Stabilisation and transport of the critically ill child 2D01, 2D07, 3A11

J Dawes, P Ramnarayan, D Lutman

Since the Department of Health Report 'Paediatric Intensive Care: A framework for the future' in 1997, paediatric intensive care services have been centralised and 24-hour retrieval services developed. However, all hospitals admitting critically ill children must be able to resuscitate and stabilise prior to retrieval, and occasionally undertake the 'time-critical' transfers themselves. This article reviews the clinical and organisational skills involved in the retrieval process, and also suggests ways in which knowledge and skills can be maintained.

Keywords: *stabilisation; retrieval; transport; paediatric intensive care; critically ill child*

Case example

A mother brought her nine-month-old baby girl into hospital, concerned that she was unusually sleepy and not feeding. Apart from mild coryza, the baby had been well when she left for work but now seemed irritable and disinterested in her surroundings. The father said she had been unsettled during the day and had vomited twice. She had not experienced any diarrhoea, fevers, rash or breathing difficulties. On arrival, her saturations were 92% in room air and her respiratory rate was 20 breaths per minute. She was warm and well perfused, with a blood pressure of 95/45 mm Hg, a heart rate of 110 beats per minute and had an axillary temperature of 36.5°C. Her pupils were 3 mm and sluggish to react, and she would only respond to painful stimulus. Her fontanelle was full and she appeared hypotonic. Intravenous access was difficult to obtain and after multiple failed attempts, an intraosseous needle was sited. She was given 20 mL/kg of 0.9% saline and 80 mg/kg ceftriaxone intravenously (IV). She subsequently had a generalised tonic-clonic seizure, which terminated after 0.1 mg/kg IV lorazepam was administered; however, she required continuous bag-mask ventilation due to poor respiratory effort. A capillary blood gas revealed a pH of 7.05, pCO_2 10 kPa, HCO_3^- 20 mmol/L, base excess -4 mmol/L, lactate 2 mmol/L, glucose 4 mmol/L, Na 132 mmol/L, K 4.1 mmol/L, Hb 10 g/dL. Her right pupil was now fixed and dilated. The paediatric consultant called the paediatric intensive care (PIC) retrieval team while the anaesthetic team prepared for intubation. Neuroprotective strategies, a dose of IV mannitol and an urgent CT head were advised. The post-intubation chest X-ray (CXR) showed a correctly placed endotracheal tube (ETT) and old rib fractures. The CT scan demonstrated bilateral subdural haematomas and hydrocephalus. She was referred to neurosurgeons at the local neurosurgical centre, who, after reviewing the scans, requested that she be immediately transferred for an emergency craniotomy. This was organised by the local hospital and the parents accompanied the baby in the ambulance.

Introduction

Following centralisation of PIC services over the last two decades, the vast majority of critically ill children presenting to district general hospitals (DGHs) are now transferred by PIC retrieval teams to dedicated PICUs.[1,2] However, centralisation has also resulted in less elective paediatric surgery being performed at DGHs, with the potential for deskilling doctors in paediatric anaesthetic skills. Children requiring stabilisation and PIC retrieval are generally young, sick, and have a high mortality rate on PICU (8%),[3] and DGH staff often have to manage such children for extended periods of time (particularly in winter months) until a retrieval team or an appropriate bed becomes available. There is encouraging evidence from the North Thames region to suggest that DGH staff do perform vital interventions such as intubation and obtaining vascular access prior to the arrival of the PIC retrieval team.[4] It is important that the skills required to manage critically ill children are acquired and maintained by all anaesthetic and intensive care practitioners.

In this review, we aim to discuss the PIC retrieval process (**Figure 1**), the knowledge and skills required to manage critically ill children, and suggest ways in which these skills can be maintained.

Initial assessment/resuscitation

Critically ill children present to DGHs with, predominantly, respiratory (35%), neurological (18%) and cardiovascular (14%) diseases.[3] A large retrospective audit from a DGH found that the commonest diagnoses included asthma, pneumonia and CNS infection.[5]

Initial assessment and resuscitation should initially follow an ABCD 'don't Ever Forget Glucose' (EFG) approach (according to Advanced Paediatric Life Support (APLS) guidelines[6]), responding to life-threatening emergencies as they are identified. This often will occur in the emergency department (ED), but the child may have deteriorated on the ward. Many EDs are equipped with age/weight specific charts

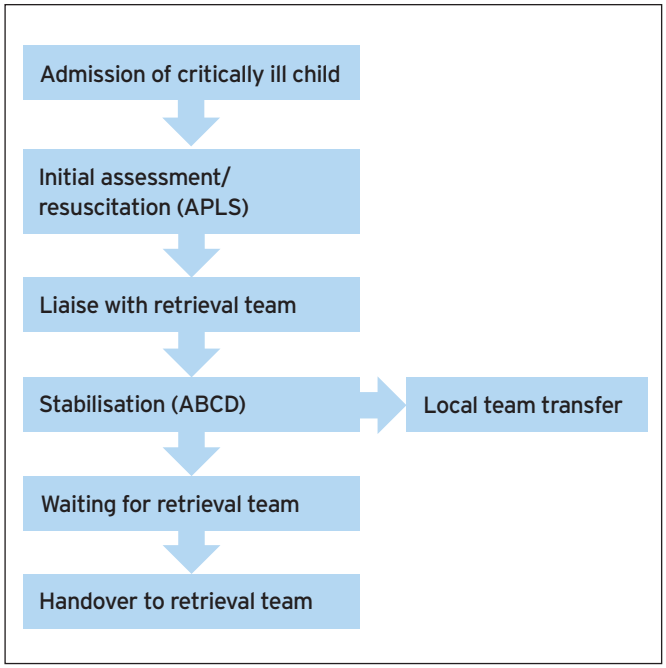


Figure 1 Paediatric transport process.

that provide information on normal physiological variables, appropriate equipment and correct drug doses for the child. It is essential to involve senior staff early in this process, including the neonatal/paediatric consultant and the anaesthetic/ICU consultant in order to ensure appropriate and timely referral and management.

Liaison with the retrieval team

It is helpful to gather as much information about the patient as possible before making the referral call to the retrieval team, and PIC networks often have proformas to assist in this process.[7] The referral should ideally be made once resuscitation is complete, although this is not always possible. Based on the information provided, the retrieval team will provide clinical advice, decide whether the transfer is indicated, what mode of transport should be used, and where the child should be taken, depending on the likely diagnosis and bed availability.

Stabilisation

It is the responsibility of the referring hospital to initiate resuscitation and stabilisation of the child prior to the arrival of the retrieval team.[8] There are guidelines to assist with this process.[9] It has been found that time spent undertaking intensive care interventions early in the course of the patient's illness at the local hospital does not worsen outcome,[10] highlighting the importance of effective and timely stabilisation. There is no need to adopt the 'scoop and run' model,[10] unless there is specific life-saving therapy that can only be provided at the receiving hospital.

The child should be stabilised in the most appropriate location at the DGH, which is usually the ED resuscitation room, theatre, recovery, special care baby unit (SCBU) or adult ICU. The appropriateness of transfer to these areas should be decided by senior staff, based on the clinical condition of the child and the availability of appropriate equipment (eg volatile anaesthetic agents for gas induction and emergency airway equipment for a difficult airway).

Airway (A)

The airway must be patent and uncompromised prior to undertaking transfer of a critically ill child. This usually means endotracheal intubation of the patient and should be carried out by a senior clinician experienced in intubating children. In the vast majority of cases, this will be required prior to the arrival of the retrieval team.

The method of intubation will depend on the indications. A modified rapid sequence induction is usually appropriate, unless there is upper airway obstruction, in which case a gas induction is often preferred. Early involvement of the ENT team is important if a difficult intubation is anticipated. Discussions of the approach in this situation is beyond the scope of this review but the reader is directed to recently published guidelines on the management of paediatric difficult airways.[11] End-tidal carbon dioxide ($ETCO_2$) monitoring should be prepared in advance and monitored continuously during transfer.[12] Peri-induction cardiovascular instability should be anticipated (especially in the child with congenital cardiac disease or shock), with fluid boluses and a peripheral dopamine infusion immediately available or in progress. The most cardiostable induction agent is advised, which can be discussed with the retrieval team. A popular induction technique includes ketamine (1-2 mg/kg), with or without fentanyl (1-2 µg/kg), followed by suxamethonium (2 mg/kg), or rocuronium (1 mg/kg) unless there are contraindications. Sodium thiopentone (2-5 mg/kg) may be useful in a child with status epilepticus as it will reduce intracranial pressure (ICP) and will often terminate seizures. An opioid-only technique with fentanyl may be preferable in the neonate with cardiovascular instability.

Cuffed ETTs are usually advised,[13,14] especially if the child is likely to require long-term ventilation.[15] Numerous formulae exist for sizing cuffed ETTs in children[16] and some will depend on the manufacturer;[14] however, a commonly-used formula for children older than two years is: age/4 + 3.5.[6] Neonates usually require a tube of internal diameter 3-3.5 mm. Cuff inflation pressures should be monitored[17] and the pressure kept below 20 cm H_2O. Effective ETT fixation is essential prior to transport, and 'Melbourne' strapping is a widely adopted technique.[18] This is particularly important in babies and infants, who have short tracheas, where small changes in head position can result in either endobronchial intubation or accidental extubation. The position of the ETT should be verified on a chest X-ray, aiming for the tip of the tube to lie at the level of the 2nd thoracic vertebra (T2). The X rays will either need to be copied and given to the transport team or image-linked to the receiving hospital, a process that can delay transfer if not anticipated. ETTs should not be pre-cut, but can be cut once their position has been verified, in order to reduce anatomical dead space. Mainstream capnograph adapters now exist that are ideal for use in neonates and children as they have low volume dead space (<0.5 mL), are lightweight and designed for single-patient

use. If the patient has a respiratory infection of unknown origin, face masks should be worn when manipulating the airway.

Breathing (B)

Once intubated, ventilation should be established on a transport ventilator, or via alternative ventilation sources from SCBU or ICU. Difficulties with ventilation can be approached using the mnemonic 'DOPES' (**Table 1**).

Different disease processes require different ventilation strategies. Peak inspiratory pressures, respiratory rates (RR) and inspiratory:expiratory ratios may need to be adjusted before satisfactory blood gas targets are achieved. All children should receive at least 5 cm H_20 positive end-expiratory pressure (PEEP), even those with asthma and head injury. Conditions associated with potential gas trapping, such as bronchiolitis and asthma, will require low RRs and long expiratory times, whereas pneumonic processes may require higher rates and longer inspiratory times.

The facility to perform blood gases at the bedside is advantageous, such as that provided with i-STAT® systems. Some retrieval services can provide mobile inhaled nitric oxide[19] in cases of hypoxic respiratory failure or in primary pulmonary hypertension of the neonate. Some services are also able to provide mobile extracorporeal membrane oxygenation (ECMO) if the baby or child is too unstable to be transported without it.

Circulation (C)

At least two working IV access points are essential for transport, in case of failure or dislodgement. If venous access is difficult and the child is cardiovascularly compromised, an intra-osseous (IO) needle should be sited. Preferred sites include the proximal tibia, distal tibia, distal femur and proximal humerus.[20] Fluids, blood products and inotropes can all be infused via an IO, but must be delivered under pressure. The largest PIC retrieval service in the UK transfers around 15 children each year (1.3% of all transports) on inotropes delivered via IO needles without a central venous line *in situ* (unpublished data, Children's Acute Transport Service (CATS)). IO needles should be well secured and the site checked regularly for extravasation. Portable ultrasound devices (ideally with a small footprint 'hockey stick' probe) can be very useful in gaining arterial and central venous access,[21] and many anaesthetists and intensivists will be able to perform these skills.

Details of circulatory support should be discussed with the retrieval team and early aggressive fluid resuscitation and inotropes may be required, particularly in sepsis.[22] Hypotension is a late sign of hypovolaemia in a child, and should be corrected rapidly to maintain cardiac output and organ perfusion. Dopamine can be infused via a peripheral cannula if central access has not been established; however, it is important to note that the different concentrations must be used for each route.[23] Inotropes should be prepared in advance of the transfer, and if already in progress, a second drug should also be available and attached ready for infusion. Adrenaline can be a useful inotrope if dopamine is ineffective – see **Table 2** for a guide to preparing inotrope infusions. A urinary catheter should usually be inserted, particularly if the child is sedated with opiates, and hourly output recorded.

In neonatal shock, consider congenital cardiac disease as a differential diagnosis; feel for femoral pulses, hepatomegaly and measure four-limb blood pressures. If there is any suspicion of a duct-dependent circulation (pulmonary or systemic), a prostaglandin infusion should be started. The infant is at risk of apnoea, particularly at doses greater than 10 ng/kg/min, so may require intubation for transfer. An increasing number of DGH paediatricians and neonatologists are able to perform bedside echocardiography, which can be invaluable in diagnosing abnormal cardiac morphology.

Problem	Management
Displacement	Endobronchial intubation: Measure distance between ETT tip and T2 on CXR and withdraw under direct vision Oesophageal intubation or 'too high': Re-site or advance under direct vision, respectively Inappropriate size ETT with large airway leak: 'upsize'
Obstruction	Physiotherapy and saline suctioning with appropriately sized suction catheter (ETT size×2) to clear secretions and/or mucus plugs May need to exchange the ETT if completely blocked
Pneumothorax	Needle thoracocentesis for tension pneumothorax: 2nd intercostal (IC) space, mid-clavicular line, with 18G or 16G cannula attached to T-piece, 3-way tap and 20 or 50 mL syringe Follow with intercostal chest drain: 5th IC space, anterior axillary line (Seldinger or blunt dissection technique) Heimlich valve preferable to underwater drainage sets for transfer
Equipment	Kinked ETT (especially in small sizes): Careful positioning or external supportive tubing to keep ETT straight Large anatomical dead space: consider cutting long ETTs (once intubated) and simplifying connectors/filters Ventilator failure: Use alternative means of ventilation
Stomach/ sedation	Gastric distension from bag mask ventilation: Insert naso- or oro-gastric tube (size 6, 8 or 10 depending on size of nares) and aspirate air from stomach Inadequate sedation: Bolus of morphine (0.1 mg/kg) and/or paralysis

Table 1 Approach to difficulties with ventilation ('DOPES').

Drug	Dose range	1 mL/hr =	Add to 50 mL	Notes
Adrenaline	0.1-2.0 µg/kg/min	0.1 µg/kg/min	0.3 mg × weight	IV or IO Always centrally In 5% dextrose or 0.9% saline
Dobutamine	5-20 µg/kg/min	10 µg/kg/min	30 mg × weight	Vasodilatation and tachycardia. Central administration if >5 mg/mL
Dopamine (central)	5-20 µg/kg/min	10 µg/kg/min	30 mg × weight	Central administration preferred
Dopamine (peripheral)	5-20 µg/kg/min	1 µg/kg/min	3 mg × weight	Max 1.6 mg/mL Dilute in 5% dextrose or 0.9% saline
Noradrenaline	0.1-1 µg/kg/min	0.1 µg/kg/min	0.3 mg × weight	Administer centrally Dilute in 5% dextrose or 0.9% saline

Table 2 Inotropic drug infusions.

INTRODUCTIONS

PATIENT DETAILS (Name, age, date of birth, weight, gestational age if under 2 years)

CLINICAL DETAILS

- History of presenting complaint (If trauma, details of timings), past medical history
- Medications, allergies, immunisations
- Family/social history, including child protection issues, if any
- Infection control issues, if any (eg known MRSA or VRE will have implications regarding cubicle use at destination)

MANAGEMENT BY REFERRING HOSPITAL

- Clinical status on arrival to hospital
- Treatment to date with respect to trends in observations and blood gases
- Blood results and imaging

CURRENT CLINICAL STATUS

- AIRWAY & C-SPINE (ETT/tracheostomy size, length, cuffed/uncuffed, grade of laryngoscopy, method of intubation, status of C-spine clearance)
- BREATHING (mode of ventilation, ventilatory parameters, SpO_2, $ETCO_2$, oxygenation index/nitric oxide use if relevant, most recent blood gas result)
- CIRCULATION (HR, BP, MAP, capillary refill time, urine output, fluids given (boluses, maintenance), including blood and blood products, inotropes, IV access)
- DISABILITY (AVPU, GCS, sedation, paralysis, pupillary size/reactions, 3% saline/mannitol use if relevant)
- OTHER/EFG (NG/OG tube, urinary catheter, blood sugar)
- INFECTION (Core/peripheral temperature, antibiotics, culture results)

OUTSTANDING ISSUES

Figure 2 Example of a handover template.

Disability (D)

Once intubated, the child must be adequately sedated and paralysed for transport. For most children, morphine and midazolam infusions are appropriate for sedation, with vecuronium, atracurium or rocuronium infusions used for paralysis. In asthmatics, fentanyl and ketamine may be better choices, to avoid the histamine release associated with morphine. Pupillary size and reaction should be noted early and checked regularly throughout the journey, particularly if raised ICP is suspected. Pupillary changes should prompt closer attention to neuro-protective strategies and consideration of treatment with mannitol (0.25-1 g/kg) or 3% saline (3 mL/kg).

Other (EFG)

Temperature control is important, aiming for normothermia unless cooling is indicated. Infants can be placed on specially designed warming devices (eg, TransWarmer® Infant Transport Mattresses), in addition to the use of hats and blankets. Core temperature must be monitored for the duration of the transfer, using an oesophageal or rectal probe.

Particularly in infants and younger children, hypoglycaemia is a common finding associated with critical illness, due to

their high metabolic rate, poor recent intake and illness creating higher demand. Hence, blood glucose levels should be monitored regularly, and infusions of 0.45%/0.9% saline with 5% dextrose[24-28] (with or without potassium replacement) used in most situations. The maintenance fluid infusion rate should be reduced to 70% (or 2/3) in the majority of sick children[25] due to high ADH secretion.

Handover

Although an initial telephone referral will already have been made, it is important that the salient points in the history, relevant investigations and management to date are communicated to the retrieval team when they arrive (see **Figure 2**). This should also be clearly documented in a transfer letter to assist the receiving hospital in planning further management. The team leader must be made aware of any changes in the clinical condition of the patient, particularly if the child has recently been intubated. If the child is potentially infectious or is already colonised with specific organisms (eg meticillin-resistant *Staphylococcus aureus*), they will require a cubicle at the receiving PICU, and thus is crucial information to be handed over to the retrieval team.

Any known or potential child protection issues must be communicated to all staff involved in the care of the patient. It is every healthcare worker's responsibility to ensure that the correct procedures are followed.[29-32]

Local team transfer

There are a few instances when the local hospital is required to transport the child, such as for a neurosurgical emergency, when there is insufficient time to wait for a retrieval team.[33] The Tanner report stated that every DGH should be prepared to undertake such a 'time-critical' transfer in a child of any age.[8] In such situations, it must be decided who are the most appropriate members of staff to accompany the child. The DGH transport team usually consists of an anaesthetist (who can re-intubate if accidental extubation occurs) and a senior paediatric or intensive care nurse. In the case of a neonate, the neonatal consultant and a special care baby unit (SCBU) nurse may be the most sensible choice. The goal is for the right team to transfer the right child to the right centre, at the right time.[18]

The PIC retrieval team will usually make the referral to the relevant surgical team and source a bed, while the referring hospital prepares for transfer. Most PIC networks will have specific checklists for DGHs to refer to in these circumstances,[34,35] an example of which can be seen in **Figure 3**.

Appropriate staff Identified	
Local ambulance service notified	
State ventilated neurosurgical emergency patient transfer Expect ASAP response time	
Essential equipment	
Airway bag (tape, mask, T piece, Ambubag, ETT, laryngoscopes)	
Drug bag (fluid boluses, mannitol and 3% saline, fentanyl)	
Ventilator and oxygen	
Infusion pumps (sedation, muscle relaxant, vasoactive infusions)	
Adequate monitoring	
ECG	
SpO_2	
Blood pressure (NIBP cuff or arterial)	
End tidal CO_2	
Physiological targets	
SpO_2 ≥94%	
Mean BP=age appropriate target	
End tidal CO_2: 4.7-5.3 kPa	
Full sedation and paralysis	

Figure 3 Examples of a checklist for transfer of neurosurgical emergencies.[35]

Transport considerations

Packaging

It is essential that the patient be restrained during transport, while allowing adequate access for clinical intervention. Babies under 5 kg can be transported in a BabyPOD™, larger children with an Ambulance Child Restraint (ACR®) and adolescents using adult trolley straps. If multiple vehicle changes are required, such as during air transfers, vacuum mattresses or aerosleds (consisting of a clip deck and a sled) can be used as an interface for the variety of different stretchers. All equipment must be secured while any vehicle is in motion, as loose objects can become dangerous projectiles in emergency decelerations and collisions. Particular attention should be paid to lines and tubes, as replacement in an emergency can be fraught with difficulty. For this reason, an emergency airway bag and ready access to an Ambu bag/Ayre's T-Piece and oxygen supply should always be assembled prior to transfer.

Communications

All members of the transport team should carry a mobile phone and be contactable by the retrieval team base, and the local and receiving hospitals. More advanced remote consultation models such as videoconferencing and telemetry have potential for use in the future, creating a virtual ICU network[36] to support DGHs during the stabilisation period.

Safety and health

Personal risk to staff should be minimised at all times during any transfer by road or by air. This includes wearing appropriate garments that are ideally reflective, protective, fire-resistant (best practice for aeromedical transport), warm and dry. Approach angles to aircrafts are crucial to safety; explicit instructions from the pilots, aircrew or airfield ground staff should be given and followed and safety briefings given full attention.

Injuries and deaths due to accidents involving land vehicles and aircraft have been reported.[37] Most children will already

Course	Organisation	Location
Resuscitation		
APLS[6]	ALSG	Various
PLS[51]	ALSG	Various
EPLS[42]	Resuscitation Council (UK)	Various
NLS[52]	Resuscitation Council (UK)	Various
Paediatric Anaesthesia		
MEPA[44]	MEPA	Various
MEPA FC (For Consultants)[45]	MEPA	Various
Oxford Paediatric Difficult Airway Workshop[48]		Oxford
Paediatric Airway Course[47]	GOSH	London
Paediatric Intensive Care		
APICS[43]	BMSC	Bristol
Stabilisation and/ or Transport		
PaNSTaR[53]	ALSG	Various
PSTAC[54]	EMBRACE	Sheffield
SPLAT[55]	BMSC	Bristol
Situation Critical[56]	CATS	London
CAST[57]	CATS	London
OPERA[58]	OxSTaR	Oxford
Stabilisation of the Critically Ill Child[59]	KIDS	Birmingham
Paediatric and Infant Critical Care Transport Course[60]		Leicester
Faculty development		
Train the Trainer[61]	SNAPS	Southampton

Table 3 Paediatric resuscitation, stabilisation and transport courses.

have been stabilised, therefore road transportation should be undertaken at normal speeds, with the use of lights and sirens reserved only to aid progress through heavy traffic. On the rare occasions where the transfer is truly 'time-critical', a 'lights and sirens' approach may be used. If a problem occurs during the transfer, the driver should be asked to pull over before any interventions are made, unless they are absolutely life-threatening. Staff should be indemnified for medical transfer work. Personal accident insurance should be provided by the transport organisation but cover is also provided by organisations such as the Intensive Care Society, the Paediatric Intensive Care Society (PICS) or the Association of Anaesthetists of Great Britain and Ireland, as a benefit of membership.

Ventilator	Gas consumption**
BabyPac	Non-active PEEP: 5L/min* Active PEEP: 11L/min**
Oxylog 1000	Minute ventilation (MV)=1 L/min (control)*
Oxylog 3000	Minute ventilation (MV)=0.5 L/min (control)

*working estimates, local CATS policy
**Refer to ventilator manual

STEP 1: Estimate total air journey time for the patient

STEP 2: Add 1 hour for loading, unloading and taxi time

STEP 3: To provide a wide margin of error, carry twice the calculated volume

MV=tidal volume x RR

Total volume of O_2 required=MV x total air journey time (min) (including 1 hour extra) x 2

Total no. cylinders required=total volume of O_2/cylinder content

Cylinder type	Volume
D	340 L
CD	460 L
ZD	604 L
E	680 L

Figure 4 Calculation of oxygen requirement for transfer.

Relatives and family

The majority of parents accompanying their critically ill children during transfers find the experience beneficial and perceive a reduction in stress.[38] Many retrieval services now aim to accommodate parents where possible,[39] although this will depend on the mode of transportation and the space available. If parents are present, the process should be explained to them, including safety aspects, the potential for deterioration during the journey and how this will be managed. However, in all cases, the best interests of the child and the ability of the transport team to function unimpeded should be paramount.

Modes of transport

The majority of paediatric retrievals in the UK use ground ambulances owing to the relatively short distances involved; they are appropriate for journeys less than 2.5 hours. Transfer by air is indicated for life-threatening illness requiring specialist intervention (eg ECMO), large distances or overseas retrieval and repatriation. The decision to move by road or air depends on the severity of the child's condition, distance to travel, availability of appropriate aircraft and crew, type and volume of equipment required and weather conditions.

In both land and air transfers, it is vital that the team is entirely self-sufficient, including ample oxygen supply and pump/monitor battery life, suction equipment, emergency drugs and any other kit that may be required (eg for needle thoracocentesis). Nomograms exist for calculating the number of oxygen cylinders necessary for transfer;[40] however, the principles are described in **Figure 4**.

Paediatric Emergencies, by ITDTS Ltd		Emergency drug calculator combined with algorithms from internationally recognised organisations. Age- and weight-specific doses for a wide range of paediatric emergencies
Paediatric Emergency Drugs, by UBQO Ltd		Formulae designed and developed by the South Thames Retrieval Service (STRS) and PICU at the Evelina Children's Hospital
PediSTAT, by QxMD Medical Software		A reference for RNs, paramedics, physicians and other healthcare professionals caring for paediatric patients in the emergency or intensive care setting
MedCalc, by Mathias Tschopp & Pascal Pfiffner		A large selection of formulae, scores, scales and classifications
Eponyms, by Ossus GmbH		Short descriptions of more than 1700 common and obscure eponyms

Figure 5 Examples of smartphone apps available.

Maintaining competencies/skills

Immediate clinical use

There are many online tools that can be valuable resources when faced with a deteriorating child. Most paediatric retrieval services have clinical guidelines, procedural advice and drug calculators on their websites to assist with the stabilisation and referral process. There is also a multitude of smartphone application software ('apps') designed to provide ready access to age- and weight-specific formulae and drug dosages (**Figure 5**). These can be invaluable for staff preparing drugs under time pressure.

Continuous professional development (CPD)

Maintaining skills in stabilisation of the sick child is a requirement of all anaesthetic and intensive care staff with responsibility for such patients. The Royal College of Anaesthetists (RCoA) revalidation CPD matrix[41] defines specific competencies for consultants and includes team working skills between DGHs and retrieval teams.

Maintaining provider (or ideally, instructor) status for APLS[6] or European Paediatric Life Support (EPLS)[42] is a good starting point, as these courses provide practical skills and knowledge in managing common paediatric emergencies, as well as specific training in paediatric resuscitation. There are also specific courses for paediatric intensive care trainees,[43] anaesthetic trainees undertaking their paediatric anaesthesia modules[44] and for anaesthetic consultants.[45] The PICS and the Association of Paediatric Anaesthetists (APA) both organise large annual conferences and are a source of information for trainees and consultants. PICS has a webpage[46] dedicated to useful courses for trainees, such as those focusing on cardiac morphology, ECHO, ECG and ventilation. Also of interest to anaesthetists are paediatric difficult airway workshops[47,48] and an advanced vascular access seminar held at the RCoA.

There are various paediatric stabilisation and transport courses organised around the UK (**Table 3**), which are frequently simulation based, enabling core clinical and crisis resource management (CRM) skills to be learnt in a high fidelity environment. For those clinicians with an interest in paediatric pre-hospital medicine, there is an annual conference run by the Emergency Medical Retrieval Service.[49]

All clinicians involved in the care of children require level 2 training in child protection. Level 3 training is aimed at staff working predominantly or regularly with children. Safeguarding competencies form part of the CPD matrix and are an important aspect of revalidation. This training can be undertaken at local hospitals, the RCoA or via the Advanced Life Support Group (ALSG).

The majority of regional PIC networks run outreach sessions for DGHs, including regular case reviews. There is usually a 'lead consultant' in each DGH who will coordinate such study days.

Finally, it is important to note that paediatric resuscitation and retrieval is a highly emotive and often stressful time for patients, families and clinical teams. It is also a relatively rare occurrence, which necessitates that clinical teams are adequately prepared for this eventuality. Training in human factors can be valuable, as effective team-working and communication can alleviate some of the anxiety within teams. Staff involved in teaching simulation or resuscitation courses should receive training in CRM and debriefing skills, of which there are courses available nationwide.[50]

Conclusion

The DGH plays a vital role in the early recognition and stabilisation of critically ill children and staff must be prepared to transfer children of all ages in 'time-critical' circumstances. This process requires careful planning and close liaison with the retrieval teams in order that the child is transferred swiftly and uneventfully. It is also important that clinicians involved in treating critically ill children have the means to acquire and maintain their skills, at local, regional and national levels. Regional PIC networks are well placed to co-ordinate regular study days and outreach sessions to support DGH staff and enable effective relationships to be built, ultimately improving the care of critically ill children.

Declarations

The authors have no conflicts of interest to declare.
No financial support for projects was received.

References

1. **Department of Health**. *Paediatric Intensive Care – A Framework for the Future*. London: Department of Health; 1997.
2. **Ramnarayan P, Polke E**. The state of paediatric intensive care retrieval in Britain. *Arch Dis Child* 2012;97:145-49.
3. **Ramnarayan P, Thiru K, Parslow RC *et al***. Effect of specialist retrieval teams on outcomes in children admitted to paediatric intensive care units in England and Wales: a retrospective cohort study. *Lancet* 2010;376: 698-704.
4. **Ramnarayan P, Britto J, Tanna A *et al***. Does the use of a specialised paediatric retrieval service result in the loss of vital stabilisation skills among referring hospital staff? *Arch Dis Child* 2003;88:851-54.
5. **Hindocha R, Beringer R, Handel J**. A district general hospital's experience of critically ill children. *JICS* 2008;9:63-65.
6. **Advanced Life Support Group**. *Advanced Paediatric Life Support (APLS) Course*. Available from: http://www.alsg.org/uk/APLS (Accessed 2 March 2013).
7. **Children's Acute Transport Service**. *Referral Form*. Available from: http://site.cats.nhs.uk/wp-content/uploads/2012/08/Referrer_ prompt_-sheet.pdf (Accessed 2 March 2013).
8. **Rollin AM**. Working together for the sick or injured child: the Tanner report. *Anaesthesia* 2006;61:1135-37.
9. **Children's Acute Transport Service**. *Clinical Guidelines: Waiting for the Retrieval Team*. Available from: http://site.cats.nhs.uk/wp-content/uploads /2012/08/cats_waiting_for_team_dgh_2011.pdf Accessed 2 March 2013.
10. **Borrows EL, Lutman DH, Montgomery MA *et al***. Effect of patient- and team-related factors on stabilization time during pediatric intensive care transport. *Pediatr Crit Care Med* 2010;11:451-56.
11. **Paediatric Airway Guidelines Group**. *Paediatric Difficult Airway Guidelines*. 2012. Available from: http://www.das.uk.com/content/ paediatric-difficult-airway-guidelines (Accessed 2 March 2013).
12. **Cummins RO, Hazinski MF**. Guidelines based on the principle 'First, do no harm'. New guidelines on tracheal tube confirmation and prevention of dislodgment. *Resuscitation* 2000;46:443-47.
13. **Newth CJ, Rachman B, Patel N, Hammer J**. The use of cuffed versus uncuffed endotracheal tubes in pediatric intensive care. *J Pediatr* 2004;144:333-37.
14. **Weiss M, Dullenkopf A, Fischer JE *et al***. Prospective randomized controlled multi-centre trial of cuffed or uncuffed endotracheal tubes in small children. *Br J Anaesth* 2009;103:867-73.
15. **BestBETs**. *Do cuffed endotracheal tubes increase the risk of airway mucosal injury and post-extubation stridor in children?* 2005. Available from: http://www.bestbets.org/bets/bet.php?id=1088 (Accessed 2 March 2013).
16. **Khine HH, Corddry DH, Kettrick RG *et al***. Comparison of cuffed and uncuffed endotracheal tubes in young children during general anesthesia. *Anesthesiol* 1997;86:627-31; discussion 27A.
17. **Parwani V, Hoffman RJ, Russell A *et al***. Practicing paramedics cannot generate or estimate safe endotracheal tube cuff pressure using standard techniques. *Prehosp Emerg Care* 2007;11:307-11.
18. Advanced Life Support Group. *Paediatric and neonatal safe transfer & retrieval*. The practical approach (PaNSTaR). Oxford: Blackwell; 2008.
19. **Lutman D, Petros A**. Inhaled nitric oxide in neonatal and paediatric transport. *Early Hum Dev* 2008;84:725-29.
20. **Vidacare**. 2012. Available from: http://www.vidacare.com/EZ-IO/Clinical-Applications-and-Education.aspx (Accessed 2 March 2013).
21. **Murphy P, Arnold P**. Ultrasound-assisted vascular access in children. *Contin Educ Anaesth Crit Care Pain* 2011;11:44-49.
22. **Dellinger RP, Levy MM, Rhodes A *et al***. Surviving Sepsis Campaign: International guidelines for management of severe sepsis and septic shock: 2012. *Crit Care Med* 2013;41:580-637.
23. Children's Acute Transport Service. *Electronic Drug Calculator*. Available from: http://site.cats.nhs.uk/wp-content/uploads/2012/08/ dgh_drugcalculator_v1.1.pdf (Accessed 2 March 2013).
24. **Duke T, Molyneux EM**. Intravenous fluids for seriously ill children: time to reconsider. *Lancet* 2003;362:1320-23.
25. **Yung M, Keeley S**. Randomised controlled trial of intravenous maintenance fluids. *J Paediatr Child Health* 2009;45:9-14.
26. **Montanana PA, Modesto I, Alapont V *et al***. The use of isotonic fluid as maintenance therapy prevents iatrogenic hyponatremia in pediatrics: a randomized, controlled open study. *Pediatr Crit Care Med* 2008;9:589-97.
27. **Neville KA, Sandeman DJ, Rubinstein A *et al***. Prevention of hyponatremia during maintenance intravenous fluid administration: a prospective randomized study of fluid type versus fluid rate. *J Pediatr* 2010;156:313-19 e1-2.
28. **Saba TG, Fairbairn J, Houghton F *et al***. A randomized controlled trial of isotonic versus hypotonic maintenance intravenous fluids in hospitalized children. *BMC Pediatr* 2011;11:82.
29. **General Medical Council**. *Protecting children and young people: The responsibilities of all doctors*. 2012.
30. **Royal College of Paediatrics and Child Health**. *Safeguarding Children and Young people: roles and competencies for health care staff. Intercollegiate document*. 2010. Available from: http://www.ukpics.org.uk/documents/ Safeguarding Children and Young people 2010.pdf (Accessed 2 March 2013).
31. **Royal College of Paediatrics and Child Health**. *Safeguarding in 2012: views from the frontline*. 2012. Available from: http://www.rcpch.ac.uk/ system/files/protected/page/020412 Safeguarding 2012.pdf (Accessed 2 March 2013).
32. **Association of Paediatric Anaesthetists**, Royal College of Paediatrics and Child Health, Royal College of Anaesthetists. *Child Protection and the Anaesthetist: Safeguarding Children in the Operating Theatre. Intercollegiate Document*. 2007. Available from: http://www.apagbi.org.uk/sites/default/ files/RCPCH_v2_2007.pdf (Accessed 2 March 2013).
33. **Society of British Neurological Surgeons, Royal College of Anaesthetists**. *Joint Statement from the Society of British Neurological Surgeons (SBNS) and Royal College of Anaesthetists (RCoA) Regarding the Provision of Emergency Paediatric Neurosurgical Services*. 2010. Available from: http:// www.rcoa.ac.uk/document-store/provision-of-emergency-paediatric-neurosurgical-services (Accessed 2 March 2013).
34. **South Thames Retrieval Service**. *Clinical Guidelines: Time Critical Neurosurgical Transfer*. Available from: http://www.strs.nhs.uk/resources/ pdf/guidelines/neurosurgtransfer.pdf (Accessed 2 March 2013).
35. **Children's Acute Transport Service**. *Clinical Guidelines: Acute Neurosurgical Emergency*. Available from: http://site.cats.nhs.uk/wp-content/uploads/2012/08/cats_neurosurgical_2011.pdf (Accessed 2 March 2013).
36. **Dharmar M, Marcin JP**. A picture is worth a thousand words: critical care consultations to emergency departments using telemedicine. *Pediatr Crit Care Med* 2009;10:606-07.
37. **Lutman D, Montgomery M, Ramnarayan P, Petros A**. Ambulance and aeromedical accident rates during emergency retrieval in Great Britain. *Emerg Med J* 2008;25:301-02.
38. **Davies J, Tibby SM, Murdoch IA**. Should parents accompany critically ill children during inter-hospital transport? *Arch Dis Child* 2005;90:1270-73.
39. **Tasker RC**. Inter-hospital transport for children and their parent(s). *Arch Dis Child* 2005;90:1217-18.
40. **Lutman D, Petros AJ**. How many oxygen cylinders do you need to take on transport? A nomogram for cylinder size and duration. *Emerg Med J* 2006;23:703-04.
41. **Royal College of Anaesthetists**. *CPD Matrix*. Available from: http://www.rcoa.ac.uk/document-store/cpd-matrix (Accessed 2 March 2013).
42. **Resuscitation Council (UK)**. *European Paediatric Life Support (EPLS) Provider Course*. Available from: http://www.resus.org.uk/pages/ eplsgen.htm (Accessed 2 March 2013).
43. **Bristol Medical Simulation Centre**. *Advanced Paediatric Intensive Care Simulation Course (APICS)*. Available from: http://www.bmsc.co.uk/

courses/APICS.htm (Accessed 2 March 2013).
44. **MEPA**. *Managing Emergencies in Paediatric Anaesthesia Course*. https://mepa.org.uk/ (Accessed December 2013).
45. **MEPA**. *Managing Emergencies in Paediatric Anaesthesia For Consultants Course*. Available from: https://mepa.org.uk/ (Accessed December 2013).
46. **Paediatric Intensive Care Society**. *Courses for PICS trainees*. Available from: http://www.ukpics.org.uk/Trainee_courses.html (Accessed 2 March 2013).
47. **Great Ormond Street Hospital for Children NHS Trust**. *Paediatric Airway Course*. Available from: http://www.apagbi.org.uk/sites/default/files/images/Paediatric Airway Course-2.pdf (Accessed 2 March 2013).
48. **Oxford University Hospitals NHS Trust**. *Oxford Paediatric Difficult Airway Workshop*. Available from: http://www.das.uk.com/content/oxford-paediatric-difficult -airway-workshop (Accessed 8 December 2013).
49. **Emergency Medical Retrieval Service**. Available from: http://www.emrs.scot.nhs.uk/ (Accessed 2 March 2013).
50. **London Deanery**. *Simulation & Technology-enhanced Learning Initiative*. STeLI faculty development. Available from: http://simulation.londondeanery.ac.uk/faculty-development (Accessed 2 March 2013).
51. **Advanced Life Support Group**. *Paediatric Life Support (PLS) Course*. Available from: http://www.alsg.org/uk/PLS (Accessed 2 March 2013).
52. **Resuscitation Council (UK)**. *Newborn Life Support (NLS) Course*. Available from: http://www.resus.org.uk/pages/nlsinfo.htm (Accessed 2 March 2013).
53. **Advanced Life Support Group**. *Paediatric and neonatal safe transfer and retrieval (PaNSTaR)*. Available from: http://www.alsg.org/uk/node/16 (Accessed 2 March 2013).
54. **EMBRACE**. *Paediatric Safe Transfer And Communication Course (PSTAC)*. Available from: http://www.montagusimulation.co.uk/Courses/CourseDetail.aspx?referrer=courselist&id=55 (Accessed 2 March 2013).
55. **Bristol Medical Simulation Centre**. *South West Paediatric Life Support and Transfer Course (SPLAT)*. Available from: http://www.bmsc.co.uk/courses/SPLAT.htm (Accessed 2 March 2013).
56. **Children's Acute Transport Service**. *Situation Critical Study Day*. Available from: http://site.cats.nhs.uk/situation-critical/ (Accessed 2 March 2013).
57. **Children's Acute Transport Service**. *CAts Stabilisation and Transport (CAST) Simulation Course*. Available from: http://site.cats.nhs.uk/cats-stabilisation-and-transport-cast-simulation-course/ (Accessed 2 March 2013).
58. **OxSTaR**. *Oxford Paediatric Emergencies Resuscitation and Stabilisation course - A team response*. Available from: http://www.oxstar.ox.ac.uk/courses-2/ (Accessed December 2013).
59. **KIDS**. *Stabilisation of the critically ill child*. Available from: http://kids.bch.nhs.uk/stabilisation-course/ (Accessed 2 March 2013).
60. **University Hospitals of Leicester NHS Trust**. *Paediatric and infant critical care transport course*. Available from: http://www.apagbi.org.uk/sites/default/files/images/Paediatric and Infant Critical Care Transport Course.pdf (Accessed 2 March 2013).
61. **The Southampton Neonatal And Paediatric Simulation Group**. *SNAPS Train the trainers course*. Available from: http://www.sort.nhs.uk/Media/Education/SNAPS-Train-the-trainer-course-6,7June2013.pdf (Accessed 2 March 2013).

Joy Dawes CATS Retrieval Fellow

Padmanabhan Ramnarayan CATS Consultant and PICU Consultant at St. Mary's Hospital
padmanabhan.ramnarayan@gosh.nhs.uk

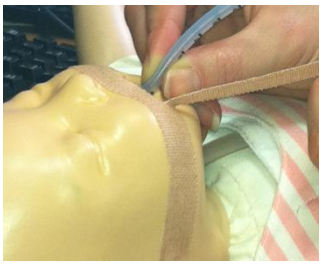
Daniel Lutman Specialty Lead for CATS, Consultant Paediatric Anaesthetist at The Royal London Hospital

Children's Acute Transport Service, Great Ormond Street Hospital

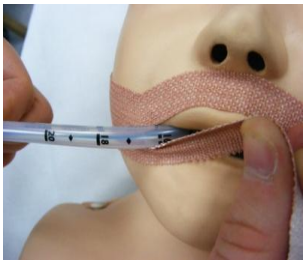
Guidelines for Melbourne Strapping of Oral Endotracheal Tubes.

Equipment Required: Red Tape & clear label (cut into 'trouser legs'), emergency airway equipment & suction.
Rationale: To ensure the safe & secure fixation of oral endotracheal tubes

Ensure the endotracheal tube is positioned to the corner of the mouth, pointing south.



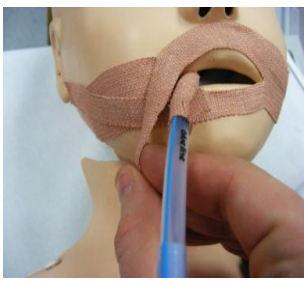
Slowly peel the first tape from the clear label. Begin on the same side of the face where the tube is. **Ensure the length of the tube is clearly visible.** Place the tape so the joining is at the corner of the lips on the cheek. Take the top 'trouser leg' and stick straight across face (between upper lip and underneath the nose)



Confirm the position of the tube before applying the bottom 'trouser leg'. Wrap the bottom trouser around the tube close to the lips, winding up the tube in a spiral fashion.
Ensure when strapping that lips and nares are kept visible and that you do not tape over them

Ensure the top of the tube is still visible after strapping (approximately 2cm). Once the tape is in place fold over a small piece in order to aid removal of the tapes for re-positioning.

Take the second tape & begin from the other side of the face. Again, place the tape at the corner of the mouth, outside of the lips on the cheek. Take the bottom 'trouser leg and tape directly across the face underneath the bottom lip.



Take the top 'trouser Leg' and place along the face (underneath the nose and above the top lip).

Once you have reached the corner of the mouth carefully proceed to wrap the tape around the tube moving up the tube as you go. Ensure you tape as close to the required length as possible .Again ensure you leave approximately 2cm of the top of the tube visible.

Great Ormond Street Hospital for Children NHS Trust

12 - Airway Management and Chest drains

Author: Daniel Lutman 2004
Updated: Quen Mok, November 2006; Andy Petros and Sarfaraz Rahiman Nov 2010;

Associated clinical guidelines/protocols:

- Tracheostomy guidelines
- Management Difficult Airway
- Chest Drains
- Melbourne Strapping / ETT secure

Fundamental Knowledge:
List of topics relevant to PIC that will have been covered in membership examinations. They will not be repeated here.

Anatomy:

- Upper airway anatomy, innervation and blood supply.

Information for Year 1 ITU Training (basic):

Year 1 ITU curriculum
Airway skills:

- Clinical assessment of airway & recognition of potentially difficult airway.
- Methods of maintaining a clear airway and use of airway adjuncts:
- Indications for tracheal intubation
- Safe intubation technique & induction of anaesthesia
- Rapid sequence intubation.
- Causes of regurgitation and vomiting: prevention and management of pulmonary aspiration
- Difficult and failed intubation drill
- Detection and management of pneumothorax (simple and tension); insertion and safe management of chest drains

Curriculum Notes for Year 1:

Airway skills:
This is a practical subject that requires supervised practice and experience, and cannot be learnt by reading alone. There are several anatomic and physiologic features in infants and children that may impact advanced airway management. (1)

- Prominent occiput – causes varying degrees of neck flexion
- Large tongue – may impede visualization during direct laryngoscopy
- Larger tonsils and adenoids – obstruction; bleeding
- Superior laryngeal position – direct visualization more challenging
- Weaker hyoepiglottic ligament – Macintosh may not effectively elevate the epiglottis
- Large, floppy epiglottis
- Shorter and narrower trachea — predisposes to right mainstem bronchus intubation or inadvertent extubation

- Funnel-shaped airway
- Compliant chest wall - more likely to experience respiratory muscle fatigue, atelectasis and respiratory failure
- Lower functional residual capacity and Higher oxygen metabolism - heightened need for preoxygenation

Clinical assessment of the airway and recognition of potentially difficult airway:
The classic papers grading the difficulty are referenced and attempts to predict difficulty are discussed in the chapter by Hagberg and Ghatge [2]. Unfortunately a difficult airway is often not identified until laryngoscopy is performed, and a previous history of difficult airway management is the best predictor that this difficulty would recur. It is therefore important to clearly document a difficult intubation.

Assessment begins with a previous and current history (3). Various congenital syndromes and acquired conditions are associated with the difficult airway, hence this problem may be more of an issue with the GOS population.

- Congenital (Pierre-Robin syndrome, Treacher-Collins syndrome, Goldenhar's syndrome, Down's syndrome, etc)
- Infections (Laryngeal oedema, Croup, Oral or retropharyngeal abscess, Ludwig's angina)
- Arthritis (Temporomandibular joint ankylosis, restricted mobility of cervical spine)
- Tumors: Cystic hygroma, Malignant tumors,
- Trauma: Facial injury, cervical spine injury, Acute burns
- Obesity

Cormack-Lehane grading of direct laryngoscopy [4]

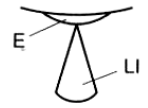
Original Cormack-Lehane system	I Full view of the glottis	II Partial view of the glottis or arytenoids		III Only epiglottis visible	IV Neither glottis nor epiglottis visible
View at laryngoscopy					
Modified system Cormack-Lehane	I As for original Cormack-Lehane above	IIa Partial view of the glottis	IIb Arytenoids or posterior part of the vocal cords only just visible	III As for original Cormack-Lehane above	IV As for original Cormack-Lehane above

Figure 8-1. Cormack-Lehane original grading system compared with a modified Cormack-Lehane system (MCLS). E = epiglottis; LI = laryngeal inlet. *Reproduced with permission from Yentis SM, Lee DJH: Evaluation of an improved scoring system for the grading of direct laryngscopy.* Anesthesia *1998; 82: 1197-1204.*

L Look externally
Look at the patient externally for characteristics that are known to cause difficult laryngoscopy, intubation or ventilation.

E Evaluate the 3-3-2 rule
In order to allow alignment of the pharyngeal, laryngeal and oral axes and therefore simple intubation, the following relationships should be observed. The distance between the patient's incisor teeth should be at least 3 finger breadths (3), the distance between the hyoid bone and the chin should be at least 3 finger breadths (3), and the distance between the thyroid notch and the floor of the mouth should be at least 2 finger breadths (2).

1 = Inter-incisor distance in fingers.
2 = Hyoid mental distance in fingers.
3 = Thyroid to floor of mouth in fingers.

M Mallampati
The hypopharynx should be visualized adequately. This has been done traditionally by assessing the Mallampati classification. The patient is sat upright, told to open the mouth fully and protrude the tongue as far as possible. The examiner then looks into the mouth with a light torch to assess the degree of hypopharynx visible. In the case of a supine patient, Mallampati score can be estimated by getting the patient to open the mouth fully and protrude the tongue and a laryngoscopy light can be shone into the hypopharynx from above.


Class I: soft palate, uvula, fauces, pillars visible


Class II: soft palate, uvula, fauces visible


Class III: soft palate, base of uvula visible


Class IV: hard palate only visible

O Obstruction?
Any condition that can cause obstruction of the airway will make laryngoscopy and ventilation difficult. Such conditions are epiglottis, peritonsillar abscesses and trauma.

N Neck mobility
This is a vital requirement for successful intubation. It can be assessed easily by getting the patient to place their chin down onto their chest and then to extend their neck so they are looking towards the ceiling. Patients in hard collar neck immobilization obviously have no neck movement are therefore harder to intubate.

Fig 1. The LEMON airway assessment method (5)

Maintaining a clear airway and airway adjuncts:

See relevant sections in APLS manual and LMA instruction manual.

Indications for intubation:

1. Anaesthetic indications
    a. Restricted access eg prone or head and neck surgery
    b. Ventilation required eg long surgery, thoracic or cardiac surgery
    c. Protection against tracheal soiling eg aspiration, oral surgery
    d. Airway obstruction
    e. Muscle relaxation required eg abdominal surgery
2. Non Anaesthetic indications
    a. Cardiopulmonary resuscitation
    b. Respiratory failure
    c. Airway protection eg in coma, uncontrolled seizures impaired airway reflexes or obstructed airway
    d. To allow aspiration of sputum/secretions

e. Control of PaCO2 in head injury patients
f. Investigations (e.g. bronchoscopy, CT, MRI)
g. Transport of a sick child.
h. Haemodynamic instability due to septic or cardiogenic shock

Safe intubation technique and induction of anaesthesia:
It is our unit policy to have 2 people present at all intubations on the ICU, even if one is experienced, in case of difficulties.

- EQUIPMENT:
  - Endotracheal tubes - ET tubes that are a half size above and below the estimated size for age must also be available. The endotracheal size and length can be estimated using the following table and formula taken from 'Drug Doses by Frank Shann 13th Ed 2005'. Although it has been traditionally taught that only uncuffed ETTs should be used for paediatric patients under 8 years of age, recent literature has shown that the modern low-pressure high-volume cuffed tubes can be used safely without an increased rate of complications [6,7]. It is important to monitor cuff pressures meticulously. Cuffed ET tube may be used in children with severe lung disease who may require high ventilator pressures; preferable for children at risk for aspiration. If a cuffed endotracheal tube is selected the formula predicted size is reduced by half a millimeter.

		Endotracheal tube				
Age	Wt kg	Int Dia mm	Ext Dia mm*	At Lip cm	At Nose cm	Sucker FG
Newborn	<0.7	2.0	2.9	5.0	6	6
Newborn	<1	2.5+	3.6	5.5	7	6
Newborn	1.0	3.0+	4.3	6	7.5	7
Newborn	2.0	3.0+	4.3	7	9	7
Newborn	3.0	3.0+	4.3	8.5	10.5	7
Newborn	3.5	3.5+	4.9	9	11	8
3 month	6.0	3.5	4.9	10	12	8
1 year	10	4.0	5.6	11	14	8
2 year	12	4.5	6.2	12	15	8
3 year	14	4.5	6.2	13	16	8
4 year	16	5.0	6.9	14	17	10
6 year	20	5.5	7.5	15	19	10
8 year	24	6.0	8.2	16	20	10
10 year	30	6.5	8.9	17	21	12
12 year	38	7.0	9.5	18	22	12
14 year	50	7.5	10.2	19	23	12
Adult	60	8.0	10.8	20	24	12
Adult	70	9.0	12.1	21	25	12

* External diameter of Mallinckrodt tubes
\+ ETT: <1kg 2.5mm, 1-3.5kg 3.0mm, >3.5 3.5mm
ETT: size mm = 4 + age/4; length (cm) at lip = 12 + age/2, at nose = 15 + age/2

  - Stylet - to reinforce the rigidity of the ET tube.
  - Bougie
  - Laryngoscopes and blades – checked to be working
  - Confirmation device - qualitative or quantitative detection of end-tidal CO2. Successful intubation is confirmed by capnography, as no other method has proved to be as reliable. Capnography may be unreliable in cardiopulmonary arrest. A chest radiograph should be obtained as soon as possible to confirm that the tip of the ET tube is located one to three centimeters above the carina and below the thoracic inlet.

Rapid sequence intubation (RSI) (8):
The goal of RSI is to take a non-fasted patient in an emergency situation from the conscious to unconscious, neuromuscularly blocked state and to perform tracheal intubation without intervening positive pressure ventilation. The important thing to remember is the increased risk of aspiration, hence positive pressure ventilation or insertion of a nasogastric tube should be avoided until the airway is secured.

Steps for RSI:

- PREOXYGENATION — If breathing spontaneously - adequate preoxygenation can be achieved using a nonrebreathing mask for a minimum of three minutes. If a child is apneic, hypoxic, in respiratory failure, or has insufficient respiratory reserve bag-mask ventilation with small tidal volumes may be performed for several minutes to achieve adequate preoxygenation.
- PREPARATION — A rapid review of key aspects of the child's history, as well as a targeted physical examination helps identify conditions that affect the optimal choices of medications for pretreatment, sedation, paralysis, and postintubation management, as well as a contingency plan in the event of a failed intubation. In addition, equipment (Suction, Oxygen, Airway equipment and Monitoring equipment (oxygen saturation, heart rate, blood pressure, end-tidal carbon dioxide))
    - Allergies to medications
    - History of or concern for neuromuscular disease and/or Any condition that could result in hyperkalemia, such as an acute crush injury or renal failure — Succinylcholine can cause a clinically significant rise in serum potassium in patients with neuromuscular disease.
    - Family history suggestive of malignant hyperthermia with anesthetics — Use of succinylcholine is absolutely contraindicated
    - Previous difficult intubation
    - Noisy breathing, particularly in sleep, suggests some degree of anatomic upper airway obstruction (such as enlarged tonsils or tongue) that may interfere with laryngoscopy or bag-mask ventilation.
    - Cardiovascular status
    - Increased intracranial pressure, focal neurologic signs
    - Bronchospasm

- PRETREATMENT —
    - Atropine — 0.02 mg/kg (minimum 0.1 mg; maximum 0.5 mg) IV for all children younger than one year, for those less than five years of age receiving succinylcholine, and for children older than five years requiring a second dose of succinylcholine.
    - Lignocaine — 1 mg/kg IV in raised intracranial pressure.
    - Opioids — usually fentanyl dose??
    - Defasciculating agents — Defasciculating agents (eg, rocuronium or vecuronium at one-tenth of the paralyzing dose) are not routinely recommended for children receiving succinylcholine.
- SEDATION AND PARALYSIS — The two essential medications used in rapid sequence intubation (RSI) are a sedative and a paralytic. The reader is referred elsewhere for profiles of Sedative and paralytic agents.
- PROTECTION— Protection during RSI refers to protecting the airway by preventing regurgitation of gastric contents and aspiration. This is accomplished with cricoid pressure and by avoiding bag-mask ventilation.
- POSITIONING —
    - To align the pharyngeal and tracheal axes, the neck is flexed forward on the shoulders, such that the external auditory canal is anterior to the shoulder. This may be accomplished in children by placing a towel or roll under the occiput. In infants, because of a prominent occiput, the towel must be placed under the shoulders to achieve this position. To align the oral axis with the pharyngeal and tracheal axes, the head is then extended on the neck, such that the nose and mouth are pointing toward the ceiling.
    - For children with suspected injury of the cervical spine, positioning must be accomplished without moving the neck. In-line manual stabilization must be maintained.
- PLACEMENT, WITH CONFIRMATION — Once adequate muscle relaxation is confirmed, laryngoscopy can be performed with careful attention to proper technique. After the tracheal tube has been placed and stylet removed, tube placement must be confirmed. Confirmation includes primary methods (such as auscultation for breath sounds over lung fields and stomach, the appearance of mist inside the tracheal tube,

and symmetric chest rise with positive pressure ventilation) as well as confirmation with detection of end-tidal carbon dioxide.
- POSTINTUBATION MANAGEMENT — Following placement and confirmation, the tracheal tube should be appropriately secured and a chest radiograph obtained to document proper placement and evaluate pulmonary status. Other issues that must be addressed include monitoring for complications related to the procedure and continuing sedation and paralysis.

CATS Clinical Guidelines 2006
Induction of anaesthesia

Notes on Anaesthetic Drug Management

General Aspects
Note that administering a general anaesthetic in an unfamiliar environment (ie a referring hospital) should be a two-doctor procedure using a local anaesthetist with appropriate skill. This enables rapid access to local resources in case of difficulty. If difficulty is anticipated or where conditions are not ideal, the following may be necessary, depending on time available:

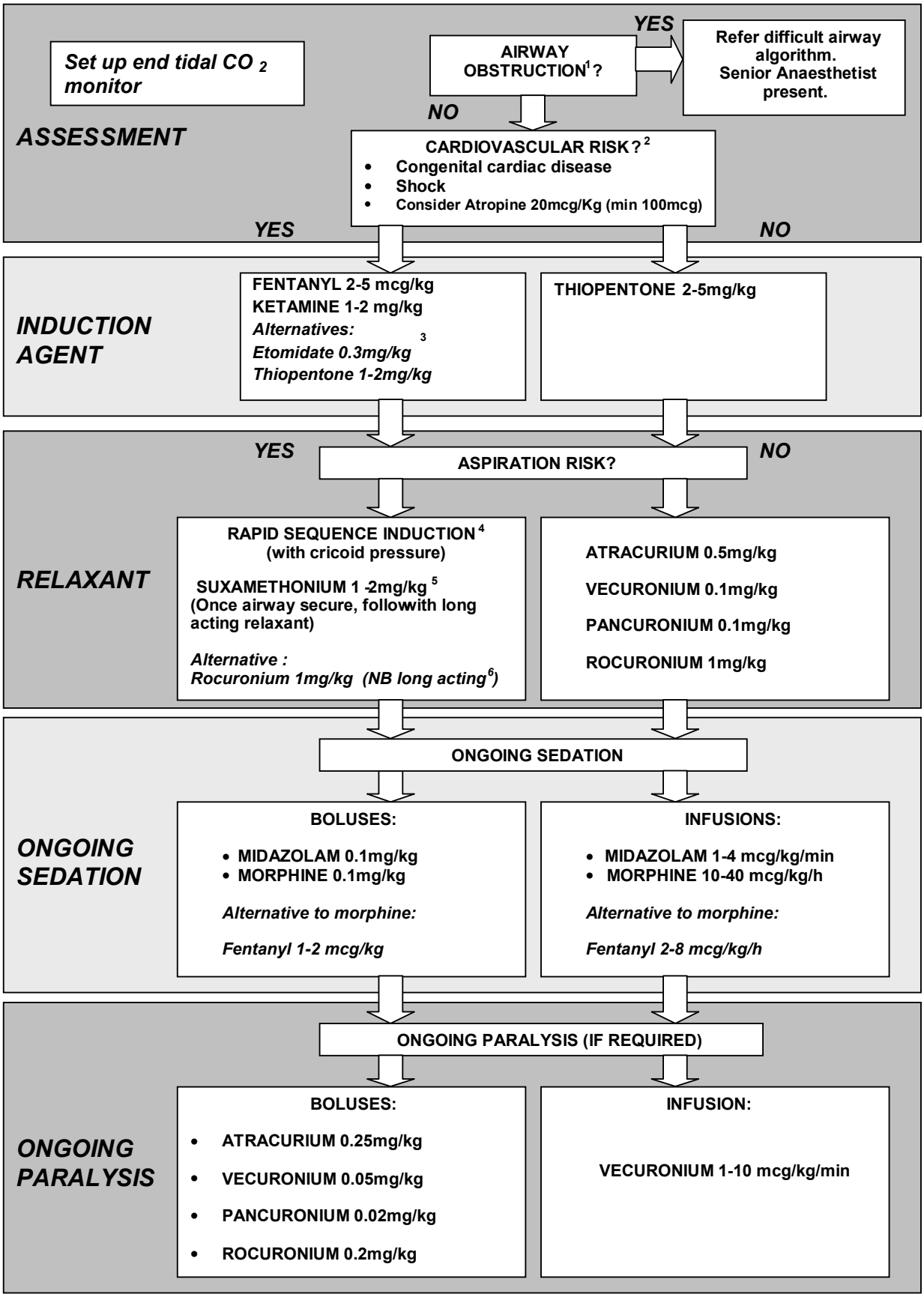
- The presence of a consultant anaesthetist from the referring hospital especially where airway obstruction is present.
- Moving the child to an anaesthetic room where more equipment may be to hand, as well as an operating department practitioner (ODP).

Approach all intubations with caution as it is impossible to exclude difficulty by examination

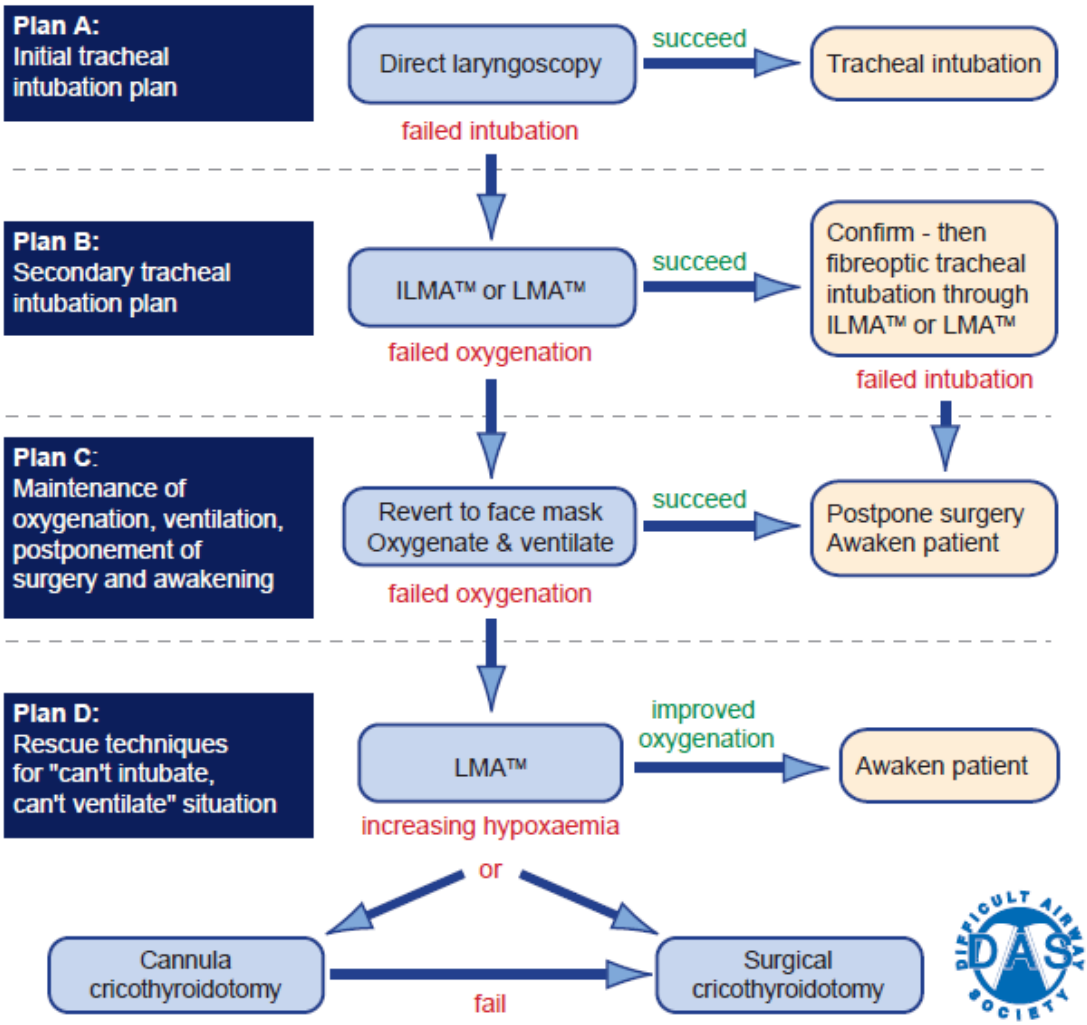
Assessment:
Management of the difficult airway requires senior anaesthetic and ENT assistance. In general an inhalational induction is favoured over intravenous induction. *Inhalational agents and anaesthetic machines should only be used by doctors trained in their use.*

Induction Agent:
Fentanyl or Ketamine are the agents of choice for the cardiovascularly unstable patient and may be used in all age groups. Etomidate use has become controversial in sepsis (Anaesthesia. 2005 Aug;60(8):737-40, Chest; Mar 2005; 127,3, Emerg. Med. J.2004;21;655-659) as it causes adrenal suppression. In cases of shock consider the use of physiologic steroid replacement eg.Hydrocortisone 1mg/kg 6 hourly iv (non-stressed physiological replacement is 0.2mg/Kg 8 hourly iv). Both thiopentone and etomidate reduce intracranial pressure. Ketamine increases intracranial pressure and should not be used if intracranial pressure is a clinical problem. For the unstable neonate an opiate-only technique may be used in which case fentanyl rather than morphine should be used due to its rapid action.

Relaxant:
Rapid sequence induction (RSI) involves preoxygenation, administering induction agent then relaxant in precalculated doses in rapid succession followed by application of cricoid pressure. The airway is then secured after onset of the muscle relaxant without mask ventilation. RSI may be practically difficult in small children and neonates owing to desaturation before full muscle relaxation. Suxamethonium is the RSI relaxant of choice. Its onset of action in 30 seconds is superior to all non-depolarising relaxants. It should not be used in patients with - hyperkalaemia, muscular dystrophy or myotonia, suspected or confirmed malignant hyperpyrexia, or 24 hours after major burn or spinal cord injury – owing to exaggerated hyperkalaemic response. In these circumstances rocuronium is an alternative if RSI is required – its onset of action is 45 to 60 seconds. Its long duration of action (40 minutes +) poses a problem if the airway cannot be secured.



Difficult and failed intubation drill (10):
The latest management guideline is in the Difficult Airway Society guidelines published in Anaesthesia [10] or their website. Although this is written for adults, the principles apply to our paediatric population, and is essential reading. Make sure that a difficult intubation is well documented in the patient notes.



Most intubations in PICU are because of oxygenation and ventilation problems and hence Plan C may not be entirely appropriate for PICU. More senior Anaesthetic and ENT help should be sought as available and child should be shifted to theatres for intubation or other procedures if time permits.

Detection and management of pneumothorax (simple and tension); insertion and safe management of chest drains (11)

Examination findings:
Increased respiratory distress.
Ipsilateral reduced chest expansion, reduced breath sounds, resonant to percussion
Subcutaneous emphysema
Hamman's sign
Mediastinal shift and tracheal displacement to the contralateral side.
In infants a sudden progressive abdominal distension may be noticed if a right sided pneumothorax causes the liver to displace downwards

Increasing airway pressures on volume control
Reducing tidal volumes on pressure control
High PaCO2

CXR may demonstrate rim of pleural gas or subcutaneous emphysema.
Anterior air on a supine film may be difficult to spot.
A change in diaphragm contour (flattening) may indicate a tension pneumothorax

Entonox is relatively contraindicated in pneumothorax as the nitrous oxide rapidly diffuses into the trapped gas.

Simple aspiration is less likely to succeed in secondary pneumothoraces. Traumatic pneumothorax or a pneumothorax in a ventilated patient should have an intercostal drain inserted. A tension pneumothorax may quickly progress to cardiorespiratory arrest, hence must be drained. There is no evidence that large tubes are any better than small tubes, although it may be necessary to replace a small chest drain with a larger one if there is persistent air leak. Suction may be added if there is persistent air leak or failure of the lung to re-expand. High volume low pressure (-10 to -20 cmH2O) suction systems are recommended.

Early referral to thoracic surgeons should be considered in persistent air leaks. Chemical pleurodesis can control difficult or recurrent air leak but should only be attempted if patient is unable to undergo surgery. Open thoracotomy and pleurectomy remains the procedure with the lowest recurrence rate but VATS (video assisted thoracoscopic surgery), pleural abrasion and surgical talc pleurodesis are all effective alternative strategies.

Other sources of information:

APLS manual

LMA instruction manual. The laryngeal mask company limited.

ASA Task force Guidelines for management of the difficult airway

Websites:

Information about capnography can be found on www.capnography.com

Difficult Airway Society guidelines for management of the unanticipated difficult intubation from the DAS website www.das.uk.com although this is written for adult patients

References:

1. Nagler J, Wang VJ. Airway management in children: Unique pediatric considerations. Uptodate September 8, 2009.
2. Hagberg CA and Ghatge S. Does the Airway examination predict difficult examination? Chap 8 In Evidence based practice of Anaesthesiology
3. Gupta S, Sharma RKR, Jain D. AIRWAY ASSESSMENT PREDICTORS OF DIFFICULT AIRWAY. Indian J. Anaesth. 2005; 49 (4) : 2
4. Cormack RS, Lehane J 1984 Difficult tracheal intubation in obstetrics Anaesthesia 39: 1105-1111
5. M J Reed, M J G Dunn, D W McKeown. Can an airway assessment score predict difficulty at intubation in the emergency department ? Emerg Med J 2005;22 :99–102. doi: 10.1136/emj.2003.008771
6. Newth CJL, Rachman B, Patel N & Hammer J. The use of cuffed versus uncuffed endotracheal tubes in pediatric intensive care. J Pediatr 2004; 144: 333-7
7. Fine GF and Borland LM. The future of the cuffed endotracheal tube. Pediatric Anesthesia 2004; 14: 38-42
8. Agarwal, D. Rapid sequence intubation in children. Uptodate October 8, 2009
9. Bledsoe GH & Schnexnayder SM. Pediatric rapid sequence intubation. A review. Pediatric Emergency Care 2004; 20: 339-44

10. Henderson JJ, Popat MT, Latto IP and Pearce AC. Difficult Airway Society guidelines for management of the unanticipated difficult intubation. Anaesthesia 2004; 59: 675-94
11. Walker RWM. The Pediatric Airway. In: Core topics in Airway management. Cambridge University Press 2005: 123-31.
12. *Henry M, Arnold T, Harvey J, on behalf of the BTS pleural disease group. BTS guidelines for the management of spontaneous pneumothorax. Thorax 2003;58 (suppl II): ii39-ii52*

Information for Year 2 ITU Training (advanced):

Year 2 ITU curriculum
Airway skills:

- Gas induction: indications, method and limitations
- Airway management in special circumstances; head & cervical spine injury, upper airway obstruction (croup & epiglottitis),
- Management of the unprotected airway.
- Tracheostomy: indications, contraindications, complications and management.
- Cricothyroidotomy
- Detection, aetiology and management of pleural effusions, empyema and chylothoraces

Curriculum Notes for Year 2:

Gas induction: indications, method and limitations

Inhalational induction is used in the situation where there is upper airway obstruction and it is anticipated that intubation may be difficult as spontaneous respiration is maintained. Alveolar (and hence blood) levels are easily controlled by adjusting inspired concentration of the inhalational agent. If the airway cannot be secured, at least the child will awaken when the volatile agent is discontinued. This should only be used by practitioners trained in the use of the anaesthetic machine. Refer to A to Z of Anaesthesia and Intensive Care for properties and undesirable effects of the different volatile agents.

Airway management in special circumstances:
Head & Cervical spine injury:

- The bougie is a useful adjunct in the patient with an injured cervical spine that facilitates intubation despite a sub-optimal view of the larynx.
- The Miller blades have the theoretical advantage of reducing the force during laryngoscopy; however, in practice this has not been shown to reduce movement of the neck. The levering laryngoscope and Bullard laryngoscope may be useful in experienced hands.

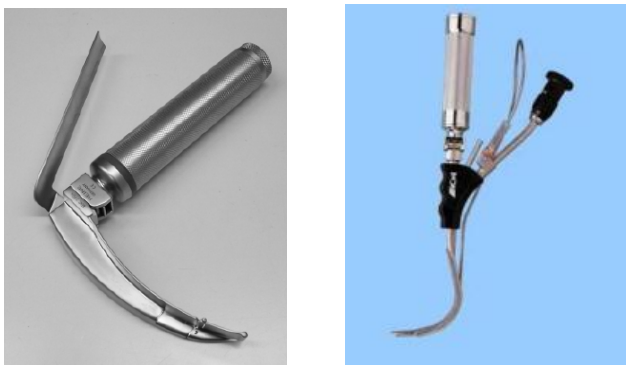


Fig 2: Levering laryngoscope and Bullard laryngoscope

- Cricoid pressure is important in the trauma patient since there may be a full stomach. The technique also improves the view at laryngoscopy with pressure applied backwards, upwards and to the right (BURP).
- Cervical spine immobilization: Rigid collars can make laryngoscopy more difficult, and therefore, should be removed before direct laryngoscopy is performed and Manual in Line Stabilization applied. If tracheal intubation is proving difficult, it may become necessary to reduce the grip as securing the airway is priority.
- Insertion of an LMA is only marginally more difficult than usual with C Spine immobilisation.
- Cricothyrotomy for 'can't intubate, can't ventilate' scenario.

Upper airway obstruction:

- Early involvement of the ENT and anaesthetic teams is important for any child who may require intubation. The child should be breathing high inspired oxygen, kept calm and allowed to adopt a comfortable position. An airway strategy should be pre-formulated by senior ENT and anaesthetic staff and equipment should be available.
- Generally, the primary plan is to establish a surgical plane of anaesthesia with an inhalational agent. Direct laryngoscopy is attempted only when the child is deeply anaesthetized. Muscle relaxants should not be used until the airway is secure.

Burns and Inhalational Injury:

- With burns involving the airway, oropharynx, or related structures, early endotracheal intubation is indicated. The edema that ensues will rapidly create a difficult intubation scenario and make securing a definitive airway a challenge.
- Early in the course of events, with appropriate induction, muscle relaxation, and cricoid pressure, direct laryngoscopy usually provides an effective mode of performing an orotracheal intubation. As edema worsens and signs of upper airway obstruction appear, endotracheal intubation becomes more difficult. At this point fiberoptic bronchoscopic-assisted intubation may be necessary.
- Endotracheal tubes should not be cut in burns patients as the tube tends to lift out with the strapping as the burned tissues swell.
- Another source of complication includes accidental extubation with head turning or mishaps on transport. Resecuring the airway in these scenarios can be extremely difficult. Tracheostomy has been suggested as a means to decrease airway-related morbidity.

Tracheostomy: indications, contraindications, complications and management

The indications for tracheostomies in children have changed in the last 30 years from treatment of acute infections of the airway to management of prolonged ventilation for neuromuscular or respiratory problems [11]. Tracheostomy is also performed for congenital and acquired airway abnormalities, as well as for craniofacial syndromes. It is associated with significant morbidity and mortality especially in infants and young child [12]. Early complications include air leaks and haemorrhage, while misplacement, accidental decannulation and tube obstruction can occur anytime and can result in death. Children who have been tracheostomised for more than a week have a delay in speech acquisition, affecting both receptive and exprressive communication. See tracheostomy guidelines for management.

Cricothyroidotomy

See APLS manual

Detection, aetiology and management of pleural effusions, empyema and chylothoraces

Pleural effusions are usually secondary to acute bacterial infections, with pneumococcus emerging as the predominant pathogen in childhood empyema. Other pathogens (Staph

aureus, Mycoplasma, Mycobacteria and viruses) can also cause pleural effusions. Rarely this may be the presenting sign of a malignancy, HLH or a connective tissue disorder.

Ultrasound scan is useful in identifying loculations and to guide thoracocentesis or drain placement. Conservative treatment with intravenous anitbiotics and simple drainage may be effective in small parapneumonic effusions. Intrapleural fibrinolytics are recommended for any complicated parapneumonic effusion (thick fluid with loculations) or empyema (overt pus). There is no evidence that any of the 3 fibrinnolytics are more effective than the others, but only urokinase has been studied in a RCT in children, and is therefore recommended. Surgical treatment using VATS should be considered if there is persisting sepsis in association with a persistent effusion. However a formal thoracotomy and decortication may be required for organised empyema. See algorithm below taken from the BTS guidelines [13]

A chylothorax is more likely following trauma or cardiac surgery due to involvement of the thoracic duct. The thoracic duct transports intestinal and skeletal lymph, as well as the majority of proteins and ingested fats and the bulk of lymphocytes, back into the circulation. This would therefore lead to hypoalbuminemia, hypogammaglobulinemia and lymphopenia, with an increased risk of infection. Conservative therapy would include medium chain triglyceride feeds and octreotide, or enteral rest with parenteral nutrition, to reduce chyle production. Albumin and immunoglobulin infusions would be necessary to replace ongoing losses. [14]. Surgical therapies include pleuroperitoneal shunts to recycle the chyle, pleurodesis or thoracoscopic repair of the thoracic duct. Biochemical analyses of the effusion may help identify the cause [15]

BTS guidelines for the management of pleural infection in children

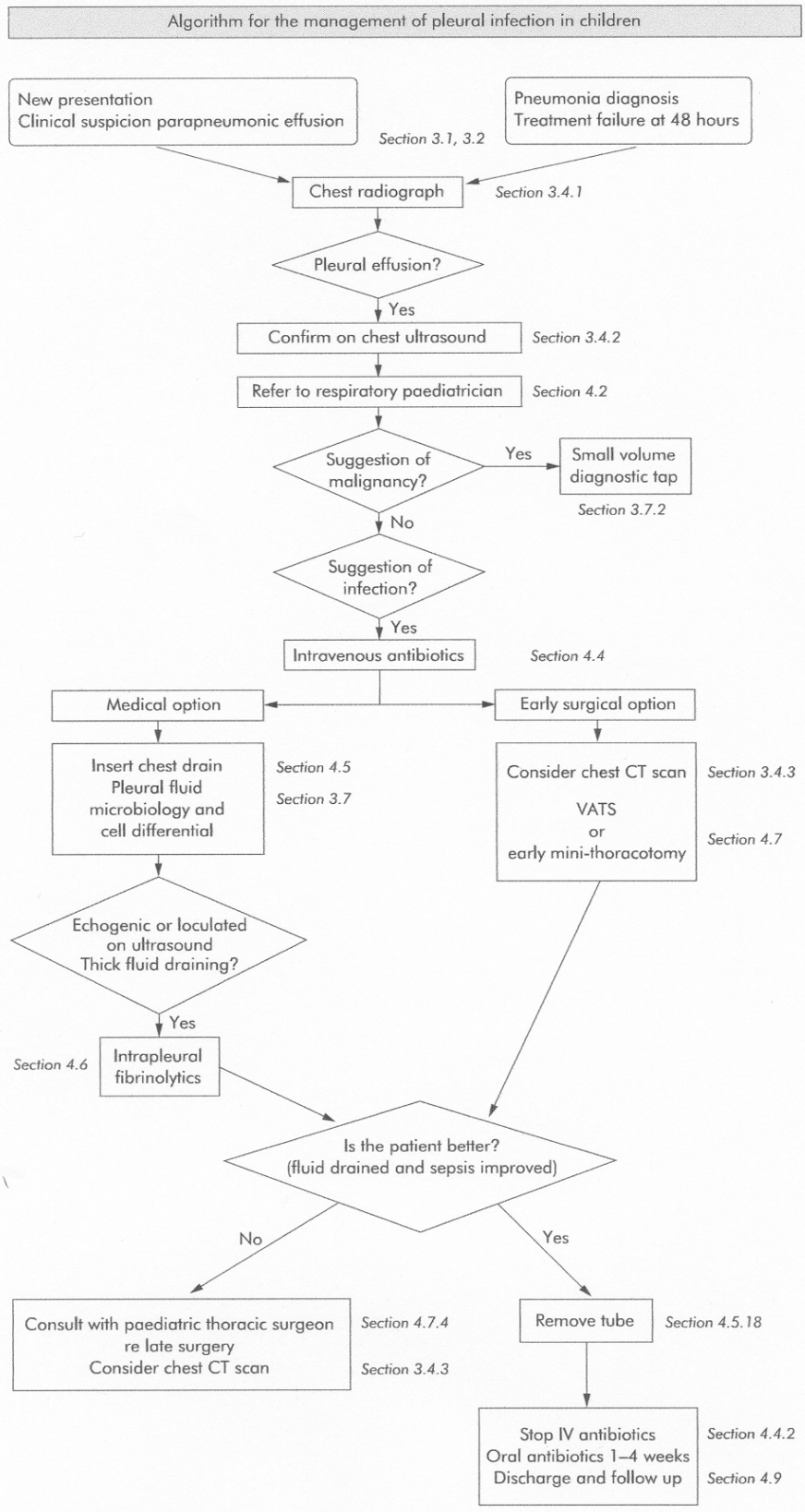


Figure 1 Algorithm for the management of pleural infection in children.

Balfour-Lynn IM et al. BTS guidelines for the management of pleural infection in children. Thorax 2005

Other sources of information:

APLS manual

Anesthesia and Intensive Care A-Z by Yentis, Hirsch and Smith. Butterworth Heinemann

Websites

http://www.virtual-anaesthesia-textbook.com

http://www.frca.co.uk

References:

1. Jacobs BR, Salman BA, Cotton RT, Lyons K, Brilli RJ. Postoperative management of children after single-stage laryngotracheal reconstruction. Crit Care Med 2001; 29: 164-168

2. Hadfield PJ, Lloyd-Faulconbridge RV, Almeyda J, Albert DM and Bailey CM. The changing indications for paediatric tracheostomy. Int J Pediatr Otorhinolaryngol 2003; 67: 7-10

3. Kremer B, Botos-Kremer AI, Eckel HE and Schlondorff G. Indications , complications and surgical techniques for pediatric tracheostomies – an update. J Pediatr Surg 2002; 37: 1556-1562

4. Balfour-Lynn IM, Abrahamson E, Cohen G et al on behalf of the Paediatric Pleural Diseases Subcommittee of the BTS standards of care committee. BTS guidelines for the management of pleural infection in children. Thorax 2005; 60 (suppl I) : i1-i21

5. Lewis RA and Feigin RD. Current issues in the diagnosis and management of pediatric empyema. Sem in Ped Infectious Diseases 2002; 13: 280-288

6. Jenkinson F, Murphy MJ. Pleural effusions: the role of biochemical analysis. Hospital Medicine 2004; 65: 481-4

