CHAPTER 13
The structured approach to the seriously injured child

LEARNING OBJECTIVES
In this chapter, you will learn:
- the structured approach to the seriously injured child

13.1 INTRODUCTION

Children are affected differently by major injuries depending on their size – physically, physiologically and psychologically. A young child cannot describe pain, or even localise symptoms. The more frightened children become, the "younger" they behave, and the less they can cooperate with management. Symptoms may be denied vehemently. Their inexperience, lack of awareness of danger and denial of threats posed puts them at particular risk of trauma. The relative elasticity of their tissues allows more energy to be transmitted to other body parts, with less being dissipated at the impact site. Their relatively small size affects the pattern of injuries sustained. For example, the point of impact of a car bumper is higher on the body of a child pedestrian, leading to different anatomical injuries than those sustained in the same incident involving an adult.

Although traumatised children have a number of unique problems, this in no way affects the validity of a structured approach. By following the principles outlined, problems should be identified and treated in the same order of priority as for adults. It should be emphasised from the start that, although assessment and management are discussed separately, this is purely to allow the steps to be shown clearly. In trauma resuscitation, it is essential to intervene immediately, as soon as a problem is found.

The form of the structured approach is shown in the box.

Structured Approach
Immediate
- Primary survey (immediate life threats)
- Resuscitation

Focussed
- Secondary survey (key features)
- Emergency treatment

Detailed Review
- Reassessment (system control)
- Continuing stabilisation and definitive care

13.2 PRIMARY SURVEY

During the primary survey life-threatening conditions are identified. Assessment follows the familiar ABC pattern with significant additions:

< Catastrophic external haemorrhage >
Airway with cervical spine control
Breathing with ventilatory support
Circulation with haemorrhage control
Disability with prevention of secondary insult
Exposure with temperature control

<Catastrophic External Haemorrhage>

In trauma <C> ABC has become the established approach for casualty care following blast or significant penetrating trauma. For children too, obvious external exsanguinating haemorrhage becomes the immediate priority. Applying direct pressure specialised haemostatic dressings or a tourniquet must be done instantly in the appropriate circumstances. The assessment can then continue with the ABC sequence.

Airway and cervical spine

Airway assessment following trauma has the highest priority and should follow the standard technique discussed in Chapters 4 and 5.

LOOK
LISTEN
FEEL

Consider protecting the cervical spine if the mechanism of injury suggests the possibility of a cervical spine injury. If protection is considered necessary, start with *manual in-line stabilisation (MILS)* by a competent assistant or if this is not possible, consider using head block and appropriate strapping.

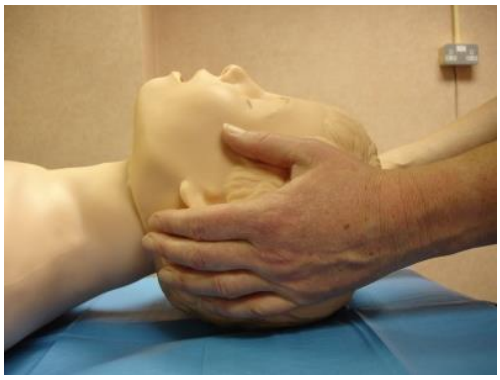

Figure 13.1: Manual in-line stabilisation

Breathing

After dealing with any immediate airway problems, breathing should be assessed as the next priority. As discussed in earlier chapters, the adequacy of breathing is checked in three domains – the effort of breathing, the efficacy of breathing and the effects of inadequate respiration on other organ systems.

These are summarised in the box. When examining the chest, the *look*, *listen* and *feel* approach is again appropriate, but it is important to remember to *percuss* also to distinguish a tension pneumothorax from a massive haemothorax.

Assessment of the adequacy of breathing

Effort of breathing

- Recession
- Respiratory rate
- Inspiratory or expiratory noises
- Grunting
- Accessory muscle use
- Flare Flaring of the alae nasi

Efficacy of breathing

- Breath sounds
- Chest expansion
- Abdominal excursion

Effects of inadequate respiration

- Heart rate
- Skin colour
- Mental status
- *Don't forget to percuss each side of the chest*

The normal resting respiratory rate changes with age. These changes are summarised in Table 13.2.

Table 13.2. Vital signs: approximate range of normal

Age (years)	Respiratory rate (breaths/min)	Systolic BP (mmHg)	Pulse (beats/min)
<1	30–40	70–90	110–160
1–2	25–35	80–95	100–150
2–5	25–30	80–100	95–140
5–12	20–25	90–110	80–120
>12	15–20	100–120	60–100

Circulation

Circulatory assessment in the primary survey involves the rapid assessment of heart rate and rhythm, pulse volume and peripheral perfusion (colour, temperature and capillary return, remembering that exposure to cold prolongs the capillary refill time in healthy people – test on the sternum). In addition, a further check should be made for significant external haemorrhage (and pressure applied if appropriate). Blood pressure takes too long to perform as part of the primary survey itself, but it should be measured as an adjunct (afterwards or in parallel by other personnel). An abnormal respiratory rate and altered mental status in the presence of circulatory compromise indicate the effect of shock on other organ systems. Using these measures an estimate of the need for fluid replacement can be made as shown in Table 13.1. Again,

remember the caveats about heart rate, differential pulse volume and capillary refill time outlined in Chapter 7. It can be difficult to assess the circulatory state of an injured child: in blunt trauma large blood losses are the exception rather than the rule. A single abnormal sign is not predictive of shock, but more than two of the signs tending to the same conclusion is predictive of the requirement for fluid replacement. See Table 13.1.

Table 13.1. Recognition of clinical signs indicating blood loss requiring urgent treatment

Sign	Indicator
Heart rate	Marked or increasing tachycardia or relative bradycardia
Systolic BP	Falling
Capillary refill time (Normal <2 sec)	Increased to >4–5 sec
Respiratory rate	Tachypnoea unrelated to thoracic problem
Mental state	Altered conscious level unrelated to head injury

Circulatory assessment must take into account the fact that resting heart rate, blood pressure and respiratory rate vary with age. The normal values are shown in Table 13.2. Note that the systolic blood pressure in children who have been injured is raised above normal and that the degree of hypertension is unrelated to age or trauma severity. The clinician should therefore view with suspicion a systolic pressure in the lower part of the normal range in an injured child.

Disability

The assessment of disability during the primary survey consists of a brief neurological examination to determine the conscious level and to assess pupil size and reactivity. The conscious level is described by the child's response to voice and (where necessary) to pain. The AVPU method describes the child as *alert*, *responding to voice*, *responding to pain* or *unresponsive* and is a rapid, if crude, assessment.

A Alert
V Responds to Voice
P Responds only to Pain
U Unresponsive to all stimuli

If the child does not respond to voice, then a painful stimulus is needed. If the child responds to pain, it is best to note what the eyes and limbs did and what sounds or words were uttered, rather than simply categorising the child as 'P'. Simple descriptions that will form the basis of a subsequent formal GCS, such as 'opening eyes to pain' or 'localising to pain' are much more informative than 'P' alone. A child who does not open his eyes to pain, utters no sounds and extends his limbs has a Glasgow Coma Score of 4 and is likely to need prompt airway protection. A child who opens her eyes to pain, shouts recognisable words inappropriately and localises to the stimulus has a GCS of 10 and is at much less immediate risk. Both are classified as 'P'.

Exposure

In order to assess a seriously injured child fully, it is necessary to take his or her clothes off. Children become cold very quickly, and may be acutely embarrassed when undressed in front of strangers. Although exposure is necessary the duration should be minimised, and a blanket provided at all other times.

Conditions identified

By the end of the primary survey, the following conditions may have been recognised and should be treated as soon as they are found:

- Airway obstruction
- Tension pneumothorax
- Open pneumothorax
- Massive haemothorax
- Flail chest
- Cardiac tamponade
- Shock (haemorrhagic or otherwise)
- Decompensating head injury

13.3 RESUSCITATION

Life-threatening problems should be treated as they are identified during the primary survey.

<Catastrophic External Haemorrhage>

Catastrophic external haemorrhage must be contained immediately. In this situation, applying direct pressure with a dressing pad, applying a tourniquet to a limb, or packing an open wound with a haemostatic substance must be done instantly.

Airway and cervical spine

Airway

The airway may be compromised by material *in the lumen* (blood, vomit, teeth or a foreign body), by damage to or loss of control of the structures *in the wall* (the mouth, tongue, pharynx, larynx or trachea) or by external compression or distortion from *outside the wall* (e.g. compression from a pre-vertebral haematoma in the neck or distortion from a displaced maxillary fracture). The commonest cause is from occlusion by the tongue in an unconscious, head-injured child. Whatever the cause, airway management should follow the sequence described in Chapters 4 and 5 bearing in mind the need to protect the cervical spine. This is summarised in the box.

Airway management sequence

- Jaw thrust
- Suction/removal of foreign body under direct vision
- Oro/nasopharyngeal airways
- Tracheal intubation
- Surgical airway

Head tilt/chin lift is not recommended following trauma, because cervical spine injuries may be made worse.

Cervical spine

For any mechanism of injury capable of causing spinal injury (or in cases with an uncertain history), the cervical spine is *presumed to be at risk*, until it can be *cleared*. Children (and adults) can suffer spinal cord injury despite normal plain radiographs. If ignored, ligamentous instability without radiographic evidence of a fracture can have devastating consequences.

If the child is unconscious or cooperative, the head and neck should be immobilised initially by manual in-line stabilisation and then, if necessary, by using head blocks and straps.Too rigid immobilisation of the head in such cases may increase leverage on the neck as the child struggles. It is imperative that the child is treated from the outset in a gentle, supportive atmosphere in a way that is appropriate for their age and that parents remain at the bedside, so that anxiety is minimised and unnecessary interventions are avoided.

Vomiting poses an obvious threat to the unprotected airway, especially if there is also a risk of spinal injury. Positioning the child safely and providing airway suction are the key interventions if the child vomits. If the child has only just arrived and the head, chest, pelvis and legs are still strapped securely to a spine board, then it is feasible to tilt the board temporarily while clearing the airway. Once the body straps have been removed, turning the child into the lateral position puts the spine at risk, unless it can be carried out *immediately* by three or four carers as a properly coordinated log-roll. It is generally much simpler and more effective to tip the trolley head-down (so that the trachea runs "uphill") and provide suction to the mouth and pharynx.

If the spine has not been cleared, manual in-line immobilisation will be needed for intubation if indicated. Clearly, if the child is paralysed, sedated and ventilated the neurological examination cannot be done and spinal immobilisation may need to be maintained for prolonged periods in such cases. Computed tomography or magnetic resonance imaging may be necessary to assess the risk to the spinal cord in this event.

Breathing

If breathing is inadequate, ventilation must be commenced. Initially bag–mask ventilation should be performed. Generally speaking, a child who requires bag–mask ventilation initially following trauma will subsequently require intubation to control the airway. Following intubation, mechanical ventilation can be commenced.

The indications for intubation and mechanical ventilation are summarised in the box.

Indications for intubation and ventilation

- Persistent airway obstruction
- Predicted airway obstruction eg inhalational burn
- Loss of airway reflexes
- Inadequate ventilatory effort or increasing fatigue
- Disrupted ventilatory mechanism eg severe flail chest
- Persistent hypoxia despite supplemental oxygen
- Controlled hyperventilation required to prevent secondary brain injury.

If breath sounds are unequal then pneumothorax, haemo-pneumothorax, misplaced tracheal tube, blocked main bronchus or pulmonary collapse, diaphragmatic rupture, pulmonary contusion and aspiration of vomit or blood should be considered, and appropriate measures should be taken. (see relevant chapters)

Circulation

All seriously injured children require vascular access to be established urgently. Two relatively large intravenous cannulae are mandatory. Peripheral veins are preferred, but in the event of failure, other options should be considered:

- Direct cannulation of the external jugular vein
- Indirect cannulation of the femoral vein using the Seldinger technique ("wire through needle" followed by "catheter over wire")
- Intraosseous cannulation of the tibia, femur or humerus
- Cut-down onto the cephalic vein at the elbow or the long saphenous vein at the ankle

Intraosseous infusion is warranted from the outset in very urgent situations or later if other options have failed. It usually proves to be quicker and easier than the more specialised techniques mentioned above. Vascular access techniques are discussed in detail in Chapter 21.

Central venous cannulation (other than by the femoral route) is hazardous in children and should not be attempted by the inexperienced clinician. Femoral cannulation is not without risk, given the proximity of the site to the femoral joint. The main use of an internal jugular or subclavian line is for monitoring central venous pressure.

If there are no immediate signs of shock, there is no need to give an *immediate* fluid bolus to an injured child. If there are signs of circulatory compromise, *uncontrolled* bleeding must be considered and confirmed or excluded quickly and pragmatically. Surgeons who can deal with any of the injuries that are suspected should be called in immediately (if they are not already part of the trauma team) and the Operating Theatre team alerted.

There is evidence that vigorous fluid administration is harmful in the presence of uncontrolled bleeding. The concern is that increasing the blood pressure back to normal rapidly may disrupt early clot formation and dilute the clotting factors, leading to greater blood loss. Fluid resuscitation therapy strategy depends on whether or not severe uncontrolled bleeding is suspected.

If there is no reason to suspect severe uncontrolled bleeding or if it has been excluded by rapid clinical examination, supported if necessary by simple imaging (e.g. chest x-ray, pelvic x-ray and trunk ultrasound), clear fluid boluses may be given in the usual dose of 10 ml/kg of crystalloid (e.g. 0.9% saline), with careful review after each aliquot. Blood and blood products should be considered if there are signs of significant bleeding or uncontrolled haemorrhage from the outset. If a pre alert has been given suggesting that the child is bleeding uncontrollably or blood has been commenced in the pre hospital phase the massive haemorrhage protocol must be initiated (refer to the management of severe uncontrolled haemorrhage in trauma section below)

If the haemodynamic state worsens or does not return to normal, the possibility of uncontrolled bleeding should once again be considered. It is recommended that in severe uncontrolled bleeding, blood and blood products should be commenced along with the administration of Tranexamic acid 15mg/kg immediately the child's condition should be constantly re assessed and surgical intervention considered.

Disability

If the primary survey reveals that the child has a de-compensating head injury, *neurological* resuscitation is required. If the Glasgow Coma Score is less than 8 and there are pupil inequalities, immediate intervention is necessary. Lesser degrees of unconsciousness or the presence of focal signs also indicate the need for urgent action. Remember that the scale is modified in the smaller child.

Interventions to be considered include:

- Oxygenation (which will already have been addressed)
- Control of carbon dioxide tension (by controlling ventilation)
- Maintenance of blood pressure to support cerebral perfusion
- Mannitol or hypertonic saline (if indicated) to lower the intracranial pressure
- Anaesthesia/sedation/analgesia to reduce cerebral metabolism
- Prompt treatment of any fits

As soon as a serious head injury is suspected, a CT scan should be ordered and the neurosurgical team (which will usually be off-site) alerted.

This will help to reduce delay in reaching a decision on the need for neurosurgical intervention. A full Glasgow Coma Score is needed at this point.
Other procedures carried out during the resuscitation phase

Chest and pelvic radiographs, if indicated, are part of the primary survey and can inform the clinical diagnosis. In unstable or high-risk children, it is appropriate to perform these radiographs during the resuscitation phase in the resuscitation room bay.

When venous access is achieved and blood is taken for cross-matching, samples for other investigations should be taken at the same time, including full blood count, clotting screen, amylase/trypsinogen, urea and electrolytes. Remember to measure the glucose, especially in adolescents (who are prone to both injury and hypoglycaemia after drinking alcohol) and in very small children.

A brief history will usually have been given by the ambulance staff together with details of the child's condition at the scene. This information is useful in allowing the clinician to consider what injuries the mechanism might have produced and to assess whether clinical deterioration is occurring. Monitoring of the respiratory rate, pulse rate, blood pressure, and oxygen saturation are important adjuncts to the primary survey and resuscitation. A urinary catheter and a gastric tube may be inserted during this phase in severely injured children.

Urinary catheterisation

In a child, a urinary catheter should only be inserted if the child cannot pass urine spontaneously or if continuous accurate output measurement is required to achieve stabilisation after a serious physiological insult. The route (urethral or supra-pubic) will depend on factors related to signs of urethral, bladder, intra-abdominal or pelvic injury (such as blood at the external meatus, or bruising in the scrotum or perineum; see Chapter 15). If a boy requires urethral catheterisation, urethral damage must be excluded first. The smallest possible silastic catheter should be used in order to reduce the risk of subsequent urethral stricture formation. If any doubt exists then the decision to catheterise the child can be left to the responsible surgeon. Urine should be stick-tested and sent for microscopy

Nasogastric tube placement

Acute gastric dilatation is common in children and the stomach should be decompressed. If there is evidence or suspicion of basal skull fracture, the tube should not be passed by the nasal route. In the intubated patient, the oral route is a simple alternative.

Analgesia

Analgesia can usually be administered just after completing the primary survey and resuscitation. A brief examination of the conscious level and of the body part in pain helps to set the baseline for titrating the dose. Morphine is the standard drug in acute trauma care. A dose of 0.1–0.2 mg/kg should be drawn up in a convenient concentration (e.g. 1 mg/ml in 0.9% saline) according to the size of the child and administered in increments. Remember that morphine may take more than 10 minutes to provide maximal effect. Fentanyl given in increments of 0.5 μg/kg is a useful alternative (in the first instance) as it has a much quicker onset, though it is of shorter duration. Both of these opioids should be at least halved in dose if there is any alteration in the conscious level or any evidence of hypovolaemia. *There is no place for the administration of intramuscular analgesia in trauma*. Entonox (a 50:50 mix of O_2/N_2O) may be considered, but is contraindicated if there is a possibility of pneumothorax or basal skull fracture.

The management of severe uncontrolled haemorrhage in trauma

Major haemorrhage following injury is not common in children. Its management requires an understanding of concepts that have become standard in adult trauma care:

- Damage control interventions, involving surgery and interventional radiology
- Maintenance of an adequate haematocrit (not so much as to maintain oxygen delivery, though this is also important, but to aid clotting by promoting platelet aggregation in small blood vessels)
- Use of optimal ratios of red cells to other blood products
- Effective use of adjuncts (e.g. tourniquets, pelvic splints and drugs such as tranexamic acid 15mg/kg)
- Avoidance of hypothermia

- Prompt restoration of perfusion after controlling haemorrhage (monitored by the lactate level returning to normal within a few hours)

If surgical control of the bleeding is problematic, a massive transfusion may be needed. Boluses may be needed in quick succession. Blood and products should be continued in repeated aliquots of 10 ml/kg. Blood boluses of 20 ml/kg are too high, unless the child is exsanguinating. In a 70 kg adolescent, 20 ml/kg of blood is equivalent to 5 adult units (280 ml each unit). This is generally too much before reviewing the haemodynamic state. It is important to understand how this contrasts with repeated boluses of clear fluid in the seriously ill child, with their leaky capillaries and preserved red cell mass.

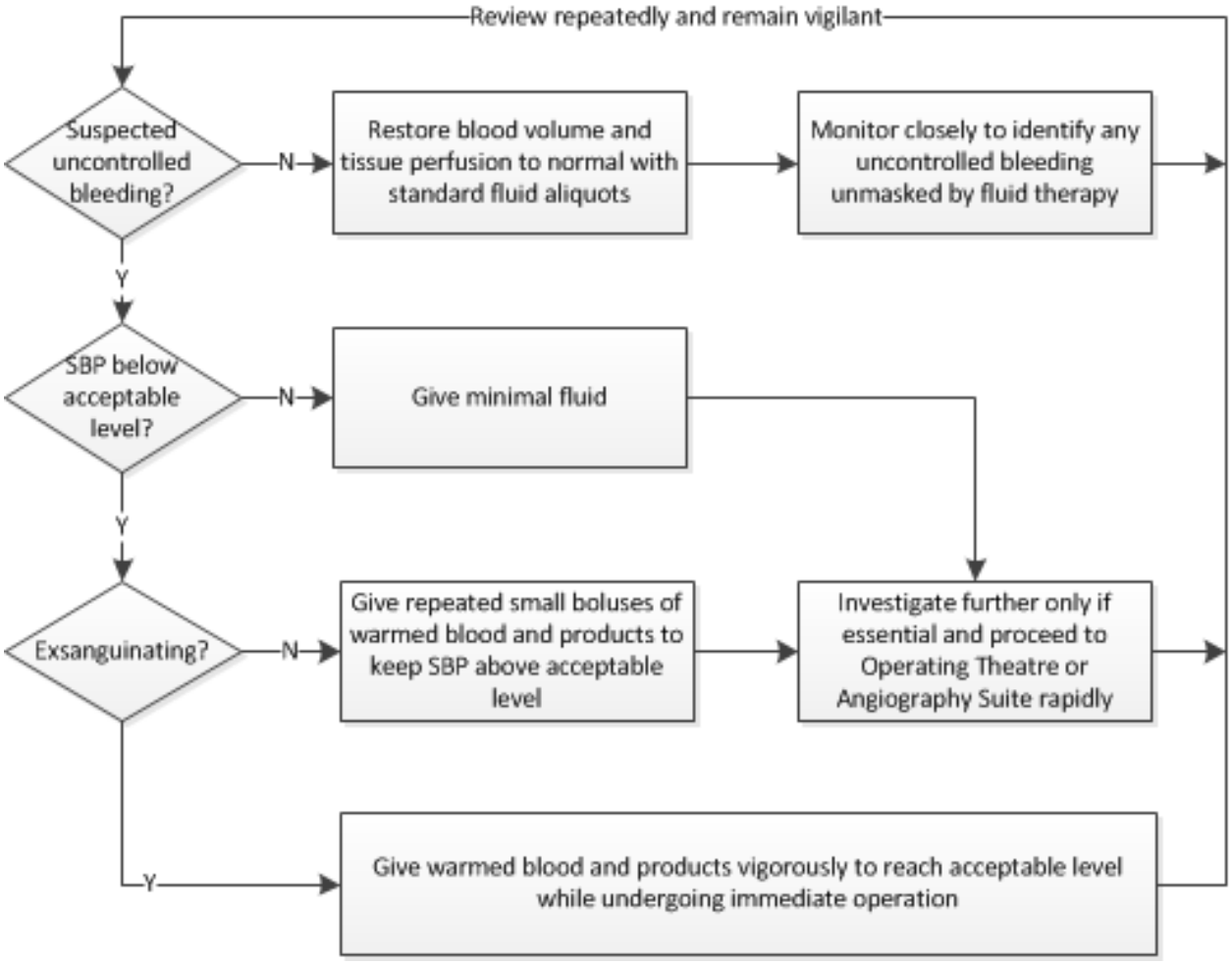

Figure 13.2: Blood and fluid therapy in severe uncontrolled haemorrhage after trauma

Key Aims in Severe Uncontrolled Haemorrhage following Trauma

- Stop the bleeding immediately by simple means (e.g. direct pressure), operation or angiographic intervention
- Maintain blood pressure at an acceptable level (SBP > 70-80 mm Hg) until bleeding controlled
- Keep Hb > 10 g/dl or haematocrit > 30% until major bleeding no longer a risk
- Keep platelet level > 100 x109 /l until major bleeding no longer a risk
- Keep INR, APTT < 1.3 and fibrinogen > 1.5 g/l until major bleeding no longer a risk
- In the face of uncontrolled bleeding, administer boluses of 10 ml/kg of blood

Use small doses of analgesia to relieve pain and prevent unnecessary hypertension and tachycardia (typically half dose increments in the face of hypovolaemia)

13.4 SECONDARY SURVEY AND LOOKING FOR KEY FEATURES

Having finished the primary survey and set in place appropriate resuscitative measures, *focused care* is the next phase of management. The central diagnostic process during this phase is the *secondary survey*, a systematic clinical examination to identify injuries. It is supplemented by observations, imaging and other investigations. Further information is gathered at this time, especially the history of the events leading up to the injury and the presence of any co-morbid factors.

History

History should be sought from the child, ambulance personnel, relatives and witnesses of the accident. Some history may have already been relayed from the ambulance control prior to admission, though it will need to be confirmed as the initial information is often sketchy and incomplete. On arrival, ambulance staff should be able to provide a great deal of information, including details of the accident site and of the pre-hospital care given. Relatives should be able to give the child's past medical history, allergies and any regular medications. Pre-existing medical conditions such as haemophilia or osteogenesis imperfecta will affect how the child is treated. It is conventional to seek details of the time of the last meal, but it is never wise to assume that the stomach is empty, as gastric stasis is a frequent consequence of major trauma. The child may withhold relevant information, such as glue sniffing or drug abuse, especially in the presence of parents. Alcohol ingestion is usually obvious despite earnest denial.

The mechanism of injury is useful in predicting potential injuries and setting the level of concern. The information in Table 13.3 should be sought.

Table 13.3. Relevant history of injury mechanism

Road accident	Other
Car occupant/cyclist/pedestrian	Nature of accident
Position in vehicle	Objects involved
Restraints worn	Height of fall
Head protection	Landing surface
Thrown from vehicle	Environment
Speed of impact	Temperature
Damage to vehicle	Contamination
Other victim's injuries	

Secondary survey

The secondary survey is a simple but thorough search for key anatomical features of injury. It is helpful to think in terms of:

- Surface (head to toe, front and back)
- Orifice (mouth, nose, ears, orbits; rectum, genitals)
- Cavity (chest, abdomen, pelvic cavity, retroperitoneum)
- Extremity (upper limbs including shoulders; lower limbs including pelvic girdle)

In blunt trauma, the child is often brought to hospital on a spine board. It is generally convenient to perform the "anterior" part of the secondary survey first. The head restraints and collar are then taken off, while an assistant holds the neck in line, to examine the head, neck, face, ears, nose and mouth. The collar can then be reapplied and, with the assistant still holding the neck in alignment, a log roll is performed to examine the spine, scapula, renal angles, sacro-iliac joints and other posterior structures. The spine board is removed at this time, if it has not been earlier.

Occasionally, a full secondary survey is delayed. If immediate life-saving interventions in the operating theatre are required, the secondary survey will have to be completed post-operatively.

Throughout this stage of management, the vital signs and neurological status should be continually reassessed, and any deterioration should lead to an immediate return to the primary survey.

Head

Clinical examination

- Inspect for bruising, haemorrhage, deformity and CSF leak from nose or ears
- Palpate for lacerations, bruising and skull depressions
- Perform otoscopy (for haemotympanum) and ophthalmoscopy (for retinal haemorrhage)
- Perform a mini-neurological examination:
  - pupillary reflexes
  - conscious level – according to the Glasgow Coma Scale (see Chap. 16)
  - motor function – reflexes, tone, power (noting symmetry)
  - sensation

Investigations (as indicated)

- CT scan of the head (see Chapter 16 for indications)
- Skull radiographs (now rarely indicated)

Face

Clinical examination

- Inspect for bruising, lacerations and deformity
- Inspect the mouth inside and out
- Palpate the bones for deformity and stability
- Palpate the teeth for looseness

Investigations (as indicated)

- Facial radiographs
- CT scan

Neck

Clinical examination

Care should be taken not to move the cervical spine during the initial assessment, when the spine has not been cleared. While the hard collar, blocks and straps are removed, an assistant should maintain in-line cervical stabilisation throughout.

- Inspect the front and back of the neck for bruising, lacerations and swelling
- Palpate the cervical spine for tenderness, bruising, swelling and deformity
- Palpate for surgical emphysema

Investigations (as indicated)

Cervical spine imaging, according to a locally agreed protocol. In the UK, this will be according to the NICE guidelines.

- Lateral view (with the arms pulled down)
- Antero-posterior view
- Odontoid (open mouth) view – omit if a CT scan of the head is separately required; a CT of the upper cervical spine should then be done instead
- Oblique views (if the lower cervical spine is inadequately visualised on the lateral view – rarely needed in children)
- CT scan
- MRI scan (especially if there are features of neurological deficit)

Flexion and extension views are controversial and should only be obtained in very specific circumstances.

Chest

Clinical examination

- Inspect for bruising, lacerations, deformity, and movement.
- Inspect neck veins.
- Feel for tracheal deviation.

- Feel for tenderness, crepitus and paradoxical movement.
- Percuss.
- Listen for breath sounds and added sounds.
- Listen for heart sounds.

Investigations (as indicated)

- ECG
- Further chest radiographs
- Special radiographs as indicated (e.g. arch aortogram)
- CT scan

Abdomen

Clinical examination

- Observe for movement.
- Inspect for bruising, lacerations and swelling.
- Palpate for tenderness, rigidity and masses.
- Auscultate for bowel sounds.

Investigations (as indicated)

- Ultrasound/FAST (see practical procedures for more details)
- CT scan (double contrast)
- Intravenous urogram

Diagnostic peritoneal lavage has been replaced by ultrasound and CT scanning.

Pelvis

Clinical examination

- Inspect for bruising, lacerations and deformity
- Inspect the perineum
- Inspect the external urethral meatus for blood
- Press over the anterior iliac crests for tenderness and check for abnormal mobility – do this once, to minimise the risk of dislodging clots and re-starting bleeding

Investigations (as indicated)

- Ultrasound
- Retrograde urethrography

Spine

Clinical examination

Examination of the spine requires the child to be log-rolled (see Chapter 22).

- Observe for swelling and bruising
- Palpate for tenderness, bruising, swelling and deformity
- Assess motor and sensory function

Investigations (as indicated)

- Radiographs
- CT scans
- MRI scans

Extremities

Clinical examination

- Observe for bruising, swelling and deformity
- Palpate for tenderness. Crepitus and abnormal movement may be found, but do not elicit deliberately as these are painful. The pattern and degree of tenderness alone will identify the need for X-ray
- Assess peripheral circulation – pulses and capillary return
- Assess peripheral sensation – to touch. It is rarely useful to test pin prick in a frightened child

Investigations (as indicated)

- Radiographs
- Angiograms

13.5 EMERGENCY TREATMENT

Emergency treatment represents the early response to key findings in the secondary survey and its adjunct investigations. While the interventions are less urgent than those in the resuscitation phase, they will still need to be carried out promptly to minimise the risk of deterioration or unnecessary morbidity. The emergency treatment plan will include treatments for any potentially life-threatening or limb-threatening injuries discovered during the secondary survey. If it does not put the child at undue risk, this plan may be extended to include definitive care of other (more minor) injuries discovered at the same time.

Emergency treatments are discussed in more detail in subsequent chapters.

13.6 REASSESSMENT

The initial emphasis was on crude physiological assessment (CABCD) in the primary survey, followed by focusing on the anatomical evaluation of injuries in the secondary survey. From the time of the initial resuscitation, pulse rate, blood pressure, respiratory rate and oxygen saturation should be measured and charted frequently (every 5 minutes initially). Beyond these continuing observations, there is now a need to return to overall physiological control by considering the following systems in more detail, especially in a critically injured child:

- Respiration
- Circulation
- Nervous system
- Metabolism
- Host defence

Respiration (A and B)

The airway should be re-checked. If intubated, is the endotracheal tube of an expected length at the teeth (for the size of the child)? Are the breath sounds symmetrical? Could the tube have migrated into a main-stem bronchus?

Arterial blood gas analysis provides essential information in the child with serious head, chest or multiple injuries (arterial oxygen and CO_2 tensions) or any child who has been intubated. Inserting an arterial line facilitates repeated measurements.

Pulse oximetry readings should be displayed continuously. End-tidal CO_2 monitoring is mandatory in the ventilated child. It shows that the breathing circuit is still connected and that the endotracheal tube has not become dislodged. The *end-tidal* CO_2 should not be regarded as a reliable indicator of *arterial* CO_2 tension, especially in a shocked child. Ventilation–perfusion mismatch causes it to under-represent the arterial level. It can be regarded as a crude indicator of pulmonary perfusion.

Circulation (C)

This system comprises the three "haems": *haemodynamics*, *haemoglobin* and *haemostasis*.

In a child with serious injuries, the pulse rate and rhythm should be monitored electrocardiographically. Non-invasive blood pressure readings are generally reliable, though in serious head injuries and multiple injuries, it is better to monitor on a beat-to-beat basis using direct arterial measurements via an arterial line usually at the radius. This also allows estimation of the haemoglobin (or haematocrit) at hourly intervals to help detect on-going bleeding and determine the requirement for further transfusion. Base-deficit (or lactate) measurements indicate the adequacy of tissue perfusion, though it is still important to reassess the child clinically. Other invasive techniques, such as central venous pressure monitoring, may be considered at this stage, but should only be undertaken by appropriately trained personnel.

In seriously injured children, the urinary output serves as an indicator of systemic perfusion and should be recorded hourly. It should be maintained at 1–2 ml/kg/hour, or higher if there has been a major crush injury or electrical burn with a high risk of myoglobinuria. If it is low, hypovolaemia is the likely cause, though other causes should be considered. If it is high, it may reflect excessive fluid therapy, but remember that diabetes insipidus can occur within a few hours of a serious head injury. After major blood loss, fresh frozen plasma and platelets may be needed to correct coagulopathy following measurement of clotting times and platelet count. Remember that hypothermia affects clotting.

Nervous system (D)

Pupil size and reactivity and the Glasgow Coma Score should be checked and recorded every 15 minutes initially. Any deterioration should prompt the need to discuss the case with a neurosurgeon or consider a CT scan (or repeat one). Intracranial pressure (ICP) monitoring is an important means of identifying life-threatening rises in pressure. In conjunction with invasive blood pressure measurements, it provides a means of tracking cerebral perfusion pressure. ICP monitoring can be established in the operating theatre or the intensive care unit. Its use should be confined to hospitals with appropriately skilled personnel, but the importance of cerebral perfusion pressure should be understood by all those who deal with critical head injuries in children.

Metabolism (Electrolytes, Fluid balance, Gut and Hormones)

This system refers to biochemical processes and includes renal, hepatic, gastro-intestinal and endocrine problems. Glucose control (Don't Ever Forget Glucose, especially in very young children and in adolescents who have taken alcohol) and urine output are key issues (see Circulation above).

Host defence (*Injury, Infection, Immunity, Intoxication*)

Host defence represents the interaction between the body as a whole and external influences. As such, it encompasses injury (including injury from poor positioning and thermal injury), infection (including wound care), immunity (including need for tetanus prophylaxis) and intoxication (including alcohol and drugs that may be present in the circulation)

Thermal injury is an important concern: hypothermia hinders blood clotting and predisposes to infection, while fever must be avoided in the severely head injured child. Wound care, antibiotic prophylaxis for open fractures, and checking that tetanus immunisations are up to date (has the child been immunised at all?) are all considered at this stage, as is careful positioning to avoid problems such as pressure injury from a badly fitting collar.

The "tertiary survey"

In addition to physiological system control, it is essential for transport escorts, intensive care staff or receiving-unit medical staff, who may take over care at this stage, to re-examine the child and review the investigations (especially the imaging) from an anatomical viewpoint to seek out any missed injuries.

Returning to the primary survey

Any sudden deterioration in the child's condition should trigger an immediate reassessment of the airway, breathing, circulation and disability so resuscitation can once more be undertaken.

> In the face of a serious deterioration, return to the primary survey.

13.7 CONTINUING STABILISATION

Continuing stabilisation and definitive care constitute the final part of the structured approach to trauma care. It goes hand in hand with the detailed physiological system control outlined above and is often carried out by teams other than those which initially received the patient. Good note taking and appropriate, timely referral are essential if time is not to be lost. If definitive care is to be undertaken in a specialist centre then transfer may be necessary at this stage.

Note taking

The structured approach discussed in this chapter can provide a framework for the writing of notes. It is recommended that these should be set out as shown in Table 13.4.

Table 13.4. Template for note taking

History

- Mechanism of injury
- Past history

Primary survey and resuscitative interventions

- <C>
- A
- B
- C
- D

Secondary survey and emergency treatment of injuries

- Head
- Face
- Neck
- Chest
- Abdomen
- Pelvis
- Spine
- Extremities

Continuing stabilisation

- Respiration
- Circulation
- Nervous system
- Metabolism
- Host defence

Referral

Many teams may be involved in the definitive care of a seriously injured child. It is essential that referrals are made appropriately, clearly and early. Guidance about which children to refer to which teams is given in subsequent chapters.

Transfer

Injured children may require transfer either within the hospital or to another centre. In either case thorough preparation of equipment, patient, and documentation is essential. Secondary transfer should not be undertaken until all life-threatening problems have been addressed, and the child is stable. Occasionally, transfer is the means of delivering life-saving care (e.g. an acute extradural haematoma) and a careful balance must be achieved between delaying such care and setting off with an inadequately stabilised child. Transport of children is discussed in more detail in Chapter 24.

13.8 SUMMARY

The structured approach to initial assessment and management allows the clinician to care for the seriously injured child in a logical, effective way.

Assessment of vital functions (airway, breathing, circulation and disability) is carried out first and resuscitation for any problems found is instituted immediately:

- Primary survey
- Resuscitation

A complete head-to-toe examination is then carried out, adjunct investigations are performed and emergency treatment is instituted:

- Secondary survey and the search for key features
- Emergency treatment

Finally, a detailed review is undertaken and definitive care is provided:

- Reassessment and physiological system control
- Continuing stabilisation and definitive care