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Special Feature

Stabilisation and transport of the critically ill child

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A historical perspective on inter-hospital transport

Over the past few years, there has been an increasing trend to centralise specialist paediatric services such as intensive care so that they are available only in a few tertiary centres. This process of centralisation has already occurred in many parts of the world including the United States, United Kingdom, Australia, and continues to take place, slowly and to a lesser extent, in Europe and parts of Asia [1, 2]. Regionalisation of care is based on the principle that patients have better outcomes when specialist expertise is concentrated in fewer centres as well as the fact that it is more cost effective [3]. The natural consequence of centralisation is that staff at smaller hospitals will become less experienced at dealing with critically ill children. When such children are admitted to their nearest hospital in an emergency situation, they will need timely and appropriate resuscitation, stabilisation and transport to a tertiary centre for advanced monitoring and treatment. Transport of seriously ill children, from home to primary care, from primary care to district hospital, and from smaller hospitals to tertiary centres, is a neglected global issue, and lack of organised transport systems, especially in the developing world, results in significant annual mortality [4].

This article will summarise the current state of specialist paediatric transport services, both in the developed world and in developing countries, and outline specific clinical management points during the transportation of critically ill children.

Organisation of specialist transport services in the developed world

A number of different models of inter-hospital transport have developed over the past few years. In many countries, transfer of these children is still undertaken by non-specialist staff from the child's admitting community hospital [5, 6]. However, transfer of critically ill children by non-specialist teams is associated with a high frequency of preventable adverse events and a higher rate of mortality [7]. In contrast, specialist retrieval teams have been shown to reduce the morbidity associated with inter-hospital transport [8]. In the US and UK, most children requiring transport to critical care units are currently transported by specialist retrieval teams. These teams are able to travel to the referring hospital and provide the same level of intensive care as can be provided in a paediatric critical care unit.

PRINCIPLES OF TRANSPORT AND STABILISATION

The aim of the transport team is to ensure that the child receives intensive care continuously, from the point of referral to the point of handover to the receiving centre. The concept of ""scoop and run", where key interventions are delayed until the patient is brought to the tertiary centre, is no longer relevant in inter-hospital transport[9]. The retrieval team should aim to stabilise the

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patient as far as possible before transfer, so that the need for life-saving interventions can be minimised during the actual journey [10]. Although the team may be proficient in carrying out these procedures in the ambulance, constraints of space, noise, lack of further assistants, and vehicular motion make it very challenging.

MODELS OF SPECIALIST TRANSPORT TEAM ORGANISATION

Two different models exist for the organisation of specialist transport teams. In the first, specialist teams partaking in transport are drawn from the staff already present on the paediatric intensive care unit (PICU), i.e. a unit-based model. In this model, staff may already be busy looking after inpatients, and are diverted to a retrieval when the need arises. This model is practical when the frequency of requests for retrieval is limited, and the number of transports undertaken is <300-400/year. The advantage of this model is that existing staff from the PICU are used for the transport, which will also provide continuity of care when the team have returned to the unit with the patient. On the other hand, when the frequency of transports is greater, inpatient care will suffer due to staff being repeatedly taken off patient care duties, and it may be better to have a dedicated team for transports, who do not have other concurrent duties. This latter model is likely to be more efficient when annual transport rate is >400/year (i.e. >1 per day). The dedicated transport team may be located within a PICU or separate from it, and it can serve multiple PICUs in a defined geographical region. To increase the overall efficiency in this model, the team may also be used to perform non-critical care transfers to the tertiary centre.

TEAM COMPOSITION AND COMPETENCIES

There is significant diversity in terms of transport team composition and their competencies and skills, e.g. physicians, nursing staff, ambulance paramedics and/or respiratory therapists. In turn, physicians and nurses may be drawn from critical care, anaesthesia or emergency department backgrounds. Paramedics may also have specialised into dedicated critical care transport paramedic roles. A number of studies have examined the need for physicians on transport. King et al published in 2007 that there was no difference between a physician-led team and a nurse-only team in terms of adverse events on transport or the ability to perform basic critical care procedures [11]. Irrespective of the team composition, it is recommended that a minimum of two personnel are available for patient care. They should have both undergone training in critical care, gained some experience in transport medicine, and have APLS/PALS certification. Team members will need to be competent at advanced airway management, ventilatory techniques, intravenous therapy, vascular access procedures, dysrhythmia interpretation and treatment, and basic and advanced cardiac life support (see Table 1). Nurses achieve these competencies by advancing their practice and undergoing a dedicated period of training in critical care transport, with regular maintenance of their competencies.

Table 1: Competencies required for paediatric critical care transport team members

APLS/PALS certification
Technical skills • Endotracheal intubation • Use of nebuliser kit • Use of oxygen masks and nasal prongs • Bag-mask ventilation • Setting up transport ventilator and familiarity with its operation • Central venous, arterial and other venous access • Intraosseous needle placement • Needle thoracostomy • Defibrillation and DC cardioversion
Cognitive skills • Recognise and manage ABC failure • Knowledge of how common paediatric emergencies present • Management of common paediatric emergencies • Troubleshoot equipment failure
Team working skills and communication • Able to work well as team leader and team member • Negotiation skills • Conflict resolution skills

EQUIPMENT FOR TRANSPORT

A minimum list of equipment and medications is summarised in table 2[12]. In summary, equipment should be readily available for airway and oxygenation, vital signs monitoring, and the pharmaceutical agents necessary for emergency resuscitation and stabilisation as well as maintenance of vital functions should be accessible. Equipment function must be verified on a regular and scheduled basis, not at the time of transport, when there may be insufficient time to find replacements. In general, equipment used in transport must be able to satisfy the following criteria:

a) Portability: Size and weight may limit the choice of equipment used for transport situations
b) Ruggedness: Equipment must be certified to withstand a wide range of temperatures, vibration, shock and repeated use.
c) Independent of mains power: It is desirable that the equipment is battery-powered and able to function for prolonged periods without mains power supply. This will minimise the risk of unexpected adverse events during transport.
d) Simple interface: Equipment must enable staff to use it without lengthy training or preparation.

Table 2: Recommended minimum transport equipment and medications

Monitoring • ECG, pulse oximetry, non-invasive blood pressure, respiration rate • End-tidal CO2 for ventilated patients • Invasive blood pressure and central venous pressure for haemodynamically unstable patients
Airway management • Paediatric and adult-size self-inflating bag-valve apparatus • Paediatric and adult-size masks • High concentration masks with reservoir bag • Cuffed endotracheal tubes (3.5-8.0) • Uncuffed endotracheal tubes (2.0-5.0) • Laryngoscopes and blades (Miller 0, 1, 2 and Macintosh 1, 2, 3, 4) • Endotracheal tube stylets • Magil forceps • Nasopharyngeal airways • Oral airways (0, 1, 2, 3, 4) • Needle cricothyroidotomy kit • Water soluble lubricant • Oxygen tubing • Nebuliser kit

Breathing • Transport ventilator • PEEP valve (if not internal to ventilator) • Chest drain kit • Butterfly needles (21, 23, 25 G) • One-way valves for chest drain (Heimlich) • Suction apparatus • Stethoscopes • Suction catheters (6, 8, 10, 12 Fr and Yankaeur)
Circulation • Intravenous cannulae (size 16-24 G) • Intraosseous needles (16 and 18 G) • 0.9% saline and colloid solution (albumin/gelofusin) • 3-way taps • Arterial transducer and tubing • Central venous catheters (4 and 5 Fr) • Blood pressure cuffs (neonatal, infant, child, adult small and large) • Pressure bags for fluid administration • Tourniquets for IV access
Infusion pumps (battery operated)

Medications

- Adenosine
- Amiodarone
- Atropine
- Adrenaline
- Calcium gluconate and chloride
- Dopamine
- Dobutamine
- Frusemide
- Glucagon
- Glyceryl trinitrate
- Heparin
- Hydrocortisone
- Isoprenaline
- Labetalol
- Lignocaine
- Mannitol
- Magnesium sulphate
- Naloxone

Medications

- Nitroprusside
- Normal saline for injection
- Phenobarbitone
- Phenytoin
- Potassium chloride
- Sodium bicarbonate
- Sterile water
- Salbutamol (nebuliser and intravenous)
- Terbutaline
- Tromethamine (THAM)

Other medications such as:

- Opiates (morphine, fentanyl or other)
- Benzodiazepines (midazolam or lorazepam)
- Neuromuscular blockade (succinyl choline, pancuronium or other)
- Prostaglandin E1
- Surfactant
- Inhaled nitric oxide
- Anti-snake venom

TRANSPORT MODES

In most parts of the world, road ambulances are most frequently used to perform inter-hospital transports. If long distances are involved in the transfer (or transport involves travelling to an island or a place with poor road conditions), either rotary wing (helicopter) or fixed wing aircraft can be used. Staff performing these air transfers should be suitably trained in flight transfers as well as be aware of air transport physiology. The particular challenges of air transfer are related to the difficulty of the flight environment in terms of lack of adequate space, excessive noise, vibration and the inability to stop and request additional help en route.

Organisation of specialist transport services in the developing world

Transport systems for seriously ill children are still in their infancy in the developing world, where access to basic medical care itself, let alone specialist care, is poor. In general, transport from home to hospital is still done by parents and a variety of vehicles such as car, taxi, autorickshaw, bullock cart and bicycle may be used. Government-run or supported emergency medical service ambulances are rare, and a diverse range of private hospital ambulances, with varying facilities, are used to transport patients from smaller clinics to larger hospitals. Providing life-saving treatments during transport may be impossible in this setting due to shortage of trained staff, lack of equipment and resources as well as lack of central communication and co-ordination.

Other challenges involve private hospitals not referring patients early to tertiary care centres due to financial motivation, parents not being able to afford specialist transport and further intensive care, and lack of a formal referral network. Despite these obstacles, specialist retrieval teams have been established and data have been published from a number of developing countries such as Thailand, Malaysia, Ghana, and South Africa[13]. All available evidence points to improved care for patients who are transported by specialist teams.

STABILISATION DURING TRANSPORT

The aim of stabilisation of a critically ill patient is to ensure that further physiological deterioration does not occur en route, and to improve outcomes by early reversal of adverse physiological trends. The goal of a specialist team is to provide early intensive care, which may improve patient outcomes, well demonstrated with goal-directed therapy in septic shock as well as from studies of traumatic head injury[14, 15]. Stabilisation can be initiated by the referral hospital by following telephone advice from the specialist team even before the team arrives at the patient's bedside. Studies show that early advice and input from the retrieval team by telephone can make a significant difference to mortality in meningococcal sepsis, and that in London, most life-saving interventions are performed by the referring hospitals rather than the transport team[16, 17]. Even when the specialist team reaches the bedside, the aim should be to perform the minimum interventions to stabilise the patient for transfer. However, in time-critical clinical conditions (e.g. extradural haematoma, necrotic bowel or volvulus, acute hydrocephalus etc), the evidence indicates that it may be preferable for the referring team to bring the patient to the tertiary centre rather than delay definitive treatment by using a specialist team[18]. In this scenario, the risk of transfer by an inexperienced team is outweighed by the benefits of urgent treatment.

CLINICAL MANAGEMENT DURING TRANSPORT

The clinical management of a patient during stabilisation and transfer are similar to established principles of Airway Breathing and Circulation assessment and management as taught on the Advanced Life support courses.

However, there may be additional relevant points, both general and specific, as detailed below:

GENERAL POINTS

1. Clinical management during transport is aimed not at the current physiological condition, but the predicted physiology during the transfer (anticipatory management). For example, patients with fluid-responsive shock should still have vasoactive infusions prepared and ready for administration, even if the child does not require them in their current state. This may be different from a PICU setting, where treatment can be easily initiated and only when required.

2. The transport environment is an intrinsically challenging environment, even if the staff are fully trained and able to undertake life-saving procedures. First of all, stabilisation of patients occurs in a setting that is not the team's familiar one (i.e. a remote hospital emergency department) and they may not be able to access all the requisite assistance, technical skills and equipment. Second, in the face of patient deterioration, there may be interventions that can only be provided in a hospital setting, e.g. neurosurgery for a rapidly expanding extradural haematoma, and the transport team should not delay transport unnecessarily. In other situations, e.g. a septic patient, they may need to spend many hours achieving central venous access and administering fluids and vasoactive agents.

AIRWAY MANAGEMENT

There is evidence from the emergency medical services (EMS) world that bag valve mask ventilation is equivalent to endotracheal intubation for airway control, but in inter-hospital transport, where the transfer times are much longer, endotracheal intubation is the only safe method to secure the airway. It is absolutely paramount that a stable and secure airway is established for physiological stabilisation and safe transport. It may be very difficult, if not impossible, to secure an airway during the journey itself, which means that any airway intervention has to be performed before setting off on transport. The implication of this point is that early and elective intubation may be the only safe way to secure the airway in some cases, even if the clinical condition does not dictate this at the time. Examples where this principle may be used are progressive upper airway obstruction in viral croup or fluid-unresponsive shock.

Once the airway is secured, it should be well-maintained during the transport with the use of tight fitting tapes and ties. Patients may need to have neuromuscular blockade with non-depolarising agents (e.g. vecuronium) during the transport. Continuous end-tidal CO2 monitoring is mandatory for critical care transport. These points are even more important when the airway intervention has been challenging (e.g. a Pierre Robin patient with difficult airway and poor view on laryngoscopy) or is predicted to be impossible with the passage of time (e.g. progressive airway swelling from facial burns). If endotracheal intubation is impossible before transport, an emergency tracheostomy may be necessary to secure the airway. There are also reports of the use of laryngeal mask airways for long distance transport, when intubation may have failed[19].

The use of cuffed endotracheal tubes (ETT) is now recommended for management of patients requiring high pressure ventilation, even among neonates (size 3.5 upwards). In practice, the cuff can be left uninflated unless a leak develops or if high pressure ventilation is required. No long term complications have been reported.

VENTILATORY ASSISTANCE

Although it may be possible to hand ventilate patients during transport, there is evidence that this practice results in unpredictable variations in gas exchange (which may be undesirable in conditions such as trauma and head injury)[20]. The use of a portable transport ventilator is the best method for mechanical ventilation during transport. Various models such as the Draeger Oxylog series, Smith Medical Babypac and Pneupac, as well as more sophisticated LTV series (Pulmonetics Inc) are available. In general, transport ventilators are less able to function like sophisticated PICU ventilators, and users may need to balance the requirement for portability with losing advanced functionality. Features such as independent adjustment of inspiratory and expiratory times, patient triggering and pressure support are optional, and may be available only on some models. However, it is recommended that any transport ventilator is able to deliver positive end-expiratory pressure (PEEP), either by means of an external valve or as part of the internal mechanism.

Monitoring of ventilation is performed through the usual methods (physical examination, pulse oximetry, blood gas analysis and capnography). End-tidal CO2 measurement is a particularly useful tool during transport, and acts as a continuous non-invasive measure of ventilation. Monitoring changes to the CO2 waveform may also be very useful during transfer – sudden loss may imply dislodged or completely occluded ETT, or disconnection of the circuit.

CIRCULATION AND VASCULAR ACCESS

The principles of managing shock are similar to the PICU environment – fluid administration and use of vasoactive agents (such as epinephrine or dopamine). Continuous haemodynamic monitoring is very important during transfer, and the presence of an arterial line and central venous catheter (CVC) may be invaluable. Most vital signs monitors will be able to display an invasive arterial waveform and also measure central venous pressure. CVCs are particularly useful when vasoactive agents need to be infused, when peripheral venous access is difficult, or when multiple intravenous infusions may need to be administered (e.g. bronchodilators for asthma). The usual choice of central access is through the femoral vein or internal jugular vein. Subclavian access is rarely used during transport, due to the higher complication rate in untrained hands as well as the potential for uncontrolled bleeding in sick and coagulopathic patients.

In case of difficulty in achieving central access, the intra-osseous route has been shown to be a reliable and useful method during inter-hospital transport. The IO route has been safely used for many hours in these cases to deliver various medications including inotropes and fluids[21].

SEDATION AND PARALYSIS

In order to maintain a secure airway, vascular access and to reduce complications during transfer, ventilated patients are usually sedated and paralysed for inter-hospital transport. Morphine and midazolam infusions are used commonly, but fentanyl, propofol, remifentanyl or clonidine infusions are also used. In severe asthma, ketamine infusion may help with bronchodilation. Ketamine may also be used for analgesia in severely burned patients.

MANAGEMENT OF COMMON CONDITIONS

The medical management of children being transported with various emergencies such as airway obstruction (croup, epiglottitis), respiratory failure (pneumonia, asthma, pulmonary oedema), neurological conditions (status epilepticus), infections (meningitis, encephalitis and sepsis) or cardiac conditions (neonatal cyanotic heart disease and myocarditis) is similar to the management on the intensive care unit. However, there may be minor differences due to the nature of transport and its destabilising effect on the patient's physiology.

AIRWAY OBSTRUCTION:

In conditions such as viral croup, bacterial tracheitis or epiglottitis, significant airway compromise may occur. While some borderline patients can be managed on critical care units with close observation, nebulised adrenaline and steroids, this may be difficult in the transport environment. Such patients will usually require a definitive airway before inter-hospital transfer, and endotracheal intubation may need to be electively performed.

Asthma: The management of asthma involves the use of oxygen, steroids and bronchodilators. The use of magnesium sulphate as an intravenous bolus (40-75 mg/kg) may prevent emergency intubation. If intubation is required, ketamine may be used as the induction agent as well as for ongoing sedation due to its bronchodilator properties. Pressure-limited ventilation with a strategy for permissive hypercapnia and controlled hypoventilation is appropriate. Suction and physiotherapy may be very important during transport due to secretions being dislodged during transfer.

Sepsis: The standard guidelines of American College of Critical Care Medicine (ACCM) may be followed – this consists of fluid resuscitation to reverse shock, use of early vasoactive agents after 40-60 ml/kg fluid, and early intubation and application of PEEP. These points become more important during transport, and infusions of inotropic agents will need to be prepared in advance for the journey even if patients are fluid-responsive at the time of departure. Prolonged stabilisation with massive fluid transfusion (>150-200 ml/kg) may result in further decompensation due to worsening pulmonary oedema, therefore, an optimal time window has to be found to transfer the patient before further deterioration.

NEONATAL CONGENITAL HEART DISEASE:

These infants are usually relatively stable and need to be transferred on prostaglandin to maintain ductal patency. High doses of prostaglandin may lead to apnoeas and hypotension (usually >20 ng/kg/min), so these children may need elective intubation before transport.

THE FUTURE OF TRANSPORT MEDICINE

As PICU becomes a more centralised resource, there will be more demand for patients to be safely transferred from local hospitals to bigger tertiary centres. There will also be an increasing realisation that patients' outcome is determined more by early and timely interventions at the referring centre than treatment provided after arrival onto the PICU. As more evidence begins to accumulate for the importance of goal-directed therapy, the use of specialist teams to deliver this expertise earlier to patients will become more commonplace.

Retrieval services will also need to demonstrate that they are performing well in terms of patient outcomes as well as user satisfaction. They will need to closely monitor key performance indicators such as the rate of adverse events, team mobilisation time, stabilisation time, and report this information back to the users. More work needs to be done to delineate specific areas of controversy in transport, e.g. where the referring team's clinical responsibility ends and where the retrieval team's responsibility begins. Despite these challenges, the importance of a specialist transport team cannot be underestimated if we are to provide the best care to our patients.

In the developing world, good transport systems are vital to ensure that patients can access specialist care at distant hospitals. In addition, the knock-on effect of a transport team is that referring hospitals will learn from them, and gradually undertake better patient management, resulting in better outcomes for critically ill children.

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