

Aeromedical transfer for the critically ill patient - an introduction and best practice clinical overview

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Summary

This article provides an overview of aeromedical transfer and some of the considerations required in the aviation environment, in terms of equipment, patient care and team safety. The overarching principles of transfer of a critically ill patient also apply and are not discussed in detail here. Aeromedical transfer is an emerging sub-specialty and there are specific considerations that must be addressed in order to make pre-hospital medicine and retrieval of patients effective, safe and (therefore) a viable alternative to road ambulance services.

INTRODUCTION

Aeromedical transfer may be used in the management of critically ill or injured patients from point of wounding (POW) to definitive care, or between hospitals as part of the evacuation pathway through the levels of secondary care. It comprises advanced resuscitation techniques and allows life, limb and eyesight saving procedures to be performed en route and in a timely fashion. In many parts of the world road transfers are neither suitable nor time effective, due to geographical remoteness, arduous terrain or hostile human factors. Aeromedical retrieval may provide the optimum solution. There is also increasing evidence to suggest that patients who receive pre-hospital stabilisation have better outcomes.^{1,2}

Options for aeromedical transfer can be broadly divided into fixed wing (FW) and rotary wing (RW), each having advantages and disadvantages compared with the other.³ FW retrieval offers casualty transfer over great distances with rapidity. It often allows an optimised clinical environment, lower ambient noise, easier communication (with patient, colleagues and flight crew) and may operate in a greater range of weather conditions. Despite this, FW retrieval flights are always bound by access to commercial airports, private runways or temporary landing zones (TLZ) and therefore incur an additional road transfer burden at source and destination.

RW retrieval offers robust flexibility and typically allows casualty collection from the point of wounding (POW) or source hospital, and direct disposal at the destination facility. Helipads are increasingly common features of regional trauma centres in developed countries and this strongly supports the RW option. Helicopter platforms incur minimal road transfers as the asset is commonly able to 'land-on'.

In addition, RW platforms tend to have faster response times (i.e. from notification of retrieval requirement to being airborne) and therefore are ideal for enabling 'Golden Hour' pre-hospital trauma care and evacuation timelines. Clinical conditions and working environments vary greatly however, from compact, bespoke platforms with excellent lighting and noise isolation, to large military-type helicopters

effective communication is problematic, even with dedicated headsets. The latter range of RW platforms is often seen in civil emergencies or natural disaster evacuations, and therefore the author recommends all retrieval clinicians have an understanding of military RW platforms used in MEDEVAC (e.g. CH-47, Lynx, Merlin, Sea King and Puma UK assets).

In order to ensure safe, auditable and defensible pre-hospital medical retrieval, organisations must have Quality Assurance (QA) and Healthcare Governance (HG) frameworks in place.³ A named clinical lead is responsible for on-call acute advice and the ownership of appraisal, QA and audit. Equipment and drug supplies must be serviced and maintained to the same standards as the parent secondary care trust (as a minimum).

PHYSIOLOGY

An understanding of the changing effects of altitude on both casualty and crew is fundamental to the safe aeromedical transfer of patients.⁵

Boyle's Law

Boyle's law states that, at a constant temperature, the pressure of a gas is inversely proportional to its volume. This is important for any gas filled space. Pathological examples include pneumothorax, pneumocephalus, small bowel obstruction and decompression illness. It also can have effects on equipment, for example cuffed endotracheal tubes. The cuff pressures should be measured prior to take off and during flight and adjusted accordingly.

Dalton's Law

Dalton's law states that the total pressure of a gas mixture equals the sum of the partial pressures of each gas, as if they existed on their own. As altitude increases, atmospheric pressure decreases and a resultant partial pressure of oxygen falls. Patients requiring a high FIO₂ at sea level, may well require intubation and ventilation for aeromedical transfer due to the reduction of oxygen delivery at sub-atmospheric pressures. It is paramount to try and anticipate if patients require intubation and ventilation prior to take off, as space, staffing and resources in the aircraft may be limited.

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Temperature

The partial pressure of water and temperature both fall with increasing altitude, resulting in a significant reduction in the humidity of clinical gases. This can affect patients with respiratory pathology and patients with burns. The ability to heat the clinical cabin area of the aircraft (and road ambulances) should be utilised whenever possible. Fluids will be cooler at altitude and efforts to warm them prior to administration should be made where possible. Solutions include the portable blood product warmers (such as Enflow and Buddy Lite systems). Conversely, hot climates can equally cause problems in some areas of the world for pre-hospital patients. Unwell patients, in a hot environment, can become even further dehydrated through occult huge insensible losses, dressings do not adhere effectively and patients are more likely become agitated and distressed. Efforts should be made to shade the patient on the scene, maintain euvolaemia and use external cooling methods (fans, stripping and spray cooling).

CLINICAL APPROACH

The medical team normally comprises a critical care physician and a flight nurse or paramedic. Basic retrieval and transfer tasks will be activated with a flight paramedic or nurse only. For critical care retrievals, the staff must be competent in advanced airway and resuscitation skills, with a minimum of two staff for a single patient transfer.^{6,7}

The clinical assessment begins as soon as the referral has been activated. A thorough triage history can give important information to both the aviation staff and the clinical team. This will encompass scene safety, weather forecast, journey length, as well as the referring and receiving facilities. A synopsis of the transfer referral will highlight any specific considerations such as multiple casualties, the type of trauma or medical condition, and whether any additional equipment or drugs is required, for example anti-venom, blood products, or vehicle extrication kit.

On arrival at the patient, scene safety should first be addressed and, once this is secured, the patient can be approached. A combination of rapid assessment and resuscitation should take place in a systematic fashion, using CABCADE (C-spine, ABCDE) or an alternative approved method. In the pre-hospital environment, only life, limb or eyesight saving procedures should take place at the scene. The transport of patients who require primary surgical stabilisation should not have their evacuation delayed while clinical teams provide advanced adjunctive medical care. On-going reassessment of the primary survey and initial secondary survey, as well as advanced resuscitation including drugs and blood products can take place en route.

Personal protective equipment (PPE)

Appropriate clothing must be chosen prior to flight, although this is more important for RW transfer than FW flights. Lessons learnt from PHEM specialists should be acknowledged and combined with clothing to mitigate the problems associated with aeromedical work. Specific considerations include hearing protection (commonly integrated into a flight helmet with internal radio communications), eye protection (from rotor blade particulate debris), robust gloves (to operate helicopter equipment and extraction machinery - especially

in cold environments) and layered undergarments to cope with changeable weather conditions and altitude. PPE must also be provided for the patient(s), including consideration of closed-circuit radio comms for the conscious and communicative patient.

Pre-hospital rapid sequence induction (RSI)

There is increasing evidence to suggest that complex trauma patients (especially traumatic brain injuries) who receive a secured, definitive airway early in their care have increased survival rates and better functional outcomes. Indications for aeromedical intubation include airway compromise, ventilatory failure, unconsciousness, anticipated clinical cause, agitated head injury patients and injured or medical patients who cannot be managed safely without a definitive airway. Patients with multi-system trauma, undergoing RSI, with manual inline stabilisation of the cervical spine, have an increased incidence of difficult, or failed, tracheal intubation. RSI should only be performed by practitioners who have the appropriate skills and competence to do so.

At all times, pre-hospital anaesthesia should adhere to the same principles as emergency in-patient anaesthesia.^{1,4}

Four staff members are optimal for an RSI: the operator performing the intubation, an airway assessment, person performing cricoid pressure and someone to perform manual inline stabilisation. As discussed above, there are rarely four members of an aeromedical clinical team (the normal number is two) and this reinforces the mantra of 'prior preparation and forward thinking' - performing certain procedures on the ground, prior to flight, with additional staff and resources (normally road ambulance crews or referring hospital staff). Preparation of the patient, equipment and drugs will decrease complications. Hard collar and blocks should be replaced by manual inline stabilisation for the procedure and then replaced afterwards.

A 'kit dump', in which drugs, oxygen, airway equipment, including difficult airway rescue adjuncts, supraglottic airways and surgical cricothyroidotomy kits, should be placed with easy access by the clinician and assistant. Drugs must be labelled clearly. The patient should be positioned with easy access from all angles, 360° if possible, and in the best possible position for intubation. A checklist and briefing should take place with all team members, including a failed intubation plan. Induction agents and neuromuscular blocking drugs used should be chosen according to patient physiology and clinician's experience. Two suction units should be checked and readily available. Pre-oxygenation should take place, and there is some emerging evidence for apnoeic ventilation. Care should be taken if using a bag-valve-mask not to increase intra-gastric pressures. PHEM organisations should have guidelines for failed intubation, again mirroring hospital medicine best practice. The recommended Difficult Airway Society guidelines (DAS, UK - www.das.uk.com/guidelines) are easy to follow and effective. After tracheal intubation, anaesthesia should be maintained with intravenous agents, titrated to patient physiology.

Blood products

The administration of blood products in the pre-hospital environment can be life saving and reduce morbidity. Packed red cells (and fresh

frozen plasma) may be stored according to MHRA requirements for blood banks and in partnership with the local secondary care trust or UK National Blood Service authority. Local protocols, written to mirror national guidelines, for the safe administration of blood products should be formulated and adhered to.⁸

Tranexamic acid (TXA) is an anti-fibrinolytic agent useful in the management of haemorrhage secondary to trauma, but also should be considered in other causes of haemorrhage. Current evidence recommends use within 180 minutes of injury (CRASH2 and MATTERs studies) however further research is on going to refine best practice recommendations in the trauma setting.^{9,10}

Finger thoracostomy is a safe and effective procedure in the treatment of pneumothorax, in patients who are intubated and ventilated. It is arguably more effective for pre-hospital patients as thoracostomy sites can be re-opened with ease using a 'finger sweep'. Chest tubes require more time to insert and are susceptible to blockage and kinking. This is difficult to address in a small space. There is no evidence that thoracostomy increases the risk of empyema over that of a chest drain inserted in the field.¹¹

Pre-hospital thoracotomy remains a hotly debated PHEM procedure, indicated only in cardiac arrest from suspected cardiac tamponade arising from penetrating trauma to the thorax. There are several case studies in the literature that report successful outcome if only attempted for the above traumatic aetiology. It is far more likely to achieve success than needle pericardiocentesis.¹²

OTHER PATIENT CONSIDERATIONS

On FW and RW aircraft, the patient's hearing must be protected, even if he/she is sedated and paralysed (see PPE section above). Anti-emetics should be considered for patients routinely if travelling by air, as log rolling and moving patients in flight is risky and difficult.

MONITORING

All critical care patients in the pre-hospital arena should have a minimum standard of monitoring, similar to patients undergoing elective hospital anaesthesia.^{6,7}

- A minimum of 2 appropriately trained staff, skilled in advanced airway management and resuscitation.
- Resuscitation and emergency airway kit readily available (oxygen supply, oral suction, self inflating bag and mask, airway adjuncts, advanced airway equipment, defibrillation, labeled sedative agents, emergency drugs to support cardiorespiratory depression available, reversal agents available).
- Continuous pulse oximetry and 3 lead ECG monitoring, non invasive blood pressure measurement, respiratory rate or ventilator monitoring.
- End tidal wave capnography.
- Two reliable sites of peripheral venous access should be placed and secured.

EQUIPMENT

Equipment should be light, portable yet robust. Battery life of the monitoring equipment should be recorded and maintained in

between transfers, and spare battery packs should be available at all times.

Oxygen tanks should be full. Oxygen and battery life of monitoring should be calculated in accordance to the anticipated task time, with back-up in the event of delays or re-tasking.

Suction equipment, with a back up facility, should be easily available on the scene and during transport. Venturi suctioning consumes large volumes of oxygen and used only when necessary. An electrical or hand held suction device avoids this problem, but are often not as effective.

Transport ventilators need to be small and light, have clear visual alarms, with standard alarms for ventilator parameters. Ideally the ventilator needs to work from an external power source, rather than oxygen, which consumes larger quantities of gas. Oxygen flow may need to be adjusted to prolong the duration of time for which oxygen is available. Non-invasive ventilation is not usually suitable for aeromedicine as the oxygen consumption is unpredictable and high. Patients needing NIV should usually be intubated, to mitigate unplanned delays such as airframe diversion for fuel, or to transit to a secondary destination facility.

Vibration and movement of the aircraft affect most monitoring equipment. Bespoke fit is an option, but is costly and requires a dedicated platform to permanently mount the devices. Clinical monitoring is therefore essential in addition to the above, however, elements of clinical examination (e.g. auscultation) are somewhat inhibited during flight (especially RW transfer). It is vital to site and secure monitoring equipment optimally prior to receiving the patient to ensure the screens are visible to both members of the medical team throughout flight. During FW take-off and landing, medical crew will need to be secured in their seats and access to the patient is particularly restricted at this time. Non-invasive blood pressure monitoring is acceptable for most transfers, unless arterial monitoring is already in situ from the referring facility. Insertion of an arterial line should not compromise the evacuation of a patient who needs time critical definitive management.¹³

INTRAVENOUS INFUSIONS

Rationalisation of infusions should be strongly considered to minimise the number of pumps for transfer. The more lines, equipment and pumps that are attached to the patient during ingress onto and egress from the platform, the more likely something will be dislodged or dislocated. This applies to most transfers, however, in order to keep weight, and thus fuel costs down, a limited number of pumps (two or three usually) will normally be available. Many drugs that in hospital would be routinely infused can be mixed or given in bolus dose. For example, muscle relaxants can be given as boluses and sedative drugs can often be combined. Syringe pumps should be compatible with multiple sizes of syringes and have visual alarms to identify occlusion or an empty syringe. For administering fluids, pressure bags will be required to give fast infusion rates, as height of the cabin is limited and gravity should not be relied upon.^{3,5}

All equipment should be checked daily and restocked as per a hospital department. A checklist should be followed before and after each retrieval task and kit bags should be secured and dated where possible

to make sure equipment stays present and stocks are up to date.

If drugs have a stated temperature window for storage and are carried in personal kit, ambient cabin temperatures should be monitored and recorded. Awareness of decreased drug life spans outside normal temperature ranges should be understood and protocols of how long drugs can remain out the fridge should be developed in accordance with manufacturing guidelines.

OTHER SPECIAL CONSIDERATIONS

Sea level cabin

A pressurised cabin is standard in most FW aircraft. It is also possible to provide a sea level cabin, however this will compromise on fuel economy and range of the aircraft. Small decreases in ambient air pressure can worsen conditions such as acute decompression illness. Transport for fixed wing aircraft at sea level cabin pressure is recommended. RW platforms usually need a minimum of 1000 feet altitude and a route will need to be planned in order to provide a flight as near to sea level as possible.^{3,5}

Obstetric and neonatal patients

Transport of labouring women is suboptimal and where possible, women should deliver prior to aeromedical transfer.³ Delivery on an airframe poses several problems including increased risk of maternal complications, and difficult neonatal resuscitation, lack of specialty care in transit and the doubling of acute patients from one to two! The need for aeromedical transfer for labouring women should be quantified against these risks as part of an encompassing medical estimate. Indications for rapid maternal transfer by air may include preterm labour, eclampsia, post partum haemorrhage, and sepsis. It may be prudent to slow the onset or progression of labour with salbutamol or nitrate. Neonatal transport is best achieved with dedicated neonatal teams, using specific neonatal equipment. An incubator, monitors, specific infusers and medical air are needed, which requires different weight and set up considerations. Once again, this returns us to the mantra of proper prior planning and preparation before embarking on the transfer.

Psychiatric patients

Psychiatric patient may pose many challenges to safe aeromedical transfer. The issues around aviation safety as well as staff and patient safety must be carefully considered. Any patient who requires transportation to inpatient psychiatric care and is deemed a risk to themselves or others, is by definition, unfit to travel on an aircraft. It is the responsibility of all team members to assess the risk of the patient, but ultimately the decision as to whether to fly is with the pilot. The medical team's goal is to enhance safety and facilitate definitive care of the patient; safe and effective transfer may require sedation or general anaesthesia. Patient consent should be sought for transport. If consent is not achievable, the appropriate section of the national Mental Health Act should be consulted.¹⁴

Bariatric retrieval

There is an increasing incidence in obesity worldwide and this affects problem for all areas of health care. Obese patients will often have a range of associated comorbidities, in addition to difficulties with intravenous access, airway, ventilation, monitoring equipment

and procedural techniques. In the pre-hospital arena, bariatric ambulances and different aircraft can be used with specialized lifting devices, stretchers and monitoring. Fuel consumption is greater due to the extra weight of this equipment, and journey planning has to be adjusted accordingly.⁵

CONCLUSIONS

Critical aeromedical retrieval involves bringing the mobile intensive care unit to the patient for facilitation of transfer to definitive care. It can significantly improve the outcome of patients, as long as appropriate pre-flight estimates are done in terms of patient selection, manning and equipment. Consideration of the patient's physiology, safety and intimate communication between facilities are required to improve morbidity and mortality.

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