Chapter 42

# Stabilisation and Transport of the Critically Ill Child

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## Introduction

Centralisation of specialist services, such as paediatric critical care, major trauma, cardiac surgery or neurosurgery, improves outcomes. For the critically ill child, accessing specialist critical care services may require transfer, either primarily by a 'front-line' ambulance (bypassing non-specialist centres) or secondarily by hospital teams after initial resuscitation and stabilisation in a non-specialist centre.

Children may be particularly vulnerable during transfer. Hospitals that admit children who may be critically ill or injured should be part of a clinical network involving paediatric critical care services and transport teams, with agreed guidelines for referral, immediate care and transport with appropriate audit and governance arrangements.

Transporting a critically ill child carries risks for the patient and requires the involvement of senior clinicians. For a critically ill child, the benefits of specialist services are usually greater than this risk, but each transport should be considered carefully.

This chapter describes general principles that specialist transport teams apply when undertaking the secondary transport of critically ill children and specific guidance for the transport of a child with a neurosurgical emergency, which may need to be undertaken by the referring hospital.

The need for transport of critically ill children is relatively predictable within a given geographical network or population. There are common diagnostic categories with predictable frequency and variation according to time of day and months of the year. Plans should therefore reflect the most commonly encountered scenarios. For example, airway emergencies are common in children, bronchiolitis is most common in the winter months and children are most involved in trauma out of school hours.

Support of respiratory and cardiovascular systems is similar for most of the commonly encountered diagnoses. Guidelines for the following commonly encountered emergencies should be available, ideally via the local paediatric critical care transport service website (for instance, from the Children's Acute Transport Service, CATS, www.cats.nhs.uk):

- Anaphylaxis
- Asthma
- Bronchiolitis
- Burns
- Coma
- Congenital heart disease
- Diabetic ketoacidosis
- Metabolic emergencies
- Neurosurgical emergencies
- Persistent pulmonary hypertension of the newborn
- Prospective planning
- Poisoning
- Sepsis
- Status epilepticus
- Trauma (now generally managed by primary or 'Front Line' responder networks)
- Upper airway obstruction

The secret to efficient stabilisation and transport of critically ill children is anticipation.

It is important to plan for transport in terms of resources, expertise and equipment before the need arises. This is important for both specialised transport services and for district hospitals who may be required to transport a child, for instance with a time-critical neurosurgical emergency.

## Referring a Child Needing Critical Care

Many regions of the United Kingdom now have a dedicated transport team for both children and neonates operating within a critical care network. Establishing the need for transport and the required time frame informs all other decisions.

There should be a close dialogue between the referring hospital and the transport team as soon as referral is considered. Specialist transport teams have dedicated consultant intensivists and are a valuable source of advice for the clinician involved in initial stabilisation of the child. Some referrals may resolve with advice from the intensive care team, avoiding the need for transport. Ideally, when a child is referred, the transport team will act as the liaison between the referring hospital and the specialist centre, leaving the referring doctor free to concentrate on the immediate clinical needs of the child.

The most senior clinician available at the referring hospital should assess the need for interventions once the decision to transport has been made. For instance, an arterial line and a central line may be indicated for a critically ill child, but is the time taken to insert them justified prior to the transport itself? If central venous access is technically difficult, how long should one persist and at what point should one abandon the attempt? Decisions about urgency of transfer also require an understanding of what will happen in the receiving hospital. Does the patient need emergency neurosurgery, or will they be transferred to the paediatric intensive care unit (PICU) for a period of ventilation and antibiotics?

Information for the transport team should be collated prior to referral.

In these complex situations, a checklist may be helpful to summarise information for referral (Table 42.1).

**Table 42.1** Referral checklist

| |
|---|
| Patient details |
| Referrer details |
| Reason for referral |
| Clinical details. Follow BAR format: |
| Situation |
| Background |
| Assessment |
| Recommendation |
| Allergies, medications, immunisations |
| Child protection issues |
| Trauma: details of injury, including timings |
| Status at referral: |
| Airway |
| Breathing |
| Circulation |
| Disability (AVPU: Alert, responds to Voice, responds to Pain, Unresponsive) |
| Everything else: blood results, blood gases, imaging, |
| microbiology results |
| Planned interventions |
| Summary of discussion |

## Acceptance and Agreement

It is vital that a critically ill child is taken to the correct receiving institution and that they are ready to receive the child. The child may be transported by a specialist transport team, or the local hospital team may be required to transfer the child themselves, depending on the availability of the transport team, the distances involved and the urgency of the clinical situation.

The transport team must know the name of the accepting consultant and the name of the receiving hospital. A member of the transporting team should contact the receiving unit immediately before departure. It is advisable to speak to someone who will be directly involved with the patient, for example the nurse in charge in the PICU. Describe the current condition of the child and any immediate needs of the patient, as well as how to get the patient from the ambulance entrance to the receiving ward.

## Generic Transport Rules

There are some accepted practice points that are common to most transporting teams and most scenarios:

- Before transport, interventions that improve patient outcome should be prioritised.
- Recognise the point at which the transport itself becomes the priority.
- Recognise there is a small risk to the health of the transporting team. The risk of an ambulance accident, for example, is small but present. Unnecessary risks (often involving adverse weather conditions or other external factors) should not be taken.

The point at which the transport becomes the priority sometimes occurs surprisingly quickly.

It is more easily recognised by someone who is 'hands off' in a leadership role. Unfortunately, in these situations the person with most clinical experience is frequently directly involved in clinical procedures. It is important that the team leader maintains a clear overview of the situation.

## Generic Goals: ABC

Physiological support may need to be instituted before a definitive diagnosis has been made.

If paediatric critical care transport is required, only perform investigations that change either clinical management decisions or the destination of the child.

### Airway

A clear airway needs to be maintained at all times.

It may be better to intubate a patient electively in the hospital environment rather than risk emergency intubation in the ambulance should the patient deteriorate en route.

Common indications for intubation include:

- Airway protection or to maintain a patent airway
- Respiratory failure
- Cardiovascular support
- Neuroprotection in severe head injury

It is important to maximise the chances of first attempt intubation success in this group of patients. Videolaryngoscope techniques offer some possible benefits to these patients when the clinician is familiar with them and should be considered.

The expected size and length of tracheal tube should be calculated for every transported patient, and one size larger and smaller should be carried for the transport.

It is not recommended to pre-cut the tracheal tube; instead, be aware and check the actual against the predicted length.

The aim should be to use a tracheal tube with a snug fit; if the tube has a large leak, it is almost always preferable to change it for one that fits more appropriately. Consider a cuffed tracheal tube, particularly in children with respiratory infection or sepsis, as lung compliance may deteriorate. The additional external diameter caused by the presence of a cuff can result in a smaller internal diameter tube being selected. Consider the risks of compromising gas flow and the risk of secretions blocking the tracheal tube on a transport in these circumstances, particularly if a very small-sized cuffed tube is selected.

Consider employing high-flow humidified nasal oxygen during emergency intubation (where an intravenous induction will be employed), as this may assist in maintaining patient oxygen saturation.

All children should have a gastric tube inserted after intubation, which should be left on free drainage.

If possible, put together an airway bag specifically for each patient transported. The airway bag should contain the following equipment:

- A functioning laryngoscope
- A replacement tracheal tube
- One larger tracheal tube, one smaller tracheal tube
- Magill's forceps
- Suction catheters
- Tape and scissors
- A face mask

The face mask is commonly forgotten if the patient is intubated prior to departure. Do not overload the airway bag, as this makes it difficult to use in an emergency.

### Failed Intubation

The Difficult Airway Society has produced helpful guidelines for these difficult situations (see https://das.uk.com/guidelines/paediatric-difficult-airway-guidelines).

In the context of critical illness, a 'cannot intubate and cannot ventilate' (CICV) situation could develop rapidly and may require consideration of rescue techniques with or without ENT expertise.

The priority is oxygenation; repeated attempts at laryngoscopy should be avoided. The main group at risk seems to be those under one year of age. It is important to consider transport early in any child in whom a difficult intubation is anticipated before their respiratory status becomes critical.

Although a supraglottic airway and breathing system has been used to transport patients successfully following failed intubation, this is not ideal, as sedation and paralysis are usually required to tolerate the airway and ventilation, which places the patient in a precarious position for the journey.

Hopefully the more widespread use and understanding of videolaryngoscopy and airway rescue techniques will make the management of these rare cases that require transport more straightforward.

## Breathing

Respiratory support can become a problem during a transport because the disease process may be evolving, and within that environment consumables such as oxygen and power are limited. The following precautions should be in place:

- A self-inflating bag should be available and in view at all times.
- An anaesthetic breathing system (bagging circuit) attached to an oxygen outlet should be ready at all phases of the transport.
- An adequate supply of oxygen should be calculated, and there should always be a backup supply; never carry all the oxygen in a single cylinder, for example.

If the patient is intubated, a mechanical ventilator is preferable to ventilation by hand. Hand ventilation uses a high fresh gas flow, and it may not be possible to deliver positive end expiratory pressure (PEEP) or control pressure as effectively as via a ventilator. Self-inflating bags are particularly difficult to use in this regard.

If a ventilator is used, the ventilator consumption of oxygen should be known and a calculation made to ensure that enough oxygen is available for the journey.

A calculation can be made using the following formula. It is safest to assume that the patient will require a $FiO_2$ of 1.0:

$$\begin{aligned}\text{Oxygen required (litres)} = {} & \text{ventilator consumption} \\ & \times \text{(litres per minute)} \\ & \times \text{journey length (minutes)} \\ & \times 2\end{aligned}$$

Most ventilators consume more gas than the minute volume delivered to the patient, and it is necessary to understand this excess to calculate the quantity of gas required for a journey.

Increasingly, ventilators use electrical power to operate and pressurise ambient air for patient ventilation. Battery life and access to en route power supplies are therefore additional considerations in most ventilated transports.

Understand, control and conserve gas and power supplies carefully during a transport. Plug in to wall supplies whenever possible. A common source of error is to fail to switch off a high-flow bagging circuit after unexpected use during the transport phase. Monitor actual oxygen consumption during a transport to make sure it approximately matches the amount calculated.

The transport ventilator and oxygen cylinders need to be secured so that they do not present a hazard to staff or the patient if the vehicle accelerates, brakes suddenly or is involved in an accident.

Use a bacterial/viral/humidifying filter in the circuit to retain heat and moisture if dead space allows. This is particularly important to prevent secretions obstructing a tracheostomy tube.

## CPAP/HFHO and HFOV

Oxygen consumption can be a distance- and time-limiting factor in transport involving continuous positive airway pressure (CPAP) and high-flow humidified oxygen (HFHO) because the gas consumption can be very high. An alternative strategy, such as invasive ventilation, can sometimes be required. Similarly, for a child requiring high-frequency oscillatory ventilation (HFOV), if conventional ventilation proves too risky, transport following initiation of extracorporeal membrane oxygenation (ECMO) prior to transport may be the best option for the patient.

## Oxygen Failure

Gas pressure alarms that are both auditory and visual are recommended for the transport environment. The self-inflating bag can provide emergency ventilation in the event of oxygen failure. The ambulance should then be diverted to the nearest emergency department.

## Ventilatory Problems during Transfer

At the point of transport, the physiology of a critically ill child is likely to be in evolution. This means that significant deterioration may occur during transport, and where possible this should be anticipated and planned for.

Consider the mnemonic ‘DOPES’ if ventilatory problems occur after intubation:

- Displaced?
- Obstructed?
- Pneumothorax?
- Equipment?
- Stomach?

Be ready to suction the airway at any stage in the transport (suctioning and a bolus of intravenous fluids are the two most frequent interventions during the transport phase).

## Ventilation Strategy

Ventilation strategy may differ between conditions; care should be taken to ventilate to normocapnia for the head injured child, but permissive hypercapnia (pH $\geq$ 7.25) is desirable in children with respiratory failure.

Children with acute severe asthma or bronchiolitis are at risk of dynamic hyperinflation and air-trapping, as expiration can be prolonged and require effort. When ventilated, this effort is eliminated, and these patients often require high inspiratory pressures and a long expiratory time to achieve expiration on the ventilator, which can limit available respiratory rate. Airway suctioning or respiratory physiotherapy can be very beneficial for these patients once sedation and bronchodilator therapy are optimal.

A child with chronic respiratory problems for whom target saturations are normally $\geq$ 88% is unlikely to benefit from attempts to ventilate to higher saturations.

It may be essential to target lower than normal saturations in some patients with congenital heart disease. In these rare cases, the greater risk to the patient is that of pulmonary over-circulation, at the expense of systemic circulation. Maintain a minimum of 75% saturations and seek expert opinion urgently.

## Circulation

Two secure intravenous lines are recommended for transport. A triple lumen central line counts as one site of vascular access.

Interosseous cannulation is a useful skill and should be considered until more definitive access can be obtained.

It is essential to monitor heart rate, rhythm and non-invasive blood pressure during any critical care transport, but they are crude surrogates for cardiac output, which is difficult to measure. Instead, a range of additional indicators are employed to evaluate the cardiovascular system. These include clinical history and anticipated clinical course, pulse volumes, capillary refill time, urine output, conscious level and response to therapeutic interventions such as the administration of a fluid bolus.

To achieve the necessary context, an understanding of age-appropriate heart rates and blood pressures is essential. This information is probably best incorporated as an aide memoire within the transport documentation.

Normal values should be targeted in most clinical situations. Exceptions include:

- Penetrating trauma where hypotensive resuscitation may be employed
- Head injury with raised intracranial pressure, when a higher blood pressure may be required to achieve adequate cerebral perfusion

## Monitoring Standards

The monitoring standards defined by the Association of Anaesthetists of Great Britain and Ireland are appropriate for all ventilated patients.

These include:

- Continuous ECG
- Blood pressure
- Pulse oximetry
- Capnography
- Temperature
- Ventilator alarms (minimum disconnect and high-pressure alarms)

Capnography is an essential component of respiratory monitoring and should be used for all transports. It is useful to monitor adequacy of ventilation, as it identifies correct tracheal tube placement (and displacement) and provides a useful indicator of cardiac output, particularly during cardiopulmonary resuscitation.

Non-invasive blood pressure monitors rapidly deplete the battery power of integrated monitors and become unreliable if there is a lot of movement. Blood pressure is most efficiently measured using intra-arterial monitoring, but time must not be wasted in failed attempts to insert an arterial line (this applies to any intervention). The time taken must not exceed the benefit of the line, and intermittent non-invasive blood pressure measurements may be the best option.

Central venous access is very useful for blood sampling as well as inotrope delivery, but again it is time consuming to insert, carries the risk of complications and it may not be possible to achieve. Recently, dilute inotropic solutions delivered through standard peripheral intravenous access have been employed successfully to achieve the desired physiological targets without risking either the time or complications of central access. This pragmatic approach has yet to be fully evaluated, but it has the advantage of simplicity, and initial experience in critically ill children is favourable.

## Documentation

An anaesthetic record is a good starting point for transport documentation. A contemporaneous record of the medical decisions and the physiological status should be made. A section summarising medical issues yet to be dealt with or any outstanding investigation results is essential. A copy of relevant documentation, scans and X-rays must be transferred either electronically or on paper to the receiving team and a copy returned to the referring hospital.

Ideally, transport documentation should be designed to facilitate decision-making processes by structuring assessment, providing information (drug calculations, tracheal tube size, normal physiological variables) and offering therapeutic goals.

Critical care transport can present many unusual situations, especially to ad hoc transport teams, and it is important to reduce the cognitive load wherever possible.

## The Transport Team

The skills of the transport team should match the requirements of the patient. A two-person team driven by an ambulance technician would be the most usual practice amongst specialist critical care transport teams in the United Kingdom for ventilated patients. Every hospital should develop a contingency plan for emergency paediatric transport, which should identify which personnel will form the transport team.

- Team leader. This should be someone with the ability to lead medical decisions, with the appropriate skills to undertake likely interventions. In practice, this is often a physician but may be an advanced clinical practitioner.
- Assistant. This should be someone able to assist the team leader in delivering the level of care required. In practice, this is often a children's nurse or operating department practitioner (ODP) but could be a paramedic with appropriate skills.
- Driver/technician. This should be someone capable of operating the transport ambulance equipment and driving the patient and team to the receiving facility in a safe, timely manner. In practice, the driver will often be an ambulance driver with training and experience in emergency response driving. The route to the receiving facility may be unfamiliar, or there may be a change en route, and the ambulance will need GPS and paper map backups.

The local ambulance service should not automatically be asked to supply a paramedic crew for the transport. The main role of the paramedic crew is for primary transport from home or roadside to a hospital facility, and a paramedic crew may be under-utilised in a physician-led secondary transport.

## Mode of Transport

### Road Transport

A 'frontline' NHS ambulance will have some of the equipment required for transport of a critically ill child. The essential requirements include oxygen, suction and a defibrillator suitable for the size of the child. Other equipment such as monitors, syringe pumps and airway/ventilation equipment may have to be sourced from the referring hospital for time-critical transfers; specialist children's transport ambulances will be fully equipped for the expected patient group.

Power sockets are usually available, and there are usually at least three seats. This will permit a parent or carer to accompany the patient if this is deemed clinically appropriate.

### Train Transport

For more stable patients, this may well prove to be a suitable mode of transport, especially given the environmental impact of other modes. At present in the United Kingdom, it has been used very rarely, but many services are hoping to develop this mode.

### Air Transport

The technical and logistical problems that accompany ad hoc secondary aeromedical transfer in the emergency setting are formidable. The main problem with aeromedical transport using fixed-wing aircraft or helicopter transfer is not the physiology of aviation, but coordination of multiple transfers, patient access and monitoring in unfamiliar, distracting, isolated, hazardous environments. Weather and landing site restrictions may reduce any potential time saved.

Road ambulances will be required to transport the patient to landing sites, and these will need to be coordinated with the aircraft. The local statutory ambulance service may be able to assist if an aeromedical transport is required.

Helicopter emergency medical service (HEMS) helicopters are limited in capacity, and it is likely that only one member of staff will be able to accompany the patient.

A search and rescue helicopter can be requested which has the capacity to transfer a medical team with the patient. In these circumstances, the transporting team should not expect any medical equipment, power or oxygen to be available. The dual pilots, navigator and winchman crew that accompany a search and rescue helicopter are an additional valuable resource for the transporting team, which may make this the best option for an ad hoc team.

## Aeromedical Transport: Altitude

It is important to liaise with the crew if altitude will cause clinical problems:

- All helicopters are unpressurised and often operate at or below 2,000 feet.
- Fixed-wing aircraft may be pressurised or unpressurised.
- A pressurised fixed-wing aircraft will not have a cabin pressure higher than 8,000 feet, even though the aircraft may fly at a higher altitude.

As a rule of thumb, at 8,000 feet (2,438 m) a healthy individual breathing air would experience a $PaO_2$ of 7 to 8.5 kPa ($SpO_2$ of 85–91%). A chartered air ambulance may be able to pressurise the cabin to sea level for the journey, but this will limit aircraft altitude and cause a fuel penalty.

Because a low ambient pressure causes expansion of trapped gases, the following issues should be considered:

- A pneumothorax will expand at altitude and should be drained pre-departure.
- Air transport is relatively contraindicated if the child has an open head injury or open eye injury.
- Air transport is relatively contraindicated for children with intestinal obstruction, as there is risk of perforation.
- Tracheal tube cuff pressures should be checked en route, and many recommend using water to fill the tracheal cuff, which will largely prevent expanded gas applying pressure to the tracheal mucosa.
- At altitude, minute volume from ventilators may increase, and end-tidal $CO_2$ monitoring must be used.
- Intravenous fluid bags containing gas may pressurise, increasing infusion rates unexpectedly.
- A vacuum mattress will soften at altitude as the gas within it expands.

## Parents and Carers

A parent or carer should accompany the patient. Unnecessary separation can add considerably to the distress of parents and carers at what is already a very difficult time. From the perspective of the transport team, parents are also an essential source of information, and it is helpful if they are present at the destination hospital when the transporting team arrives. It may be useful to re-examine the medical history with the parent or carer during the journey if circumstances permit.

The journey may also be a good opportunity to answer questions or provide explanations for parents or carers who may not have fully appreciated what has happened.

## Health, Safety and Insurance

The patient, parent or carer, equipment and staff must be adequately restrained when the vehicle is moving. Seat belts must be used. Some improvisation is usual in an emergency ad hoc transport, and inevitably there will be some risk to the team and patient from the transfer. Assessing risks and keeping them to an acceptable level is part of the overall process of transfer, and all members of the team need to participate. Oxygen cylinders are particularly dangerous, not just given the contents and pressure but also as heavy objects that need to be properly restrained when the vehicle is in motion.

Teams should consider a personal death or injury insurance such as that available to Association of Anaesthetists (AA), Intensive Care

Society (ICS) or Paediatric Intensive Care Society (PICS) members. All National Health Service (NHS) staff are eligible to benefit from the NHS Injury Benefits Scheme via the NHS Litigation Authority; however, this can be a legally complex and time-consuming process. As a result, the AA, ICS, PICS and allied organisations have arranged personal accident insurance for members undertaking patient transfers. Those likely to form part of a transport team should consider taking out this kind of insurance.

## Death of a Patient during Transport

If a child has suffered an irrecoverable head injury or major trauma, or brain stem death is inevitable, it is better to spare the family and the child the distress of a futile secondary transfer where no clinical benefit is likely.

If a child unfortunately succumbs during transport, it may be appropriate to continue to the planned destination to confirm death or divert/return to the nearest hospital accident and emergency department capable of managing the situation.

Emergency transfers will normally need to be referred to the coroner in the usual way.

## Time-Critical Neurosurgical Emergencies

The child requiring urgent neurosurgery, for instance because of extradural hematoma, blocked ventriculoperitoneal (VP) shunt or bleed into a previously undiagnosed cerebral tumour, should be transferred to a specialist neurosurgical centre as soon as possible. Transfer by the referring hospital team is usually the most clinically appropriate, but decisions should be made in joint consultation with the neurosurgeons and the specialist transport team. Transfer by an experienced anaesthetist is usually appropriate.

Useful pointers for urgent transfer include the following:

Following trauma:

- Rapid loss of consciousness
- Initial lucid interval followed by loss of consciousness
- Unequal pupils
- Cushing's triad – hypertension, bradycardia, abnormal respiration
- Focal neurological deficit, such as hemiparesis
- Obvious external injury, such as a depressed skull fracture

Non-traumatic:

- Suspected blocked VP shunt
- Rapid loss of consciousness in a previously well patient
- Unexpected cardiorespiratory arrest in a young infant (consider non-accidental injury)
- Focal neurological deficit, including focal seizures in an older child
- Antecedent severe headache and vomiting

Outcomes can be improved by reducing the time to surgery, but basic neuroprotection must be in place prior to transfer. Hypotension and hypoxaemia are associated with poor outcome and must be avoided at all times. Initial management of acute neurosurgical emergencies is in accordance with Advanced Paedeatric Life Support (APLS) guidelines:

- Set age-appropriate target values for mean arterial pressure (Table 42.2).
- Stabilise the airway (and cervical spine), breathing and circulation.
- Establish two points of IV access.
- Pass a urinary catheter and orogastric tube.

Indications for intubation:

- GCS $\leq$ 8 or rapid decrease in GCS
- Signs of raised intracranial pressure (ICP): unequal pupils, Cushing's triad
- Loss of airway reflexes
- Ventilator insufficiency
- Spontaneous hyperventilation ($PaCO_2 \leq$ 3.5 kPa)

Neuroprotection after intubation:

- Secure the tracheal tube and confirm bilateral air entry.
- Continue cervical spine immobilisation if indicated with sandbags and tape. Cervical collars are difficult to fit, especially to those under five years old, and an individual

**Table 42.2** Target values for mean arterial pressure in children with a neurosurgical emergency

| Age (years) | Target mean arterial pressure (mmHg) |
|---|---|
| <2 | >55 |
| 2–6 | >60 |
| >6 | >70 |

assessment will be required to assess benefit in the unconscious patient.

- Maintain oxygen saturation ≥94%, maintain normocapnia ($PaCO_2$ 4.7–5.3 kPa).
- Capnography is mandatory.
- Paralyse and sedate with morphine, midazolam and vecuronium infusions.
- Boluses of fentanyl 5 mcg $kg^{-1}$ may be useful to prevent responses to suction.
- Target adequate blood pressure to maintain cerebral perfusion pressure.
- Target mean arterial pressures according to the age of child are shown in Table 42.2.

Inotropes may be required:

- Dopamine 5–10 mcg $kg^{-1}$ $min^{1}$
- Noradrenaline 0.02–1 mcg $kg^{-1}$ $min^{-1}$
- Adrenaline 0.02–1 mcg $kg^{-1}$ $min^{-1}$

If there are concerns about raised ICP or rapid changes in clinical signs (e.g. pupillary changes or Cushing's triad), consider interventions to reduce ICP:

- Mannitol (0.25–0.5 g $kg^{-1}$ IV) and/or
- Hypertonic saline (2.8% saline, 3 ml $kg^{-1}$ IV) – target a serum sodium 145 mmol $l^{-1}$.
- Record pupil signs and vital signs every 15 minutes.
- Maintain central temperature 35–37°C. Avoid hyperthermia but do not target hypothermia.
- Identify and treat seizures with a loading dose of phenytoin 20 mg $kg^{-1}$.
- Fluid restrict to 50% maintenance.
- Use isotonic fluids only.
- Maintain normal blood sugar – for example, by adding dextrose to 0.9% saline:
  - For a child <2 years if blood glucose ≤4.4 mmol $l^{-1}$
  - For a child ≥2 years if blood glucose <3.9 mmol $l^{-1}$

Antibiotic prophylaxis is recommended for penetrating head injuries or when there is evidence of cerebrospinal fluid (CSF) leak. Consider associated injuries if there is hypotension and falling haemoglobin.

Ideally, associated injuries should be excluded or stabilised prior to transfer.

## Urgent CT Scan

A CT scan should be done within 30 minutes of suspicion of a mass lesion but does not take priority over neuroprotection and should only be carried out once neuroprotection goals are met.

If the CT scan indicates that urgent neurosurgery is required, transfer should take place immediately (target maximum <60 minutes from the end of the scan).

Indications for urgent CT scan in a child are:

- GCS <13 at any time since injury
- GCS equal to 13–14 at two hours after the injury
- Suspected open or basal skull fracture
- Post-traumatic seizure
- Focal neurological deficit
- >1 episode vomiting
- Amnesia >30 minutes of events before impact
- Dangerous mechanism of injury
- Coagulopathy

Although useful, insertion of a central line and arterial line should not delay transport.

In this situation, inotropes may need to be run via a peripheral cannula and the non-invasive blood pressure cuff used, such is the importance of timely surgery in this group of patients.

Table 42.3 provides a template checklist for non-specialist teams required to transport a child.

**Table 42.3** Checklist for non-specialist teams required to transport a child

| Checklist item to consider | Tick when completed/ considered |
|---|---|
| Receiving hospital staff spoken to by the responsible consultant. | |
| Ambulance service request (999 call or via duty controller). State ventilated neurosurgical emergency. Request ASAP response time. | |
| Estimated journey time from local ambulance service. | |
| *Airway equipment:*<br>Face mask<br>Ambu bag<br>Tape<br>Tubes<br>Laryngoscope<br>Scissors | |
| *Drugs:*<br>Fluid bolus<br>Mannitol | |

**Table 42.3** *(cont.)*

| Checklist item to consider | Tick when completed/ considered |
|---|---|
| Sedation<br>Paralysis<br>Inotropes | |
| Ventilator and oxygen calculation | |
| Infusion pumps | |
| Mobile phone with appropriate telephone numbers | |
| *Monitoring:*<br>ECG<br>$SpO_2$<br>Blood pressure (NIBP or arterial)<br>End-tidal $CO_2$ | |
| *Physiological targets:*<br>$SpO_2$ 96% or more<br>Blood pressure (NIBP or arterial) – age-appropriate target<br>End-tidal $CO_2$ required to achieve $PaCO_2$ 4.7–5.3 kPa | |
| Sedation | |
| Paralysis | |
| Torch | |
| Call receiving hospital immediately prior to leaving | |

## Penetrating Trauma

The majority of blunt trauma can be managed non-operatively and will respond to restoration of circulation attention to coagulation. A specialist transport team can then retrieve the patient after a full assessment has been made.

A child that presents to an adult trauma unit or other non-specialist hospital with penetrating trauma resulting in life-threatening haemodynamic instability requires special consideration.

The decision in this situation hinges on the surgical expertise at the non-specialist hospital at that moment, and damage limitation surgery may need to be attempted onsite if appropriate.

Immediate advice should be sought from the duty consultant at the nearest major trauma centre.

If damage limitation surgery cannot be attempted locally, the patient will need to be transported to the nearest major trauma centre or other specialist facility, and the best chance of survival probably lies with an immediate non-specialist team transfer or local HEMS provider.

The most senior clinician available should accompany the child on the transport. Aggressive fluid resuscitation in this situation may cause exsanguination and should be limited to achieve low-normal blood pressure.

Preplanning for this situation, usually as part of a trauma network, offers the best outcomes.

### Key Points

- The need for transport of a critically ill or injured child is predictable and should be planned within clinical networks.
- The retrieval team is an invaluable source of advice during initial stabilisation prior to transport.
- The airway should be secured early, prior to transport of critically ill children.
- Time-critical transfers may need to be undertaken by the referring hospital. Appropriate equipment and protocols should be prepared well in advance.
- Completion of a transport checklist reduces critical incidents during transport.

## Further Reading


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