to avoid permanent disability or death. Patients with suspected or possible cervical spine injury must have their cervical spine properly immobilised until formal assessment occurs. If the patient doesn't need intensive care, the responsibility of cervical spine clearance lies with the trauma team leader.

Indications for C-spine immobilisation:

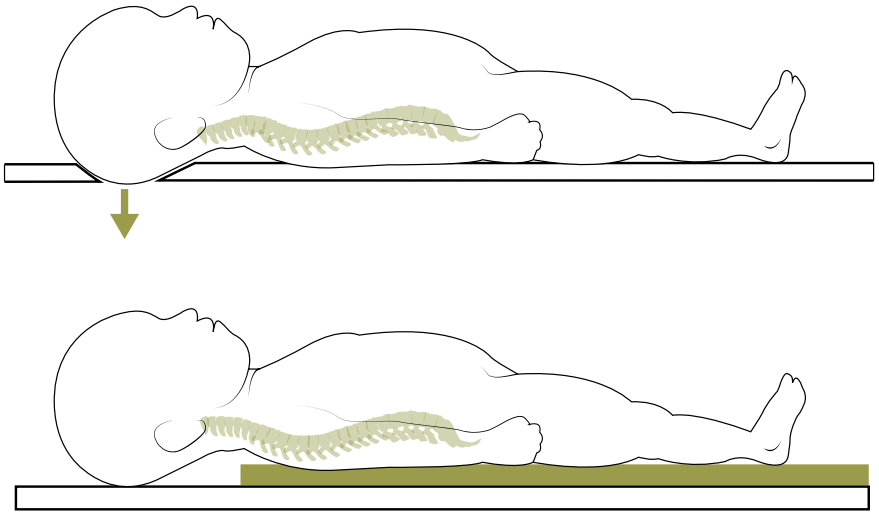
1. All children with altered level of consciousness
2. Patients in whom the mechanism of the injury could have resulted in injury to the spine
3. All patients with signs and symptoms consistent with spinal cord injury:
    - history of transient paraesthesia, dysaesthesia, shooting pains or subjective extremity paralysis
    - complaints of neck pain or discomfort, or presence of muscle spasm
    - limited range of motion or tenderness over the spin
    - presence of sensory-motor deficits.

Full and correct immobilisation includes all of the following:

- Neutral position on a firm surface. If child is more than 3 years of age, use hard collar reinforced by blocks or sandbags with tape.
- If child is less than 3 years of age, blocks or sandbags and tape.
- Where above not available, manual in-line immobilisation must be used.

Note: hard collar must be the correct size for the patient and soft collars are not acceptable.

In children under 2 years of age, who have larger heads, the following should be done: occipital recess or thoracic and lumbar support (as shown below) sandbags/tapes and hard collar for young children.



Constant reassurance is required to help keep the child still and reduce their anxiety levels. If the child is anxious or unco-operative and a thorough examination is not possible, try and maintain in line C-spine immobilisation with or without a collar.

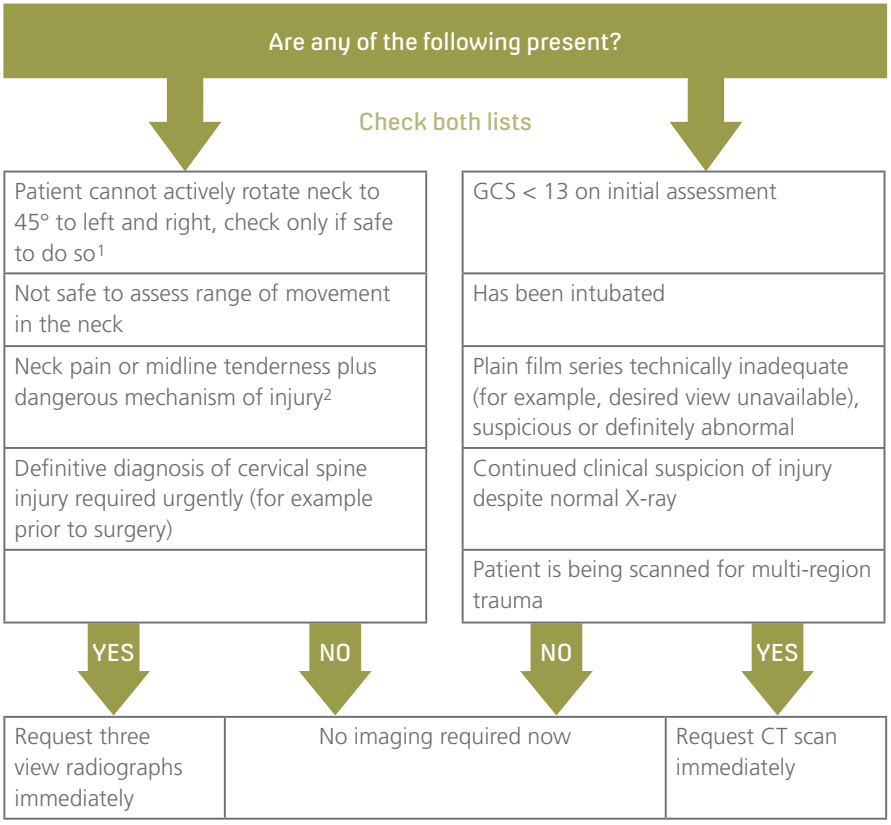
Imaging for cervical spine injuries: *NICE Guideline 56 – Investigation in the ED*

1. Children aged 10 years or more can be treated as adults for the purposes of cervical spine imaging.
2. Children under 10 years should receive anterior/posterior and lateral plain films without an anterior/posterior peg view.
3. Children under 10 have increased risk from irradiation, so restrict CT imaging of cervical spine to children with indicators of more serious injury, in circumstances such as:
   - severe head injury (GCS ≤ 8)
   - strong suspicion of injury despite normal plain films
   - plain films are inadequate.

As a minimum CT imaging should cover any areas of concern or uncertainty on plain film or clinical grounds.

Selection of children (age 10+) for imaging of the cervical spine:

NICE Guideline 56 – Investigation in the ED



1) Safe assessment can be carried out if patient: was involved in a simple rear-end motor vehicle collision; is comfortable in a sitting position in the emergency department, has been ambulatory at any time since injury and there is no midline cervical spine tenderness, or if the patient presents with delayed onset of neck pain.

2) Dangerous mechanism of injury: fall from > 1 m or 5 stairs; axial load to head – for example, diving; high-speed motor vehicle collision, rollover motor accident, ejection from a motor vehicle, accident involving motorized recreational vehicles, bicycle collision.

07.c.iii Needle cricothyroidotomy

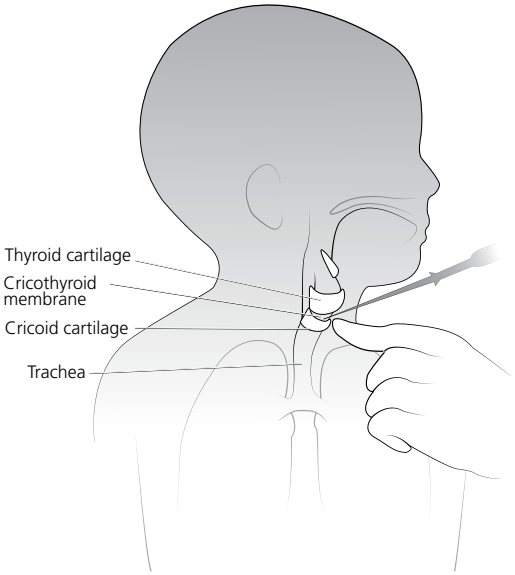
Indications: 'cannot ventilate, cannot intubate'

Equipment needed:

- 18g cannula, 10 ml syringe, 5 ml saline (to confirm the location of trachea, by aspirating air)
- Manujet (with pressure control proportional to age)

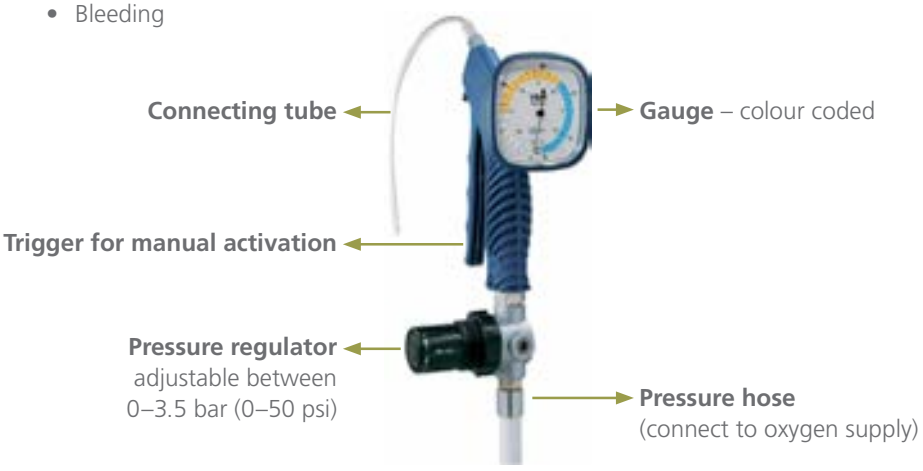
Technique:

- Attach a 10 ml syringe to the cannula. Insert the cannula at an angle of 45 degrees towards the feet through the cricothyroid membrane in the midline.
- Confirm the location of the cannula in the trachea by aspirating air into syringe. Advance the cannula into the trachea and remove the needle.
- Secure the cannula in place and connect the manujet system through the connecting tube that comes with the manujet.
- The other end of the manujet system is connected to the oxygen outlet on the wall or oxygen cylinder.
- Set the pressure limit on the manujet according to the age group, before starting to ventilate. Press the handle on the manujet for about a second. Check the ventilation by seeing the chest rise. Increase the pressure slowly (to a maximum of 40) until satisfactory chest rise or an improvement in oxygenation is achieved.
- It is important to visualise the chest fall as well during the 3–4 second pause between manujet inflations. This is achieved by maintaining a patent airway (supraglottic) or by attaching a three way tap to the tubing connected to the manujet, which is then opened to the atmosphere from the trachea.



Potential complications:

- Failure to identify trachea
- Subcutaneous / mediastinal emphysema
- Bleeding

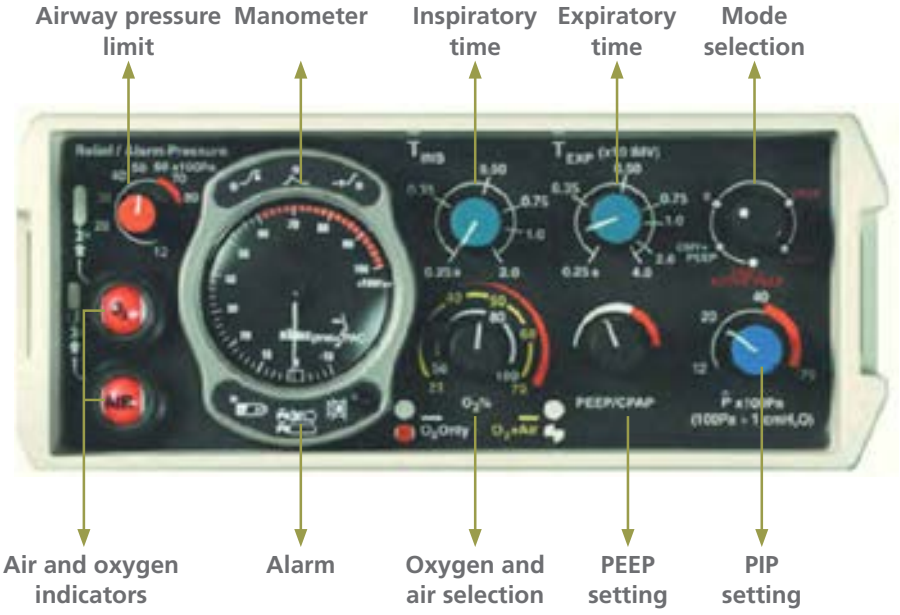


Surgical cricothyroidotomy

Surgical cricothyroidotomy is usually reserved for children above 12 years of age.

07.c.iv Use of Pneupac® babyPAC™ ventilator

- BabyPAC™ is used to ventilate children less than 15 kg. For children more than 15 kg, oxylog 3000/ventipac can be used.



- Ensure the required cables are attached to the babyPAC™. Connect the white oxygen cable to the wall oxygen or a full oxygen cylinder using the Schraeder valve. The black air cable does not need to be connected to an air source for trauma patients. Ensure the ventilator tubing is connected to the babyPAC™ body.

  Correct connection of oxygen is indicated on the front panel of the babyPAC™, with a white ball becoming visible as the oxygen cable is connected.

- Set the dials on the babyPAC™ ventilator for a sedated and muscle relaxed child. These are starting settings and normally will require adjustment once the ventilator is connected to the patient.

  a. Set the pressure limit to 30 cm H_2O. This does not need to be altered at all.

  b. Set the inspiratory time to 0.75 second and expiratory time to 2 seconds.

  c. Set the delivered oxygen to 100%.

  d. Set the PEEP to 5 cm H_2O. This is half way through the white section of the dial. The actual PEEP delivered can be viewed on the pressure dial whilst ventilating the test lung.

  e. Set the peak inspired pressure (PIP) to 20 cm H_2O. The pressure delivered can be viewed on the pressure dial whilst ventilating the test lung.

  f. Set the ventilator mode to CMV + active PEEP (positive end expiratory pressure), by turning the dial anti-clockwise. The ventilator will now begin cycling. Attach a test lung to check.

Test the ventilator alarms and function.

a. Set the ventilator mode to CMV + active PEEP, by turning the dial anti-clockwise. The ventilator will now begin cycling and all the alarm lights will flash in turn. A single burst of the high priority audible alarm is given at the same time. The orange silenced indicator should flash for 60 seconds.

b. Check that the flow is coming from the patient connection port by feeling the flow when placed close to the back of the hand or face.

c. Occlude the proximal connection port of the patient circuit and check that the pressure dial gives a reading between 15–25 cm H_2O during each inspiratory phase. The audible alarm should not sound.

d. Leaving the high pressure alarm setting at 30 cm H_2O, set the inspiratory pressure to 40 cm H_2O. Occlude the proximal connection port of the patient circuit and pneumatic audible alarm should sound, accompanied by the high inflation pressure alarm. The pressure dial should read between 25–35 cm H_2O. After occlusion for one second, the high priority electronic audible alarm will also sound. Turn the inspiratory pressure back down to 20 cm H_2O.

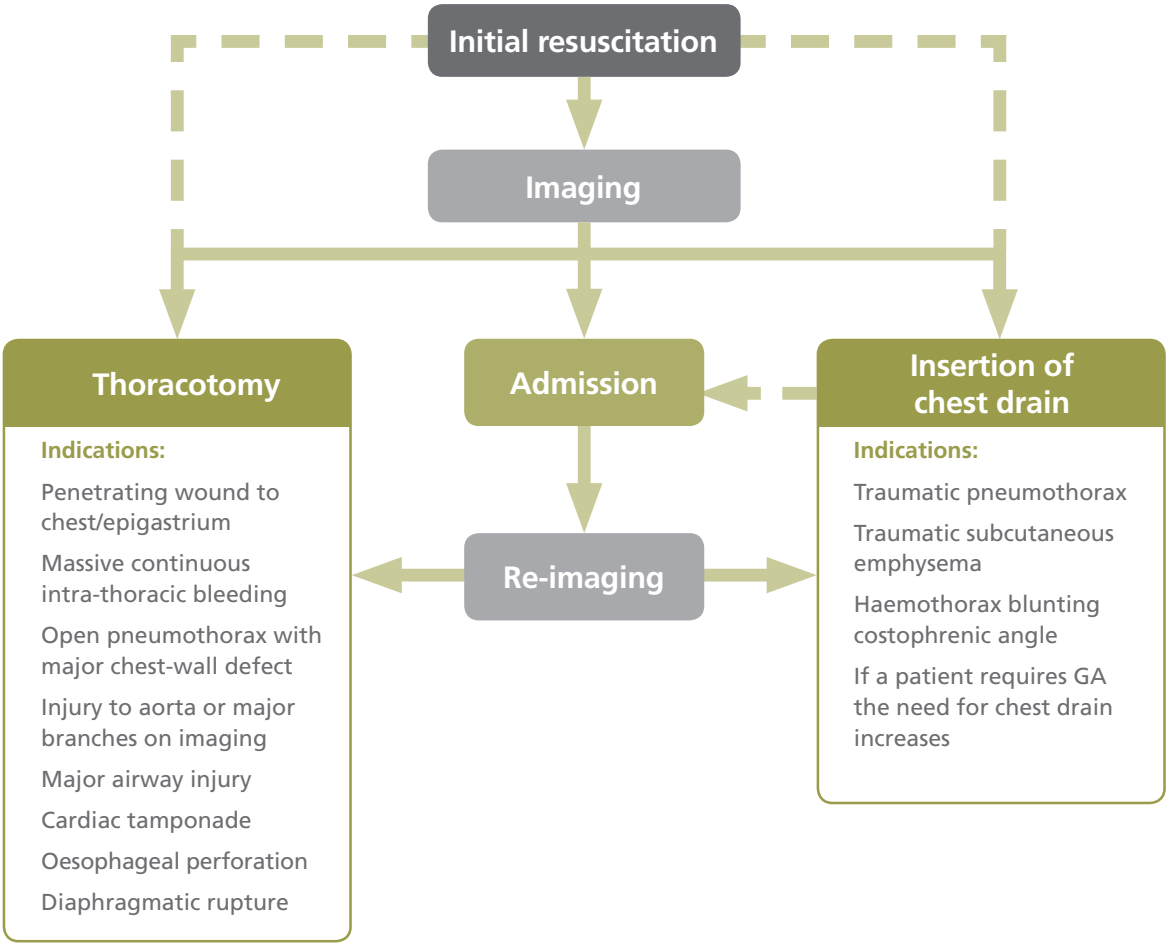
e. Allow the ventilator to cycle with no obstruction at the output port and check that the low inflation pressure (disconnect) alarm operates after 8 seconds.

- Connect the babypac ventilator tubing to an HMEF and $ETCO_2$. For children weighing 4 kg–15 kg, connect the babyPAC™ ventilator circuit to the end tidal CO_2 adaptor and a small heat moisture exchanger and filter (HMEF). For children weighing less than 4 kg, connect the babyPAC™ ventilator circuit to a heat moisture exchanger and end tidal CO_2 adaptor.

- Connect the assembled ventilator circuit to the child's endotracheal tube. Observe the child's chest movement and end tidal carbon dioxide trace. Adjust the ventilator settings according to chest movement, end tidal carbon dioxide monitoring and pulse oximetry. Change back to ventilating the child with a self-inflating bag if no chest movement is observed.

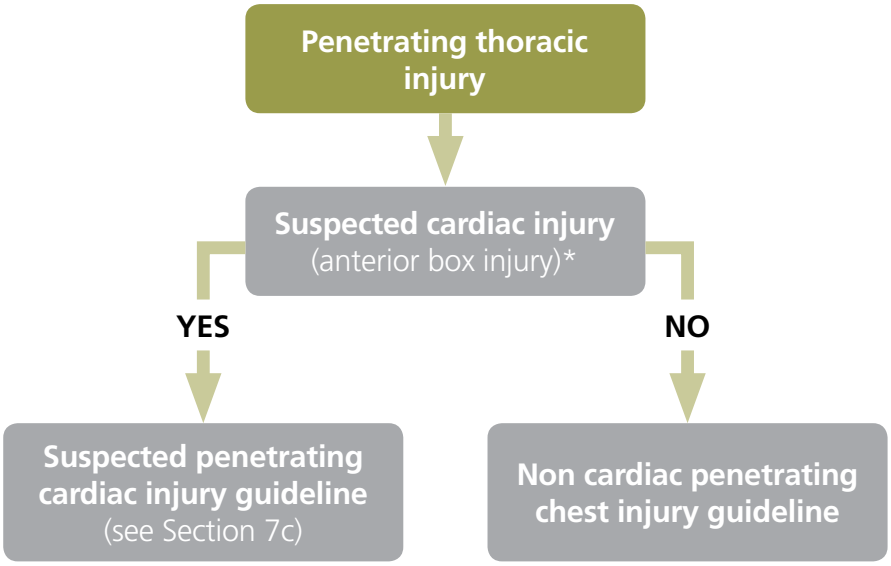
07.c.v Blunt thoracic trauma

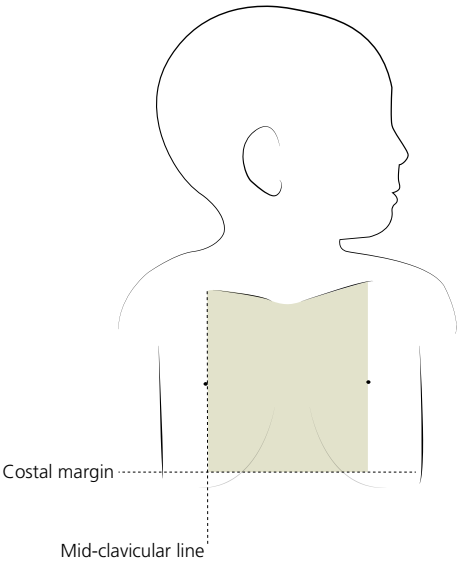
Management of patient with thoracic trauma



07.c.vi Penetrating thoracic trauma

Early decision making algorithm for management of penetrating thoracic trauma





**The anterior box is an anatomical region of the anterior chest and abdomen bounded superiorly by clavicles, mid-clavicular lines laterally and the costal margin in the mid-clavicular line inferiorly.*

Non cardiac penetrating chest injury guideline

For paediatric patients identified with penetrating thoracic trauma, where cardiac injury is NOT suspected:

- Ensure that an emergency thoracotomy set with appropriately sized instruments is available in the resuscitation room.
- Invoke the Paediatric Massive Blood Loss Protocol.
- Dress the wounds to prevent expansion of traumatic pneumothorax.
- On arrival the patient should be managed in accordance with TEMPO.
- Emergent thoracotomy may be required in the peri-arrest or arrest situation.

07.c.vii Suspected penetrating cardiac injury guideline

Penetrating cardiac injury has two main modes of presentation:

- cardiac tamponade
- hypovolaemia.

A patient may display features of both tamponade and hypovolaemia.

When a **penetrating cardiac injury** in a child is **suspected**:

- Paediatric Trauma Call with early alerting of:
  - NCS
  - Emergency Department Consultant
  - Anaesthetic Consultant on-call
  - Consultant Paediatric Surgeon on-call
  - Theatre Co-ordinator.
- Trauma team must ensure that an emergency thoracotomy set is available in the resuscitation room.
- An emergent thoracotomy (in ED or in theatres) should be performed if the patient:
  - arrests in ED / Theatres
  - is peri-arrest
  - arrested within 10 minutes of arriving in ED.
- The decision to perform a thoracotomy should be made by the trauma team leader.

Emergency thoracotomy

Emergent thoracotomy is used to gain rapid access to the thoracic cavity to facilitate immediate intervention in resuscitation. It is sometimes referred to as resuscitative thoracotomy.

Emergent thoracotomy is often aimed solely at managing those patients with a simple cardiac wound leading to tamponade and cardiac arrest.

Indications for emergent thoracotomy

Penetrating injury to the anterior box resulting in:

- cardiac arrest that has occurred within 10 minutes
- effective BLS has been delivered in the period from start of cardiac arrest until the decision to perform the thoracotomy is made.

Contraindications for emergent thoracotomy

Absolute

- No signs of life (or CPR) for >10 minutes.

Relative

- Gunshot wounds
- Blunt injuries

Technique

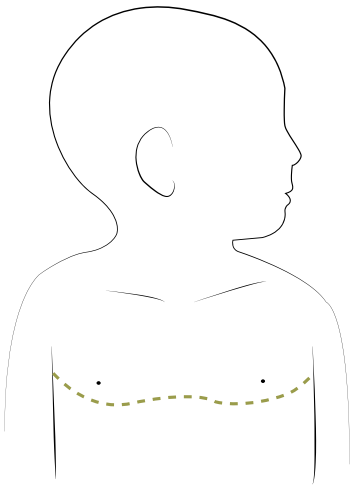
Instruments:

- Skin marker
- Skin prep
- Scalpel
- Sterile scissors (eg. Mayos or Tuff-Cuts)
- Appropriately sized clips
- Gigli saw
- Needle holder
- Forceps – DeBakey's
- Suction
- Foley catheter

Procedure:

Thoracotomy

- Patient should be intubated and ventilated and have good venous access. This can be done simultaneously as performing the thoracotomy by other members of the team.
- Abduct both arms to 90 degrees.
- Mark sites for thoracostomies bilaterally and skin incision (following 4th or 5th ICS, and joining up in midline) with a skin marker.
- Gown and glove.
- Prep skin with chlorhexidine or betadine.
- Create bilateral thoracostomies.
- If the patient has a ROSC after thoracostomies do not proceed to thoracotomy.
- Create long skin incision joining thoracostomies along line that was marked.
  - The incision should extend from right posterior axillary line to left posterior axillary line. Failure to take the incision far enough posteriorly will result is difficulty opening the chest.
  - This first incision should extend through skin, to subcutaneous fat.



- Using a large pair of sterile scissors, extend the thoracostomies to the sternum. Guard against injury to underlying lung and heart during this step.
- Use the scissors to cut the sternum.
  - If the sternum cannot be cut using scissors pass a suitable clip behind the sternum and pass through Gigli saw. Attach the saw blade to handles and saw through the sternum (should not take more than 2–3 pulls).
- Lift the anterior chest open. Get an assistant to hold the chest open.
- Divide the fibrofatty tissue (thymus or remnants) as close to sternum as possible.
- If there is difficulty in lifting the chest high enough, consider extending the incisions posteriorly.

Open pericardium

- Identify the heart. If a tamponade is present, the pericardium will appear tense, dark and bulging.
- Apply two clips to pericardium on anterior surface, tent up and open pericardium between clips.
  - If you go too high the pericardium will be thicker and more difficult to mobilise.
  - Keeping anterior will avoid damage to phrenic nerve, which runs along left lateral border of the heart.
- Divide the pericardium superiorly and inferiorly with scissors.
- Evacuate clot from pericardium using your hands and inspect heart.

Bi-manual cardiac massage

- If the heart makes no spontaneous movement start internal cardiac massage.
- Place right hand behind heart.
- Place left hand over anterior surface of heart with apex lying against palm.
- Squeeze heart from heel of hand towards fingers in a milking motion.
  - Keep hands flat.
  - Avoid direct pressure with the finger tips into heart muscle as this may cause myocardial rupture.

Cardiac wounds

- Identify any cardiac lacerations.
- Small wound (< 1 cm) can be left if there is little blood loss.
- If a cardiac laceration bleeds significantly the options are:

  To suture wound
  - Use pericardial buttresses to prevent the suture tearing through the myocardium.
  - Place the first sutures at the lateral edges of the laceration to prevent it from extending.
  - Be careful of occluding coronary arteries when placing sutures.

  Occlude wound with finger
  - Be careful not to plug the hole with a finger as this may simply extend the wound.

  Occlude wound by inserting a Foley catheter and inflating balloon
  - Do not over inflate balloon of Foley catheter as this may impair ventricular filling.
  - Do not pull too hard on the Foley catheter as this may cause it to tear through the myocardium, leading to a much larger myocardial tear.
  - Counter traction should be applied to the Foley catheter to stop it pulling through the myocardium.

- Ensure that you check the posterior surface of the heart. This can be achieved by gently lifting it up. Be aware that if you lift the heart too much you can occlude the great vessels.

Pulmonary wounds

- If there is an obvious bleeding pulmonary wound it should be sutured.
- For unilateral pulmonary injury with extensive blood loss, and no obvious wound this may be controlled immediately by:

  Clamping the hilum with a Satinsky clamp

  Performing a pulmonary hilar twist[2]

  – Divide inferior pulmonary ligament – there is a small vein immediately below the ligament which acts as a useful landmark.

  – Lower lobe is then rotated anteriorly over the upper lobe (twists vessels around bronchus).

  – Maintain position by packing chest.

  – This results in physiology similar to that seen during pneumonectomy.

Hypovolaemia

- If hypovolaemia turns out to be the primary pathology then the following manoeuvres can be considered:

  – Clamp aorta as low as is possible. This can be achieved by digital pressure to buy time for dissection to allow an aortic cross clamp to be applied.

  – If a Foley catheter has been used to occlude a cardiac laceration this can be used as a route for administering WARM fluids.

  – Fluids given directly into the heart must be *warm* to avoid the risk of cardioplegia.

Ventricular fibrillation

- Should this occur, close chest.
- Apply defibrillator pads to chest wall as normal and defibrillate.
- Ensure that there are no pools of fluid that may cause arcing.

Return of spontaneous circulation (ROSC)

- Following ROSC there will be bleeding from the inferior mammary arteries. This should be controlled by clipping or ligating these vessels.
- If the patient is in theatre all identified injuries should be addressed as clinically appropriate.
- If the patient is in the ED they should be anaesthetised as required and transferred to theatre for completion of the thoracotomy.

07.c.viii Circulation

Fluid management and administration of blood products should be guided by the trauma team leader along with paediatric team. The use of inotropes is not uncommon and should be started when hypotension exists inspite of adequate fluid/blood replacement. Please prepare inotropes according to the monograph.

Intraosseous route

Intraosseous (IO) route is frequently used in emergency resuscitation of paediatric patients. Please follow the local guidance for different brands and types of intra-osseous needles.

Indications:

1. Intravenous fluids or medications are urgently needed and a peripheral IV cannot be established after **two attempts or 90 seconds** and the patient exhibits one or more of the following:
   a. An altered mental status (GCS of 8 or less)
   b. Respiratory compromise (SaO_2 90% after appropriate oxygen therapy, respiratory rate < 10 / > 40 min)
   c. Haemodynamic instability (systolic BP less than age accepted normal).

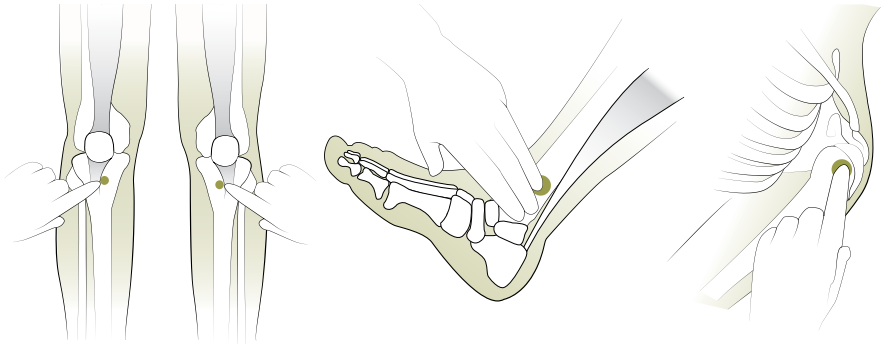
2. IO should be considered **PRIOR to peripheral IV** access attempts in the following situations:
   a. Cardiac arrest (medical or traumatic)
   b. Profound hypovolemia with alteration of mental status
   c. Patient in extremis with immediate need for delivery of medications and or fluids.

Contraindications:

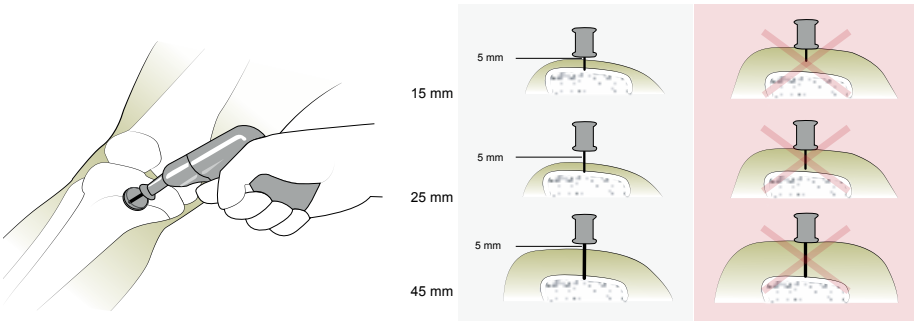
a. Fracture of the bone selected for IO insertion (consider alternate site).
b. Excessive soft tissue at the insertion site with the absence of palpable anatomical landmarks (consider alternate site).
c. Previous significant procedures (IO within 24 hours – consider alternate site).
d. Infection at the site selected for insertion (consider alternate site).

Procedure:

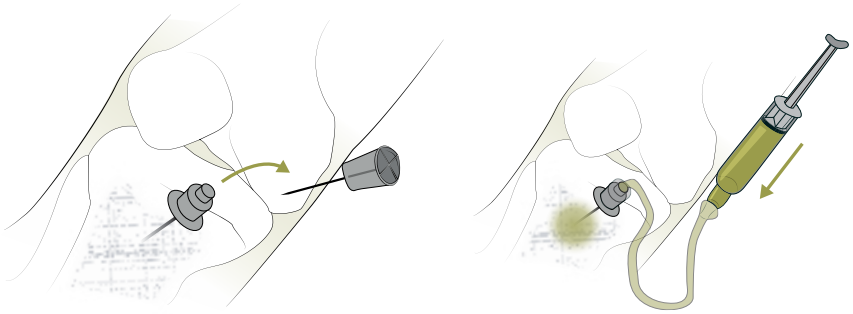
- If patient is conscious informed verbal consent should be obtained.
- Use age appropriate needle (EZ-IO, the most commonly used intraosseous needle in the region comes in three sizes)
  - EZ-IO PD® 15mm (3–39 kg)
  - EZ-IO AD® 25mm (40 kg and over)
  - EZ-IO AD® 45mm (excessive tissue).
- Locate appropriate insertion site



- Aseptic technique.
- Stabilise site (this may need additional help from second person)
- Position driver at 90 degree angle to the insertion site as shown in figure. Gently power or press needle set down until needle touches the bone.

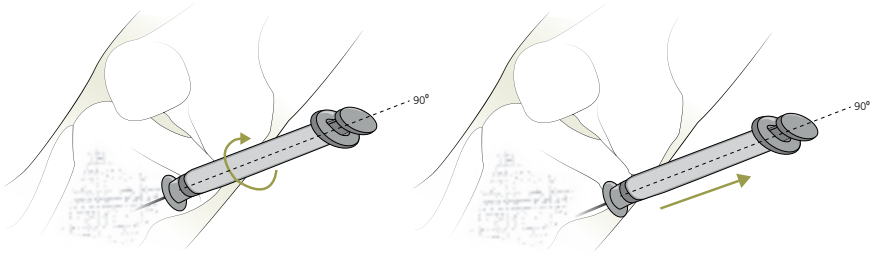


- Penetrate the bony cortex by squeezing the driver's trigger and applying gentle steady downward pressure.
- Release the driver's trigger and stop insertion process when sudden 'give' or 'pop' felt or desired depth is achieved.
- Remove power driver and stylet.



- Confirm placement by aspirating through needle and sample can be used for analysis.
- Consider slow administration of 1–2 ml of 2% lignocaine through the EZ-IO prior to starting infusion as bolus infusion can cause severe discomfort.
- Flush the catheter with 10 ml syringe bolus of saline. **NO FLUSH = NO FLOW**
- Start infusion under pressure (syringe bolus, infusion pumps, pressure bag).
- Secure catheter and tubing. Apply dressing and wrist band.
- Frequently monitor IO site for extravasation of fluid.

- IO catheter **MUST** be removed within 24 hours. Attach luer lock syringe and continuously and gently rotate clockwise while applying traction. Don't **ROCK** or **BEND** the catheter during removal.



Cautions: stylet and catheters are not MRI compatible.

07.c.ix Trauma (damage control laparotomy)

Paediatric trauma cases that require an immediate damage control laparotomy are very rare; therefore, this should be undertaken by a consultant general surgeon with experience of damage control surgery (unless a consultant paediatric surgeon is available). Consultant to consultant discussions to facilitate this should be undertaken for each case. Advice and help from paediatric surgeons can be obtained through the NCS.

Table 1 – Mean arterial pressure targets

Use vasopressors / inotropes (preferably noradrenaline if central access possible, otherwise dopamine) to maintain MAP if needed.

Age	MAP
< 2 years	> 55mmHg
2–6 years	>60 mmHg
> 6 years	>70 mmHg

Environment

- The transfer of severe traumatic brain injury is time-critical because the patient might need urgent surgery to avoid death and/or neurological morbidity. Early identification and urgent transfer to a neurosurgical unit is the key for the best outcomes in these children; once identified, the patient needs to be transferred to the Major Trauma Centre without any delay. Please call NCS to co-ordinate transfer and advice from the relevant specialists.

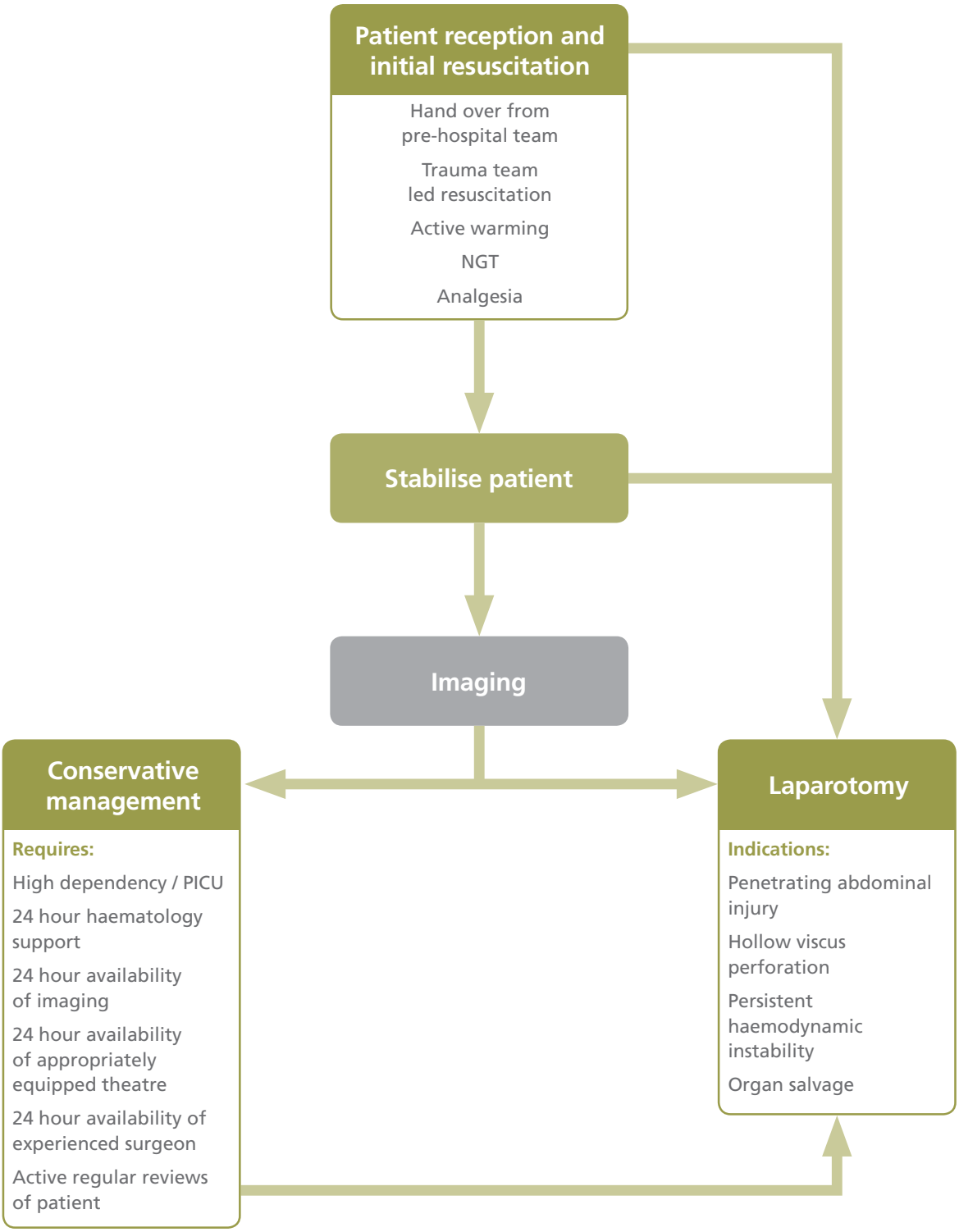
Checklist before transfer of a head injured child

- Ensure the patient is stable: consider items on transfer checklist
- Ensure the NCS consultant knows the expected time of arrival
- Ensure adequate escort: airway competent doctor (usually anaesthetist) and appropriately trained paramedic / nurse, or the Major Trauma Outreach Service
- Minimise the number of trolley transfers, 15° head up tilt
- Prepare boluses of IV anaesthetic before manipulation or movement if suspected raised ICP
- Use mannitol 0.5–1.0 g/kg or hypertonic saline (2–4 ml/kg if 5%) if raised ICP on CT or pupillary inequality
- Ensure adequate monitoring: ECG, SpO_2, invasive BP (or automatic NIBP), $ETCO_2$
- Check ABG and Hb prior to transfer. Catheterise before transfer
- Check spare intubation equipment, check oxygen cylinders, self-inflating resuscitation bag
- Check emergency drugs, IV fluids, IV access equipment, inotropes

Blunt abdominal trauma

Blunt abdominal trauma in children tends to be managed in a much more conservative manner than in adults. Children are abdominal breathers. Therefore, any abdominal injury will compromise the ventilatory effort of children. The task of initiating interventions, which improve ventilation in these patients, is as important to the managing clinician as making decisions regarding the management of the intra-abdominal injury.

General algorithm for managing blunt abdominal trauma in a child



Considerations in ED resus:

- Ensure blood is available early in the resuscitation. The paediatric massive blood loss protocol should be initiated as soon as the presence of significant blunt abdominal trauma is recognised.
- Place a nasogastric tube in all children with blunt abdominal trauma if no head injury. All children with suspected intra-abdominal injury should receive antibiotics (due to the risk of hollow viscus perforation). All children should receive adequate analgesia at an early stage. This will help their breathing as well as being humanitarian.
- Hypotensive resuscitation has no place in the management of children with blunt abdominal trauma; a child possesses a large physiological reserve, and so hypotension is a preterminal sign.
- All trauma patients should have a urinalysis.

- **Initial imaging**
  The gold standard imaging modality for children with blunt abdominal trauma is CT scan with contrast. Only CT imaging can give accurate information regarding grading of injury to solid intra-abdominal organs.
- Decisions regarding conservative management should be based on:
  - the haemodynamic status of the child
  - results of CT imaging.
- Discuss the patient early with a paediatric surgeon for all management decisions and the best place for patient's management.

- **Monitoring**
  Record observations every 15 minutes for the first 4 hours of admission, and then every 30 minutes for the first 12 hours. They should then be recorded hourly until the first 24 hours is complete.

  Fluid balance should be closely monitored so that an accurate picture is obtained.

- For conservative management:
  - two routes of vascular access should be obtained
  - bloods for cross-matching, full blood count and coagulation studies
  - fluid resuscitate patient using 10ml/kg boluses of warm fluids (after 40mls/kg crystalloid has been given since injury blood should be used)
  - correct hypothermia and coagulopathy if present.
  - strict bed rest.

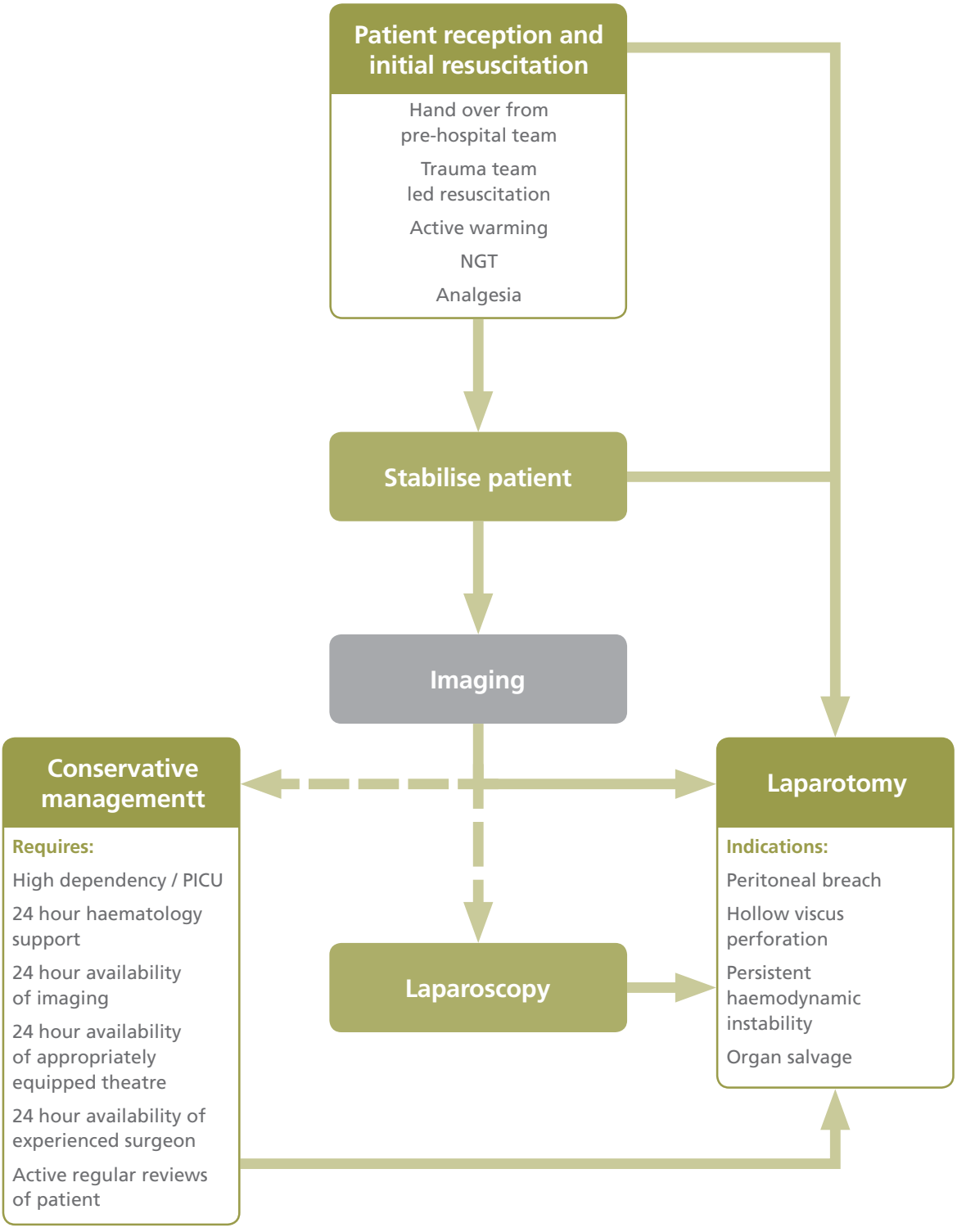
The decision that conservative management has failed and that the patient requires a laparotomy rests solely with the responsible surgeon.

Always consider if interventional radiology may be an alternative to laparotomy.

Penetrating abdominal trauma

As a general rule all penetrating wounds require exploration.

General algorithm for managing penetrating abdominal trauma in a child



- Paediatric massive blood loss protocol should be activated early.
- If the patient is stable imaging (CT scan with IV contrast) should be performed to gain more information regarding the exact nature of the injury.
- There is significant risk of major vessel injury.
- If a foreign body is still in place, it should not be removed in the emergency department. It should only be removed in a theatre, which is fully equipped and staffed. When the foreign body is being removed, the surgeon must be prepared to perform an emergency laparotomy to gain vascular control if the patient deteriorates rapidly.

- Penetrating trauma may involve more than one region:
  - stab wounds of the lower intercostal spaces may involve the chest and the abdomen
  - stab wounds of the anterior box (see section 7.c.vi) may traverse the peritoneum to penetrate the heart.

- If there are clear signs of peritoneal breach (free air on imaging, peritonism, abdominal distension) urgent laparotomy should be performed. Ideally this should be performed by a paediatric surgeon. If the patient is too unstable for transfer the case should be discussed with a paediatric surgeon. If there is doubt regarding peritoneal breach, the wound should be explored under general anaesthetic, with the surgeon able to proceed and deal with findings. Exploration under local anaesthetic is rarely satisfactory.

07.c.xii Pelvic injuries

Pelvic injuries should be assessed and managed by an orthopaedic surgeon. The following is a guide should an orthopaedic surgeon not be present initially

Beware! Paediatric patients are not always tachycardic at presentation. Apply a pelvic splint if there is suspicion of potential injury.

The initial management aims to:

- splint the pelvis to provide tamponade and prevent movement
- detect the presence of a pelvic fracture with an early X-ray / CT
- differentiate between pelvic and intra-abdominal bleeding.

The following is the standard operating procedure:

- Apply pelvic binder with history of blunt trauma and hypotension (see below).
- Pelvic binder can be applied even if lateral compression injury is suspected.
- The binder should be placed around the trochanters, not the iliac crests.
- If binder applied pre-hospital leave it. Check position and X-ray.
- If hypotensive, begin fluid resuscitation.
- Do NOT examine the pelvis for mechanical stability.
- Do NOT logroll the patient until the pelvis is cleared.
- Obtain an early pelvic X-ray (or immediate CT) to clear the pelvis.

If this X-ray is normal, the pelvis is cleared: remove binder and then consider repeating the X-ray. (An AP compression – openbook – injury can be perfectly reduced by the binder so that the plain X-ray and CT scan is normal. A check X-ray after removal of the binder will identify this problem.) If there is haemodynamic instability, replace the binder.

If a pelvic fracture is present:

- You can leave binder in place for up to 24 hours unless patient has severe neurological deficit (eg. paraplegia).
- Examine carefully for open wounds, especially in the perineum.
- If there is an open wound, including vaginal lacerations, antibiotics must be administered. Unless contraindicated, Augmentin, Gentamycin and Metronidazole are recommended.
- How essential is the logroll?
  - If unilateral pelvic injury: log-roll to opposite side.
  - If bilateral pelvic injury: avoid log-roll if at all possible.
- Female patient: catheterise if able. See catheterisation guidance below.
- Male patient: refer to catheterisation guidance below.

Adequate examination of the perineum, vaginal and rectum in paediatric patients will probably require an examination under anaesthesia. If so this needs to be co-ordinated with the orthopaedic team to ensure that the patient is moved in an appropriate manner to allow examination of the perineum, whilst reducing movement and preventing exacerbation of the pelvic injury.

Potential urethral injuries

If there are any concerning features present, then the case should be discussed with the on-call paediatric surgical consultant or one of the consultant paediatric urologists prior to catheterising the child.

Concerning features in a child with a pelvic fracture are:

- blood at the meatus
- haematuria since injury.

In the absence of any concerning features, in particular blood at the meatus, or any history of haematuria since the accident, a single, gentle attempt at passing a urinary catheter may be undertaken. Sterile technique must be used and the procedure performed by an **experienced surgeon or urologist** – this is not the time to teach the technique.

- If clear urine drains, then all is good.
- If there is any element of blood staining in the fluid draining from the catheter, then a contrast study (retrograde cystogram) is mandated.

If there is any blood at the meatus prior to catheterisation, or any history of haematuria since accident, then a retrograde urethrogram is indicated before attempts at catheterisation.

- **Urethrogram positive:** call consultant paediatric surgeon and/or paediatric urologist. Decisions now very difficult. If a suprapubic catheter is needed suggest discussion with the pelvic and acetabular surgeons as this will have major implications for any internal fixation.
- **Urethrogram negative:** catheterise. If haematuria present, perform a retrograde cystogram.

Suprapubic drainage if required should be achieved under general anaesthesia.

07.c.xiii End of life and organ donation in children

The death of a child is an uncommon event but needs to be handled with professionalism and sensitivity, especially with regard to supporting the family involved. A multidisciplinary approach is required with early involvement of the paediatric medical and nursing teams.

Paediatric organ donation and transplantation can have a significant life extending benefit to their recipients. Increasing identification and referral of potential donors suggests that should a child be admitted to the ED with a catastrophic brain injury they should be considered for organ donation regardless of age. Therefore because of the specialist expertise required both in withdrawal of life support in children, progression to declaration of brain death and possible organ donation, best practice dictates that this should be carried out after transfer to the paediatric intensive care unit (PICU). In addition, the withdrawal of life support in a child involves extensive parental discussion and support often taking days. Early referral to the paediatric intensive care consultant via NCS is advised to facilitate admission. Referral and discussion with a specialist nurse for organ donation (SNOD) can then be initiated by the PICU team.

Practice does not differ from adult best practice and the family must be allowed time to understand and accept organ withdrawal of life support before organ donation can be discussed. The most appropriate environment for this is the PICU.

07.d • Rehabilitation

The adult rehabilitation section should be read alongside this guidance as many of the overriding principles are relevant to children.

Goals of rehabilitation

- Children have ongoing developmental needs. The goal of paediatric rehabilitation is not just to return to pre-injury levels of functioning, but for the child to continue learning new skills.
- Children should be cared for within a specialised designated service which meets their complex and rapidly changing rehabilitation needs.
- It is essential to have an identified lead consultant (likely a paediatrician) to co-ordinate care and liaise with other specialists as required.
- All staff across each discipline must be able to understand and manage developmental change within the context of the recovery process.

Family involvement

- In some instance, the child may not be the only member of the family injured.
- A holistic approach to the needs of the family is essential and the whole family should be kept informed at every stage and involved in any decision making.
- It has been shown that good, high quality support for and with the parents is likely to improve outcomes for children as they grow up.

Rehabilitation needs

- From the outset, every injured child should have a rehabilitation prescription tailored to their needs and should involve co-ordination of care between the hospital, local services and the community team.
- All services should be involved from an early stage, including education, educational psychology, social care, psychology, physiotherapy, speech and language, occupational therapy and primary care.
- Definitive planned surgery for amputations should be performed in consultation with the consultant in rehabilitation medicine and prosthetic services, allowing pre-amputation discussion with the child (if appropriate) and parents.
- Early discharge planning, in consultation with the local hospital and community team, is the key to effective and seamless transfer of care.

Transition

- Cognitive, emotional and behavioural problems may become worse at times of change.
- Further assessment and rehabilitation will become essential during transition between schools and different education systems, particularly moving from primary to secondary education.
- It is also important to ensure seamless transition from paediatric to adult services by planning ahead as this can be a very stressful time for the family.
- It may be necessary to continue rehabilitation prescription until early adulthood in order to meet the needs of an individual.
- Continued liaison should ensure continuity of care and ideally a key worker allocated prior to discharge from hospital.

Discharge and ongoing care

- Unlike adults, children who make good recovery from impairment for a specific time should not be discharged from the rehabilitation prescription; brain development is not complete until around the age of 22 and many acquired injuries may not show themselves for several years.
- Children and young people often go on to develop cognitive, emotional and behaviour problems several years after the initial injury as they move from childhood to adolescence to adulthood.

Helpful information and support groups for families and professionals

Child Brain Injury Trust
www.braininjurytrust.org.uk

Helpline: 0303 303 2248
email: info@cbituk.org

Headway
www.headway.org.uk

Helpline: 0808 800 2244
email: helpline@headway.org.uk

The Childrens Trust Brain Injury Hub
www.braininjuryhub.co.uk

Tel: 01737 365 000