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TRANSPORT OF THE CRITICALLY ILL PATIENT

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INTRODUCTION

The critically ill patient often requires transfer for specialised diagnostic procedures or access to specialized care.[1] Interhospital transfers are expensive, logistically challenging and not without risk.[2] This possible risk and negative outcome of moving the critically ill patient should always be weighed against the anticipated benefit.[1] In the UK it is estimated that over 10 000 inter-hospital transfers of critically ill patients are undertaken each year[1] and in the USA 5% of ICU patients are moved to a different hospital.[2]

The increasing need for inter-hospital transfers is mainly as a result of the increasing complexity of healthcare with development of specialised regional centres, and in South Africa often attributed to the lack of ICU beds.[3] From March 2013 to February 2014, the Pietermaritzburg hospital complex received over 2000 referrals to their ICU's. Almost 1500 were accepted for admission and 910 experienced delayed admission, predominantly due to resource shortages. 'No ICU bed available' contributed to 64.6% (n = 588) of delays.[4] ICU facilities are only available in 23% of public hospitals and ICU's tend to be located in urban areas. The distance to a facility with ICU capabilities is more than 100km for 50% of public hospitals and for almost 10% of these hospitals, this distance is more than 300km. Collection of patients are often delayed for up to 6hours.[5]

Many international organisations including the Association of Anaesthetists of Great Britain and Ireland (AAGBI)[6] and the Intensive Care Society (ICS)[7] have compiled guidelines for the transfer of critical patients. Paediatric and neonatal guidelines have also been developed by the American Academy of Pediatrics.[8] The care delivered during the transport of patients should reflect the meticulous attention patients receive in ICU. Transferring the ICU patient is fraught with challenges and these transfers not only require skilled and knowledgeable team members but also detailed preparation and planning. Even the seemingly innocuous intra-hospital transfer between 2 departments can be challenging and not without risk.[3]

In South Africa, critically ill patients are commonly transported long distances by non-ICU teams. Equipment, knowledge and skill is often limited. McKerrow et al. conducted a retrospective review of emergency paediatric referrals from January to June 2012. Patients transferred from lower-level facilities in Kwa-Zulu Natal to Grey's Hospital were reviewed. The mean distance of transfers was 131km and time 9hours. Most ICU transfers (76.7%) were undertaken by teams with an advanced life support paramedic which means that in 23.3% of ICU transfers no advanced life support was available. During ward transfers, only 25% of patients were accompanied by an advanced life support paramedic. More than 30% of the ICU cases and over 10% of the ward cases required immediate resuscitation on arrival. Failure to stabilize children prior to transportation or during transit may be due to lack of skill on the part of the attending healthcare practitioners but may also reflect transport delays or illness progression.[9]

Successful transportation of the critically ill patient relies on the prevention of anticipated potential complications. This starts with adequate and appropriate training of transfer personnel as well as selection of appropriate equipment. At the very least, the transfer should do no harm. Of utmost importance is interdisciplinary teamwork, good communication and appropriate decision-making.[3] Detailed planning, monitoring and vigilance during transport may reduce negative events and reduce complications.[1]

AIM OF THIS TOPIC

As anaesthetists and critical care specialists, our patients are often subjected to transport, whether it be intra-departmental or between hospitals. In order to adequately assess and prepare our patients for this treacherous journey, it is imperative that we understand the perils that they face out of the comfort and care of our ICU's. Many parallels can be drawn between pre-hospital medicine and peri-operative practice. The shared principles of crew resource management, appropriate preparation and meticulous attention to detail is essential in preventing mistakes in our daily practice. The aim of this presentation is to create awareness about the hazards and risks of transporting critically ill patients. This will not only assist in triaging patients for acceptance into our own ICU's but will allow us to adequately prepare our patients in order to provide them with the best possible care at all times, in and out of the ICU.

HISTORY OF PATIENT TRANSPORT

The history of patient transport starts in ancient times when carts were used to transport incurable patients. This was probably in the form of hammock-based carts constructed around 900AD. The Knights Hospitaller set up hospitals to treat wounded pilgrims during the crusades of the 11th century but it is not clear how these patients got there. In 1100 AD the Normans suspended patients between 2 horses and variations on this were used until the 20th century.[10] The development of transport techniques were born from military needs. Paintings of ancient Roman battle grounds suggest that some warriors cared for wounded soldiers and in Roman and Greek times chariots were used to transport the wounded. Ambulancias were first used in 1487 during the siege of Malaga in Spain although wounded soldiers were only picked up after cessation of the battle.[10]

The creation of the initial concepts of military transport medicine is credited to Dominique Jean Larrey, chief physician to Napoleon Bonaparte. Dr Larrey was concerned about wounded soldiers during the battle between the Prussians and the French and set about developing a new ambulance system. He recognized the need for triage and specialized training for caregivers in the field. He implemented horse-drawn carriages with trained caregivers which were first used by Napoleon's Army in 1793. They administered early treatment in the field and transported injured soldiers during active battle.[10,11] Larry adapted these ambulances for different conditions including a litter that was carried by a camel in Eqypt.[10] American military physicians Drs. Joseph Barnes and Jonathan Letterman, built upon Larrey's work during the United States' Civil War. They ensured at least one ambulance allocated to each regiment. These accommodated atleast 2 or 3 patients. Steamboats and railroad treatment facilities were also introduced.[10]

Modern warfare produced the military battlefield ambulance medic and variations on this were put into practice in the 1830s in civilian medicine. The introduction of a transport carriage for cholera patients in London, 1832 heralded a major advancement in civilian transportation. Technological advances during the 19th and 20th centuries led to the modern self-powered ambulance and the first motorized ambulance appeared in 1899. It had a top speed of 16mph and could travel as far as 20 – 30miles.[10] The medical interest in flight expanded when the potential for the aeromedical transport was first realized during the siege of Paris in 1870. The Chief of Dutch Medical Services, Dr deMooy realized that ground transport was a major cause of death to injured combatants. A stretcher suspended from a hot air balloon drawn by horses was used to successfully transport 160 wounded French soldiers and civilians.[10]

The world's first air ambulance was flown in 1910, at Fort Barrancas, Florida but crashed during its maiden voyage. The German Air Force Medical Service was established in 1910 to examine military aircrew and two flight surgeons were appointed to the Royal Flying Corps in England in

1912.[11] The first fixed wing air ambulance was used during World War I in 1915 when a wounded French soldier was evacuated from Serbia by airplane. The first civilian air medical transport was completed in 1928 and the first US flight nurse corps was established in 1943.[10] Helicopters were commonly used in the Vietnam and Korean wars in the 1950s and 1960s to evacuate the injured soldier.[1] Patients were carried outside the aircraft with no medical care while in transit.[10] External litters permitting a ‘scoop and run’ medical rescue improved mortality rates considerably.

Battlefield evacuation techniques over the last 150 years have refined civilian transport systems. Trauma surgeons and neonatologists started using military transport techniques in the 1960s. In 1966, The White paper entitled “Accidental Death and Disability: The Neglected Disease of Modern Society” was published. US researchers concluded that wounded soldiers had better rates of survival than motorists injured on the freeway. This inspired the first experiments with civilian paramedics in the US. Two main types of EMS services were created. Hospital based programs with some medical training and funeral homes with volunteers who had little or no training in medical care, providing transport with a hearse.[10]

The rotary wing air ambulance is the most recent mode of transport extracted from the military experience.[1] The development of aviation medicine is linked with the history of aviation. Events in the aviation industry shaped the growth and direction of aviation medicine, and landmarks such as the World Wars and the launch into space marked phases of rapid expansion.[11] Life-support equipment suitable for use in aircrafts had to be developed as did the new art of intensive medical care in flight. Clinical aviation medicine has advanced considerably in the last 25 years. The Scottish Air ambulance was established in the 1960s and the first hospital based HEMS in America was founded in Denver, Colorado in the 1970s. By 2000 there were over 750 dedicated medical helicopters in the US.[11]

In South Africa, Red Cross fixed wing aircrafts were used in the 1960s, mostly to transport doctors to rural clinics. By 1982 the Flight for Life helicopter programme was established and by 2000 Air Rescue Africa was developed. In the 2000s Netcare 911 established their aeromedical division with rotary wing and fixed wing crafts and by 2009 an increasing number of Red Cross helicopters were available. In 2010, ER24 also developed a HEMS service in Johannesburg and by this time there were multiple rotary wing and fixed wing services all over South Africa. The lessons learnt in Korea and Vietnam proved the enormous value of the helicopter for the transport of casualties. Many countries now have a dedicated helicopter emergency medical service for rapid access to intensive medical care, often in flight.[11]

ADVERSE EVENTS ASSOCIATED WITH PATIENT TRANSPORT

Moving the critically ill patient is not without risk and adverse events commonly occur.[12] The frequency of adverse events has been linked to the various factors including the severity of illness, the duration of the transfer and the experience of the transport team.[2] Avoiding adverse events during transfer is the primary aim in providing safe and efficient transport.[1]

International studies vary with regard to the incidence of adverse events in transfer, from 87.5% with non-specialised teams to 4% with specialised retrieval teams.[9,30] A prospective audit from the Netherlands reported complications in 34% of transfers with the majority (70%) being potentially avoidable. Many of these events related to equipment failure, inadequate preparation and poor documentation or communication.[12] In a study from the UK, 56 transfers of paediatric patients were prospectively analysed. Seventy five percent experienced adverse events and 20% had life-threatening complications. The most common adverse events found were drug administration errors, hypothermia, cardiac complications, procedural errors, cyanosis and loss of IV access.[1]

The most common adverse events seem to be related to equipment malfunction and this is most frequently due to battery failure. Orr et al, prospectively analysed 1085 children during transportation. Unplanned events and 28day mortality were analysed. 55 of the patients (5%) experienced adverse events and 28day mortality was 10%.[13] In a study done in Australia, Beckmann et al showed that equipment problems were responsible for 39% of unplanned events whereas patient management issues were responsible for 61%. Major physiological derangement (15%), physical or psychological injury (3%), prolonged hospital stay (4%) and death (2%) were amongst the most common.

Over 900 contributing factors were highlighted which included problems with communication, inadequate protocols, poor training of transport crews, errors in judgement and problem recognition, inadequate preparation and inadequate servicing of equipment.[14] Other audits suggest that between 4 and 15% of patients have detrimental hypotension or hypoxia on arrival at the destination hospital and 10% have injuries that were not detected before transfer.[3]

In the study mentioned earlier by McKerrow et al., loss of IV access, dislodgement of intercostal drains, airway deterioration and seizures in transit were found to occur during transport of critically ill children. Adverse events were more frequently experienced during transfer of critical care patients, with 15.6% of PICU referrals experiencing complications and no problems reported from the ward referrals. 31.5% of children referred to the PICU and 11.3% referred to the wards required immediate resuscitation. During transportation and referral, patient's vital signs did not improve toward normal physiological ranges.[9] Similarly Hatherill et al. reported a high incidence of adverse events during transfers to the PICU at Red Cross War Memorial Children's Hospital in the Western Cape.[15]

The number of incidents compared with the vast array of contributing factors shows that the 'Swiss Cheese' model is just as applicable to transport medicine. In an ideal world each layer which protects the patient from errors or incident (e.g. guidelines and checklists, human judgement, monitor alarms, backup batteries and so on) would be intact.[3]

STRESSORS OF TRANSPORTATION

Moving critical patients out of hospital exposes them to a hostile environment.[16] These patients already have deranged physiology and they do not tolerate movement, temperature changes and vibration well. For this reason patients often experience adverse physiological responses to being transferred.[3]

Mirroring the exact stable conditions of an ICU setting is never possible. The clinical transport team will be smaller and isolated from the resources of the hospital. Therefor the team must be self-sufficient during the journey. It is extremely difficult to perform any practical procedure in a moving vehicle or in the limited space of an air ambulance. Reliable monitoring is crucial during transportation and movement artifact can significantly hamper reliable functioning of equipment. Critical incident reporting shows that equipment failure does occur even if proper precautions are taken.[16] At the very least, transferring a patient should do no harm, but studies show that even this goal is not always possible.[3]

It is therefore clear why complications during transfers are not uncommon and risks and benefits of each individual transfer should always be weighed. Risks of transferring critically ill patients include but are not limited to:

- An environment that is hostile and unfamiliar
- Adverse physiological responses
- Equipment problems
- Limited resources
- In-transit complications and
- Failure of continuity of care[16]

The effects of transportation can be divided into physiological effects and static effects. It can also be classified into general effects related to all modes of transport and effects specific to air transport.

General physiological and static effects of transportation

- **Physiological effects of inertia**

During transfer, patients can experience significant physiological changes. Inertial forces from acceleration and deceleration can cause significant changes in blood pressure, heart rate, intracranial and gastric pressure especially in the critically ill patient with a reduced capacity to compensate. The impact of these inertial forces results from Newton's laws of motion.[12]

Physiological consequences of acceleration[12]

According to Newton's third law of motion, for every action there is an equal and opposite reaction. During acceleration there will be an equal and opposite force applied to the patient. This is termed inertia and causes displacement of non-tethered organs and fluids such as blood towards the patient's feet. The degree of displacement depends on the rate, magnitude and direction of acceleration. Commonly the axis of acceleration is in the cephalic-caudal direction, which has the most significant effect on physiology.

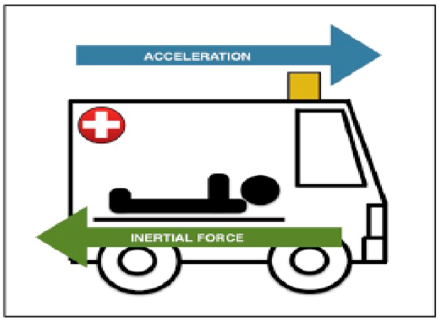


Figure 2a: Acceleration

Cardiovascular system:

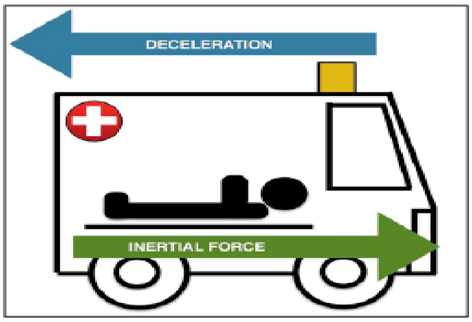
- During acceleration, blood will pool in the feet. This results in decreased venous return and cardiac output causing hypotension. In the healthy individual, the baroreceptor receptor reflex would compensate for this by an increase in vascular tone. However, in critical illness this reflex can be significantly reduced or absent either due to the critical illness e.g. sepsis or secondary to drug therapy. This may result in profound hypotension requiring increased inotropic and vasopressor support. Hypotension is exacerbated by a reduction in preload as caused by hypovolemia or positive pressure ventilation. This can be attenuated by elevation of the legs during acceleration.

Neurological system:

- Hypotension can lead to reduced cerebral perfusion pressure. This is especially significant in those with head injuries where cerebral perfusion pressure needs to be maintained.

Physiological consequences of deceleration[12]

Deceleration would have the opposite effect. The external force causing deceleration is towards the patient's feet and displacement of blood would therefore be towards the head. The breaking force of an ambulance is much greater than its acceleration force and as such deceleration has a greater impact on the patient.



Cardiovascular system:

- During deceleration, venous return will be increased due to inertial forces 'pushing' blood in a cephalic direction. This can lead to cardiac failure, pulmonary edema, and arrhythmias in patients with cardiac impairment.

Neurological system:

- The intracranial pressure increases due to the displacement of venous blood and CSF. This is important in patients who already have a raised ICP as their cerebral perfusion may be further compromised during deceleration. A head up tilt of 15° will reduce this effect.

Gastrointestinal system:

- Inertial force displaces the stomach towards the patient's head and this can increase the risk of aspiration. This upwards displacement of viscera can also increase trans-diaphragmatic pressure and cause increased intra-thoracic pressures.

Musculo-skeletal system:

- In patients with significant spinal injuries the inertial force acting during deceleration results in axial loading which can cause displacement of unstable spinal fractures.

It is important to note that these forces also apply to equipment and medical personnel. For this reason equipment should be secured and all medical personnel should be seated and secured with a seat belt during ambulance movement to reduce risk of injury. Medical staff are less affected physiologically due to having intact compensatory mechanisms and the direction of inertia acting in the anterior-posterior direction because of their seated position.[12] There is however little to be gained by rapid acceleration and deceleration. Instead a steady pace should be maintained as this is safest for the patient but also for medical staff and the public.

- **Temperature**

In extreme heat and cold the patient is exposed to the risk of hypo- and hyperthermia as it is not always possible to regulate the cabin temperature in an ambulance. It is therefore, important to monitor a patient's temperature closely during transfer and prepare for cold temperatures with additional blankets and fluid warmers. The ability to heat the cabin of the ambulance should be utilized whenever possible.[12]

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 to become agitated and distressed. Efforts should be made to shade the patient on the scene, maintain euvolemia and use external cooling methods (fans, stripping and spray cooling).[17]

Temperature effects also apply to crew members. With the body struggling to keep its temperature down the crewmember will experience an increase in heart rate and BP, and signs of dehydration e.g. thirst, nausea, headaches and poor urine output will start to show. Prior to flight especially on hot days, crewmembers should drink fluids prior to feeling thirsty, keep in the shade as much as possible and limit and slow activity to only what is required. With hypothermia, toes and fingers will start to feel cold, muscles will feel stiff and weak, crewmembers may feel tired and drowsy and may start to shiver. Crewmembers should dress warmly with appropriate headgear as this is where most heat is lost, eat foods high in sugar and drink warm fluids.[18]

- **Limited space**

Space is extremely limited in ground and air ambulances. In ground ambulances, only access to one side of the patient is possible. In air ambulances, especially rotary wing aircraft, access to the patient's lower body is often difficult either because of the crew being strapped into their seats at the patients head or the legs of the patient extending into the tail of the craft.[19] Patients at risk of deterioration should be intubated prior to departure and any anticipated procedures should be carried out before beginning the transfer.

- **Pressure care**

Early stages of pressure sores can be detected after only 20 minutes on hard spinal boards in normal patients with normal skin perfusion. This can occur even more rapidly in the critically ill on vasopressor support. For this reason, extrication boards should not be used for prolonged transfers and the Royal College of Surgeons of Edinburgh have released a position statement in 2013 on pre-hospital spinal immobilization to this effect. A vacuum mattress should be used wherever possible during transfers.[12]

Always protect and monitor pressure areas during long transfers. Due to limited space, the temptation exists to rest equipment on the patient. This must be avoided. During prolonged transfer, blood and other bodily fluids can pool in dependent parts of the body and in addition to pressure over bony prominences, this may contribute to tissue maceration and the development of pressure sores.[12]

- **Motion sickness**

Motion sickness is caused by the continual overstimulation of the mechanisms of the inner ear. Turbulence, fear of flying or seeing the horizon at different angles are some of the stimulating situations. It can be prevented by eating sufficient meals, not flying when sick and using flight approved medication. In flight, close your eyes periodically, restrict head movement, open vents and don't read.[18] Anti-emetics should be considered for patients routinely if travelling by air, as log rolling and moving patients in flight is risky and difficult.[17]

- **Human factors**

Researchers from the Human Performance Training Institute (HPTI) in Switzerland and the USA have focused on human performance in the health care field because they have found close parallels between aviation and medicine. They discovered that pilots and emergency care personnel have similar command styles and that medical personnel had little appreciation for the negative effects of fatigue, how autocratic styles discourage inputs from junior staff members and that the prevailing mindset was not conducive to team-building.

Crew resource management (CRM) focuses on identifying a team in an emergency, and on vigilance and situational awareness. The primary objective of managing human factors is to improve communication and to avoid mistakes.[18]

Physiological effects specific to air transfer

It is important to understand the physiological effects of aeromedical transport because critical care patients may be transported by air. This knowledge will improve patient preparation prior to transfer and is essential in predicting and preventing adverse events and limiting physiological changes.[12]

- **Atmospheric pressure**

Increasing altitude increases the risk of hypoxia and hypothermia due to the drop in atmospheric pressure. As described by Dalton's Law, with increasing altitude, the partial pressure of oxygen falls resulting in a decrease in alveolar partial pressure of oxygen which may cause hypoxia unless supplemental oxygen is administered.[17]

Commercial aircraft cabins are usually pressurised to 5000 – 8000ft. 8000ft is the maximum altitude where no physiological effects would occur. Supplemental oxygen is needed above 10 000ft at night and above 12000ft during the day. 18 000ft is the threshold altitude if no equipment or oxygen is available and even with 100% oxygen, decompression syndrome will still occur above 40 000ft. Pretoria is situated at 5000ft, Johannesburg at 6200ft and Bloemfontein at 3500ft above sealevel.[11] In healthy individuals, supplemental oxygen is usually not required until above 10 000ft. However, patients' already needing a high FiO2 at sea level will require higher FiO2 at altitude and may therefore be expected to require intubation and ventilation. It is of cardinal importance to anticipate this prior to take off.[17]

In the event of a patient becoming hypoxic in flight, this can be treated by either increasing the inspired oxygen concentration (FiO2) or by increasing the partial pressure of oxygen by reducing the altitude of flight or pressuring the cabin to a lower altitude.[17] Air crew may also be at risk and symptoms of hypoxia should be looked for. The stages of hypoxia include: indifference, compensatory (hyperventilation), disturbance (vision, alertness, personality traits, psychomotor dysfunction, hyperventilation symptoms) and finally the critical stage with loss of consciousness.[11] For this reason crew members should be fit and in good health, not smoke and ensure that supplemental oxygen is used above 10 000ft.[18]

Important to consider is patients with significant alveolar: arterial gradient mismatches such as advanced COPD, pulmonary contusions or pulmonary fibrosis as the relative hypoxia at altitude will result in a lower PaO2 in this patient group. It is therefore important to discuss the flying altitude with the pilot prior to takeoff so that a risk assessment of the potential impact of altitude on the patient can be made.[12] Patients with decompression syndrome should not be flown more than 1000ft above injury altitude.[11]

- **Volume expansion**

Boyle's Law states that at a constant temperature, the pressure of a gas is inversely proportional to its volume.[12]

The physiological effect of volume expansion during ascent is important for any gas-filled space:

- **Intercostal drains** should be inserted prior to air transfer for any size pneumothorax.
- Patients with **bowel obstruction** or recent bowel surgery requiring **anastomosis** should be flown at lower altitude or land transfer considered.
- Pain and discomfort during ascent and descent can be caused by expansion of air in the **Eustachian tubes** if patients are not able to equilibrate. This applies to medical staff.
- Presence of **intracranial air** or **pneumoperitoneum** are relative contraindications to air transport. In a patient with intracranial air, the volume expansion may worsen ICP and reduce cerebral perfusion.
- **Decompression illness** is an important factor to consider when arranging air transportation.

- **Equipment with air filled cuffs** such as endotracheal tubes, Sengstaken-Blakemore tubes, stoma bags and inflatable pressure bags should have their pressures monitored and adjusted accordingly. Alternatively the endotracheal cuff can be filled with saline as liquid expands much less than air.[12]

- **Noise**

Helicopter transmissions, engines and rotor systems emit loud, high frequency noise. There is no interference with speech from 0 to 50dB of background noise and 50dB is about similar to background noise in a classroom. 60dB is a loud street noise for e.g. trucks. The level of noise in the cabin of a commercial air liner is about 80dB and here normal conversation is not audible more than 2meters away. At 84dB, shouting is required for communication more than 1meter away. This is the level of noise in many factories, and hearing protection is required above this level. Speech is usually not possible above 90dB. Noise levels outside a running helicopter may reach as high as 130dB.[18] Discomfort is experienced above 120dB with pain above 130dB. Tympanic rupture can occur above 140dB.[11]

The primary negative impact of noise in the aviation medicine environment is complicating communication. Special alphabets and standard phrases make communication easier and less fatiguing.[11] Noise in the airplane also leads to increased stress and fatigue and can lead to acceptance of lower standards of performance and accuracy.[11] Increased stress levels can lead to hyper arousal with poor performance and irritability.[18] Other psychological effects can be experienced including sleep problems, concentration and memory problems, and headaches. More unusual are symptoms of vertigo and nausea related to noise. The noise can also be distressing for conscious patients. The patient should always be provided with ear protection/headset even if sedated or intubated.[11]

Permanent high frequency hearing loss can occur with extended exposure. The maximal permissible continuous exposure level is 90dB (more than 1 sec). Pulses of sudden onset and brief duration (<1sec) of more than 140dB is harmful. Exposure to more than 90dB for a short time can cause temporary hearing loss for several hours and being exposed to this level for >8hrs per day for 3months can cause permanent high frequency hearing loss.[11,18] Hearing protection is essential. Ear muffs, headphones and helmets can all be utilised as passive forms of protection. Standard quality ear muffs offer up to 20dB of attenuation when well fitted but can be hot and more costly than ear plugs. Aircraft headphones give varying degrees of attenuation depending on their design.[11]

- **Temperature**

Air temperature falls by 2°C for every 1000ft increase in altitude. In aircrafts where cabins are not isolated and not able to be pressurized, patients are at risk of hypothermia and appropriate measures to reduce heat loss is needed.[12] Environmental control is limited in most helicopters and aircrew and patients are subjected to environmental extremes which may affect performance.[11]

- **Humidity**

The partial pressure of water and temperature both fall with increasing altitude resulting in a significant reduction in the humidity of clinical gases leading to more rapid evaporation of moisture from the skin and lungs. Patients undergoing long transfers should have their input and output closely monitored to avoid hypovolemia and dehydration.[12] Reduced humidity can affect patients with respiratory pathology and patients with burns.[17] Thickened secretions and risk of mucous plugging can occur and a heat moisture exchange filter (HMEF) or humidified oxygen via a facemask should be used. For extended transfers patient’s eyes should be lubricated with artificial tears and frequent mouth care is also important.[12]

- **Forces of inertia**

Patients being transported by air, be it helicopter or airplane will still be exposed to the same acceleration and deceleration forces as discussed above for land transfer. Acceleration/deceleration forces are usually less than 2G in commercial crafts. The only consideration is that the forces may be acting in a different axis due to the direction of travel and how the patient is orientated. The best position for the patient is sideways. The same considerations as above still apply.[12]

- **Turbulence**

Stress caused by turbulence causes discomfort to the crewmembers by shaking them around, exerting unusual gravitational forces on them, and perhaps causing motion sickness.[18]

- **Vibration**

A combination of low and high frequency vibrations resonate through the aircraft, especially during helicopter transfer producing acute and chronic effects. Disturbances in speech, visual acuity and fine motor coordination are common and operational fatigue and muscle workload is increased. Hyperventilation, chest pain, increased blood pressure and heart rate and headaches can occur.

Following chronic exposure, micro-musculoskeletal trauma may contribute to spinal degenerative joint disease and intervertebral disc degeneration although this has not been studied by case-control or prospective studies.[11] Vibration also affects monitoring equipment in particular non-invasive BP cuffs that function via the oscillometric method. Patients who require accurate BP monitoring should therefore have an arterial line inserted prior to transfer to allow more accurate blood pressure monitoring during flight.[12] Severe turbulence may cause the instrument panel/medical equipment to vibrate or the eyeballs to judder, making it difficult to read and to control. Vibration can be reduced by well mounted and well cushioned seats.[18] All equipment must be tightly secured.[11]

- **Flicker vertigo**

This is a problem unique to rotary-wing aircrafts. Sunlight passing through the main rotor blade produces a medium frequency flicker in the cabin, similar to the flicker of a failing fluorescent light tube. This can induce vertigo or motion sickness and even epilepsy in susceptible individuals. Nausea, vomiting, sweating and light-headedness may be experienced and the sensation of the flicker may persist for hours. Patients' eyes should be protected from the flicker especially if they have a history of motion sickness or epilepsy.[11]

- **Spatial disorientation**

This is a condition in which perception of direction does not agree with reality. It is a temporary condition that can be caused by poor weather conditions with low visibility. The semicircular canals in the inner ear that informs the lower brain of rotational accelerations reacts only to rate of change and not to sustained change. This can result in false sensations of rotation. These errors are normally easily corrected by visual information which may be lacking in poor weather conditions.[18]

The above considerations are all important, however, in practice many of the above complications may not be as significant as you might expect. This is because helicopters typically fly at an altitude of 1000ft or less. This reduces the effect of volume expansion and drop in partial pressure of oxygen. Aeroplanes are able to fly at much higher altitudes than helicopters but they are able to pressurize their cabins to sealevel. However this limits the altitude that aircraft is able to ascend to due to the pressure difference across the cabin walls. Flying at lower altitude is also possible but this increases exposure to weather, turbulence and cost.[12]

ORGANISATION

Transport of critically ill patients should not be undertaken lightly; it requires organisation and structure. There are 2 models for transport teams. The first is when a retrieval team is sent out to the referring hospital with the aim to stabilize the patient before transfer back to the specialist centre. The second is when a transport team is dispatched by the receiving hospital or an independent ambulance company is used, as is the case in South Africa.[3]

Logistical aspects of transportation

Minimum requirements for safe patient transfer:

- Guidelines for referral and for the transfer itself
- A designated consultant responsible for transfers
- Specifically prepared and packed equipment
- Personnel nominated to check, clean and recharge equipment
- Specialised medical and nursing personnel
- Training for transfer personnel
- Good communication within and between hospitals
- Regular audit[3]

An initial assessment of the patient and the situation should be done and lines of responsibility should be identified. The transfer and its team should be managed by a central control centre. Communication is vital during the organisation and the actual transfer.

Evaluation is a dynamic process with continuous re-assessment. It includes the following:

1. Level of care required?
2. Need to transfer and the degree of urgency?
3. Best location to undertake further stabilization?
4. Level of expertise required to stabilize and transfer the patient?[16]

Other questions to consider includes the Why; What; When; Where; Who and How of the transfer?[3]

Why is the transfer taking place?

The reasons for transfer should be justifiable, preferably by demonstrating direct benefit to the patient and weighing this against the risk of moving the patient.[3]

What are the risks?

Risk analysis is essential so that identifiable risks are avoided or managed appropriately. This may be clinical or logistical concerns and there may also be risks to the transfer team to consider. Clearly, if the risks outweigh the benefits then an alternative solution must be found.[3]

When should the transfer take place?

The timing of the transfer is critical. Guidelines have been published to help the decision-making process for example in head injury patients (Neuroanaesthesia Society of Great Britain and Ireland), but for others it is more difficult. For instance, in patients with multi organ failure, the balance of risk and benefit needs to be carefully considered before the decision on whether and how to transfer the patient is made.[3] Senior staff should be involved in this decision and it should be based on the risks and benefits of immediate vs delayed transfer.[19]

The timing will depend on the clinical condition and needs of the patient, time of day and available transport crew and services. Transfers should ideally take place in daylight hours as transfers after hours or over weekends have been shown to be more hazardous. This is possibly due to team fatigue, technical difficulties associated with night time vision and often reduced staffing. A balance should be achieved between optimisation prior to transfer and the clinical urgency of the situation.[19]

Where is the patient's destination?
It is vital that the transfer team, ambulance crew and next of kin are informed of the patient's receiving facility as well as the specific ward and receiving doctor. Only supplying the name of the hospital is not sufficient.[3]

Who will escort the patient? ....
The transport team
Successful transfers require a well-coordinated team effort. In first world countries, a full-time intensivist should be responsible for the transport service, training of crewmembers and audit of transfer activities.[3] The aeromedical team normally comprises of a critical care physician and a flight nurse or paramedic. Ground transfer will be activated with a paramedic team. 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.[17] Also important is leadership and critical thinking skills, proficient communication and good interpersonal skills. Crew must be team players and able to work in an uncontrolled environment.[11]

If a non-physician team is doing the transfer, a command physician should assume responsibility for treatment during the transfer.[8] When using an independent company, a medical doctor on call dedicated to support their staff is usually on call. The cost of training is outweighed by the positive impact on outcome an experienced and skilled team could have.[1]

- <u>Specialised teams</u>

It is generally accepted that specialised teams should transfer critical patients.[2] Pearl and colleagues argued in 1987 that the critically ill patient should be accompanied by a transport physician, in order to maintain an equivalent level of care as in an ICU with an intensivist. However there are no prospective randomised controlled trials comparing a physician-based team with a non-physician-based team. The available evidence is mainly from paediatric care and of a lower level quality. Even though specialised physician transfers were more common, of 130 paediatric transports, 20% of problems occurred with a non-physician-based specialised team and only 8% occurred with a physician based team. The remaining 72% of problems occurred during transfers done by untrained escorts.[2]

In the previously quoted studies done by Orr[13] and Beckmann[14], specialised and non-specialised transport teams were utilised. Unplanned events were more common with non-specialised teams.[13] It is postulated that non-specialised groups focus on expediting transfer to definitive care, whereas specialised teams focus on stabilisation before and during transport. They aim to take the ICU to the patient. Eventhough they spent almost double the time at the scene, their outcomes were better.[13] Better protocol adherence were found during air transfers which could point to the advanced training of the flight physician. Vos and colleagues compared transfers performed by the referral specialists vs transfers performed by specialised retrieval teams that consisted mainly of paediatric intensivists.

Retrieval teams experienced less complications, less equipment restraints and less requirement for interventions on arrival.[20] This was similar to another study by Bellingan et al, showing reduced mortality and acute physiological disturbances when a specialised retrieval team was utilised.[21]

At Johns Hopkins, Kue et al evaluated adverse events during 3383 transfers by a dedicated transport team. The incidence of adverse events was 1.7%, the most common adverse events having been hypoxia, hypertension and hypotension. This was easily corrected by interventions with oxygen and vasopressor manipulations.[22]

The advantage of a specialised retrieval team is its familiarity with transport procedures and equipment. Various other advantages of retrieval teams have also been suggested. Britto et al. concluded that specialised teams are better at stabilising patients before transfer and may also be better equiped to deal with logistical problems. These teams can be deployed in rural and remote areas and provide critical care skills to resuscitate and stabilise patients prior to transfer. However, a major disadvantage is that there would also inevitably be times when the team would be unavailable and hospitals would then have to fall back on local expertise that may well have become de-skilled through lack of practice.[16]

Although clear cut evidence is not available, expert opinion is clear: critically ill patients should preferably be transferred by a specialised retrieval team. This is recommended by most intensive care societies[2] and the ICS and the AAGBI now recommend that specifically trained personnel or retrieval teams from the accepting hospital should conduct the transfer.[6,7]

- <u>What happens in South Africa?</u>

Transfer of patients in South Africa is not standardised. Emergency ambulance service and ambulance transportation is provided by each province independently and is generally known as 'Metro'. There is also vast differences between private and government sectors. The government system is supplemented by private ambulance companies, the 2 biggest ones in South Africa being Netcare 911 and ER24 although various small companies also exist. These services are supported by voluntary ambulance services namely Red Cross and St. John Ambulance.

Red Cross Air Mercy Service provides an air ambulance service in Western Cape, KwaZulu Natal and Polokwane. Both helicopters and fixed wing aircrafts make up this service. Private air ambulance services are also provided by private companies. Netcare 911 offers a 24hr rotary wing and fixed wing service in Johannesburg and an additional rotary wing service is also provided by ER24 in Johannesburg. Other private air ambulance charters are also available throughout the country, including Aerocare operating from Bloemfontein.

All EMS practitioners are required to meet the standards of the HPCSA. In South Africa there is currently 3 different levels of proficiency of emergency care providers available through short courses administered at various institutions:

- BAA (Basic Ambulance Assistant)
    - This is a basic life support (BLS) certification and is the minimum qualification required. Training includes a 4 week period of lectures and practical sessions and crew members are provicient in basic life support including CPR and first aid, and use of ambulance equipment including an automated external defibrillator (AED).
- AEA (Ambulance Emergency Assistant)
    - This is an intermediate life support (ILS) certification.
    - These practitioners must have a minimum of 1000 hours of practical experience as a BAA and the course consists of a 3 month period of lectures and practical sessions. AEA's are provicient in intravenous therapy, needle cricothyroidotomy and thoracocentesis, manual external defibrillation and ECG interpretation, and are able to administer a few selected drugs.
- CCA (Critical care Assistant) or National Diploma
    - This is an Advanced Life Support (ALS) certification.

- The CCA program is an extensive 1 year program with 6 months of theoretical teaching and 6 months of vigorous on the job practical experience. Candidates must have a minimum of 1200 hours of practical experience as an AEA.
- The national diploma is a 3 year course for which no previous EMS experience is required. This course also includes rescue training.
- ALS providers are provicient in advanced airway management and have an array of emergency drugs to their disposal.

A new move is being made by the HPCSA which involve limiting the short course degrees as outlined above. Three new qualifications have been introduced:

- ECA (Emergency Care Assistance)
  - This is a 1 year course and falls between a BLS and ILS qualification.
- ECT (Emergency Care Technician)
  - This is a 2 year course and exists just above intermediate life support level.
  - It is similar to ALS but without advanced airway management manoeuvres and restricted use of drugs.
- BTech/BEMC (Bachelors degree in emergency medical care) / ECP (Experienced Care Provider)
  - This is a 4 year professional degree and is also an Advanced Life Support (ALS) certification.
  - Candidates have an additional scope of practice over the CCA / National Diploma qualifications:
    - Thrombolysis
    - Rapid sequence intubation with the use of Etomidate/Ketamine and Pancuronium/Vecuronium/Rocuronium/Suxamethonium
  - Candidates are also trained in the rescue disciplines including fire search and rescue, trench rescue, aquatic rescue and structural collapse.
  - Further advancements to Master and Doctorate programmes also exist.

Standing orders or guidelines exist and physician consultation are always possible but for the most part the ECP, CCA and ECT functions as independent practitioners. Ambulances are usually staffed by a BAA and AEA provider with ALS providers working on rapid response vehicles. BAA and AEA ambulances are able to transport stable patients but for any patient with central invasive lines, vasopressor therapy or invasive airway devices an ALS practitioner is needed.[23]

There is currently just over 90 operational ALS providers in the province of KwaZulu Natal. These providers are shared between private and public sectors. Most of these practitioners are also centralised in urban cities. Due to this limited number of ALS providers in the rural areas, there is often a substantial delay in transportation of patients and a significant number of critically ill patients are transferred by non-ICU or non-ALS transport.[5]

How will the transfer be undertaken?

Mode of transport

Principal modes of transport include land ambulance, rotary wing (helicopters) and fixed wing aircraft (aeroplanes). Each mode has its own unique advantages and disadvantages.[19]

Time-critical transfers require careful thought about the mode of transport. Helicopters have been more available in recent years but a risk-benefit evaluation should be done to evaluate each transport mode. It is vital to be aware of the limitations of helicopters and also of the risks to both patient and crew.[3] The mode of transportation is ultimately determined by the transferring physician, in consultation with the receiving physician. The decision is based on the urgency, stability, location and time saving anticipated with air transport, mobilization time, weather and traffic conditions. Other important considersations include medical interventions necessary during transfer, cost and the availability of personnel and resources.[3,8,12]

All transport vehicles must have the following:

- Trolley access and fixing systems
- Sufficient space for 2 or 3 medical attendants
- Lighting and temperature control
- Adequate gases and electrical supply
- Good means of communications[3]

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. FW retrieval offers faster transfer over great distances. It often allows an optimised clinical environment, lower ambient noise, easier communication 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 and therefor incur an additional road transfer burden at source and destination.

RW retrieval offers robust flexibility and typically allows casualty collection from the point of injury or source hospital and direct disposal at the destination facility. They also tend to have faster response times. However working environments vary greatly, from compact, bespoke platforms with excellent lighting and noise isolation to large military-type helicopters. Effective communication is problematic even with dedicated headsets.[17] Advantages of road transport include rapid mobilisation, lower overall costs, fewer limitations by weather conditions, easier patient monitoring and less potential for physiological disturbance. It is suggested that helicopters should be considered for transfer distances above 80km and FW for distances above 240km. The ultimate decision for each individual case should be based on clinical judgement.[2]

Many studies have shown the time saving benefit of air transport, but this can easily be offset by increased mobilisation time and by additional ground transport requirements between landing site and hospital. Stafford and colleagues compared transfer times between air (rotary wing) and ground transfers and the time benefit found for air transport was only 27 minutes.[24] No prospective randomised controlled trials show any influence on patient outcome by the modest reduction in transport time with air transport. In 2011, a large retrospective study in the United States involving transfer of almost 75 000 patients showed that rotary wing transfer was only a predictor of survival for the severely injured patient. But keep in mind that air transport crews are often better trained and skilled than ground crews.[25]

Borst and colleagues compared outcome of almost 4000 patients transferred by either rotary wing craft or by specialised acute life support road ambulances.[26] Mortality rates were comparable with similar crew experience. This emphasised the importance of prioritising the patient that will benefit most from a decreased transport time. Other important factors to consider when choosing a mode of transport include the additional costs, potential risk, impact of noise and vibration, weather conditions, prolonged mobilisation times and the confined space in the cabin.[2]

The advantages and disadvantages of different modes of transport are summarized in table 1.[3]

	Advantages	**Disadvantages**
Road ambulance	• Familiar • Lower overall cost • Rapid mobilisation • Less dependent on weather conditions • Less monitoring difficulties	• Slower over long distances • Affected by traffic • Better suited for shorter distances • Unable to access patients in some locations e.g. mountainous regions
Rotary wing	• Efficient for journeys over 80km • Good in remote or inaccessible locations • Faster than land transfer in some instances • No need for land transfer at either end if hospital has helipad	• Slow to mobilise • Costly • May need ground transport • Unable to fly in bad weather • Often only available in daylight hrs • Noise levels often high • Vibration • Unfamiliar and additional training required • Very limited space • Unpressurised cabin
Fixed Wing	• Efficient for long journeys • Where road access is difficult • Able to pressurise cabin • Compared to RW: - Faster - More space - Less noise and vibration - Less weather dependent - Less costly - 24hr service	• Costly • Organisation difficulties – slow to mobilise • Delays in take off • Need for land transfer before and after • Further training of medical staff required

Flying is in essence the art of throwing yourself at the ground and missing – Hitch Hikers Guide to the Galaxy

A few extra words on rotary wing ambulances…[18]

Air Ambulance Operations Law (Part 138) had its inception to the South African Civil Aviation Authority (SACAA) law books in 1997. Even though the law was set, there were no clear technical standards. Since then the technical standards, SA-CATS-OPS 138 (South-African – Civil Aviation Technical Standards and Operations for Part 138) have continually been reviewed and modified.

Section 22A of the Aviation act, 1962 empowers the SACAA to determine technical standards for civil aviation as documented in the regulation in Part 138 (Air Ambulance Operations). Document SA-CATS-OPS 138 contains rules, standards, requirements, specifications, methods, procedures and characteristics that are applicable in respect of air ambulance operations. This is the ‘minimum standard required’ and aims to improve the understanding of the workings and limitations of the pilots and helicopters to improve the team’s effectiveness and safety. The essence of the CAT 138 is safety through clear, joint decision making.

All crew working on a rotary wing ambulance is required to complete the CAT138 course every 2 years and have to abide by the relevant regulations and legislation administered by the Department of Health, the Health Professions Council of South Africa and the Professional Board for Emergency Care.

<u>Loading and unloading</u>[18]

Loading and unloading should only occur once the rotors are at a complete standstill except in circumstances deemed necessary by the pilot-in-command. This may only be done in times of a serious emergency and if it is undertaken by appropriately trained personnel.

Payload[18]
The weight that can be lifted by the helicopter, called the maximum all up weight is determined by the lifting capacity of the engine and rotor blades at sea level. Factors affecting the payload include:
- Altitude: Less dense air has less effect on the rotor blades and thus less lift
- Temperature: Air expands with an increase in temperature resulting in the density of the air becoming less

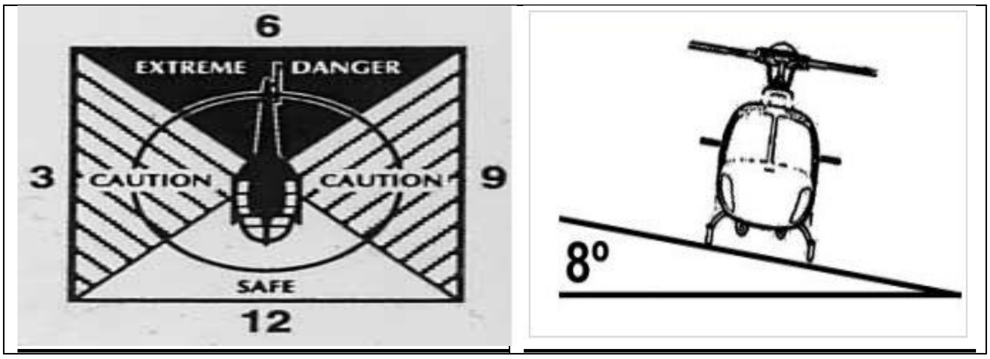
Communication[18]
International Air law requires all aircraft to carry radios permitting two way radio communications at all times. This is required to maintain contact with air traffic controllers in the various airspaces and other aircraft to communicate positions and maintain a safe separation. VHF (very high frequency) is the standard radio carried by all aircraft. These radio’s are limited by the fact that they are line off sight only and don’t have long range.

Limitations of rotary wing flight[18]
- Weather / environmental
  - Visual Flight Rules (VFR) means that although further limitations exist, the most important are that the pilot must have the ground in sight and a visual horizon at all times
- Altitude limitations
  - Supplemental oxygen must be provided to the pilot and passengers above 12 000 ft during the day and 10 000 ft at night
- Daylight and night time
  - Part 138 Air law states that a helicopter may fly at night under HEMS operations provided that such a helicopter is an IFR (Instrument Flight rules) certified multi engine helicopter, operated under IFR regulations. As a further safety precaution they can also fly with 2 pilots at night.
  - A single engine helicopter may take off for a case 45minutes before the published sunrise time of the day and may not continue operations more than 45minutes after the published local sunset time.

Emergency helicopter landing zone[18]
Any landing area that is not a designated, approved helicopter pad or heliport is designated an emergency or temporary landing zone (LZ).

At any LZ, the following rules should be followed:
- The LZ should be at least 30 metres by 30 meters
- The terrain should have less than a 10 degree slope
- The area should be free of hazards e.g. wires, cables, telephone and power lines, fences, trees and moveable objects.

No person may approach the helicopter without permission from one of the flight crew. Always wait until the rotor blades have come to a stop and the pilot signals that it is safe to approach. Remain in full view of the pilot between 10 and 2 o’clock of the nose at all times.
Always assume a crouching, low body profile. Even though rotor blades are in fact much higher, this indicates to others that you are aware of the rotor hazard and safe guards against sudden wind gusts that can cause the rotor blades to dip down to human level. Approach and depart from the down slope side if the helicopter has landed on an incline. Never approach a helicopter from the rear. The tail rotor turns so fast that it is often not visible to the naked eye.[18]



The DO and DO NOT of safety[18]

- DO NOT load/unload whilst the rotors are still turning unless instructed by the helicopter crew to do so
- DO NOT approach a running helicopter without permission
- DO NOT walk around the tail of a helicopter
- DO NOT smoke within 25m of a helicopter
- DO NOT carry long items like drip stands, splints or extend your arm up to hold the drip
- DO NOT wear a hat without holding on to it
- DO NOT activate smoke grenades or canisters upwind of the helicopter
- DO NOT fire flares less than 1000m from the helicopter
- DO request pilot's permission to approach the helicopter
- DO control bystanders and animals, without cordoning tape
- DO secure loose articles, blankets, burn sheets and clothing to prevent them from flying up into the rotor blades
- DO protect the patient from the rotor wash and dust
- DO fire flares away from the helicopter

The transfer

Preparation and packaging includes preparing the patient, the equipment and the supplies. Selection of appropriate equipment is essential and adequate supplies of fluids, drugs, oxygen and batteries must be available. The transfer crew should also be prepared with attention to warm clothes, suitable footwear (not scrubs and clogs), mobile phones and money.[16] 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 includes scene safety, weather forecast, journey length, as well as the referring and receiving facilities.[17]

Preparation of the patient starts with the initial assessment and resuscitation, and is followed by a period of stabilisation.[16] Scene safety should first be addressed and, once this is secured, the patient can be approached.[17] Stabilisation should follow the CAB approach as outlined by the advanced trauma life support (ATLS) and advanced cardiac life support (ACLS).[3] Appropriate resuscitation is essential to reduce physiological disturbances associated with movement. In the pre-hospital environment, only life, limb or eyesight saving procedures should take place at the scene.[17] This "scoop and run" approach is not indicated in the interhospital transport of critically ill patients. Evaluation, stabilisation and preparation for transfer should be started by the referring team while awaiting the arrival of the transport team. This avoids delays caused if the transport team still has to stabilise and perform lengthy procedures before the transfer. However non-essential procedures should not delay the transfer.[8]

Due to the limitations of patient management in an aircraft, various guidelines have been developed to assist and guide management in transit. The following guidelines have been developed for The Aviation Medicine Course as presented by the Universities of Cape Town and Stellenbosch. As with most guidelines they are not based on high level evidence but depend on expert opinion:[11]

1. Airway / Ventilation
   a. If it is deemed likely that airway intervention will be needed in transit, this should be achieved prior to transportation. Laryngeal mask airways are not acceptable for airway management for critically ill patients undergoing transport.
   b. All patients with a GCS of 8 or less or with difficulty maintaining an airway or severe respiratory distress should be intubated prior to flight. If air transport is undertaken, it is ideal for the cuff to be a low pressure-high volume type. Fill the cuff with sterile saline.
   c. All trauma patients should be transported on supplemental oxygen.

2. Haemothorax / Pneumothorax / Pneumomediastinum / Surgical emphysema
   a. If indicated, intercostal chest drains should be inserted prior to transfer. A Heimlich valve or vacuum chest drainage system should be used instead of the typical glass bottle.
   b. On a fixed wing flight in particular, all patients with a pneumothorax or surgical emphysema should have an intercostal drain placed pre-flight.
   c. Prophylactic chest drains should be inserted when fractured ribs or a flail chest is present or suspected.
   d. On unpressurised flights, the patient should be monitored for a tension pneumothorax

3. Circulation and intravenous access
   a. Volume status should be assessed and normalised prior to departure as hypovolemic patients tolerate movement poorly.
   b. Secure intravenous access is critical prior to transfer and may include central venous access. Fluids, inotropes or vasopressor therapy may be needed to maintain adequate perfusion.
   c. Ensure that you have good venous access for the duration of the flight. All patients should have at least 1 peripheral line established. However for short flights time on scene should be less than the flight time therefor if an IV attempt fails, crew should consider transport without IV access.
   d. 2x large bore (14G / 16G) peripheral IV lines particularly for trauma patients pre-flight (even if only for a t.k.o lines in case one line should become inoperable).
   e. Plastic IV fluid containers are desirable as opposed to glass (breakage; sudden decompression).
   f. Consider use of an infusion device or pressure infuser as a means to maintain flow rate.
   g. The need for central venous pressure and cardiac output monitoring should be assessed on an individual basis. ECG and blood gas should be analysed immediately prior to transfer.

4. Medications
   a. Administer preflight medications as needed e.g. mild sedation for anxiety.
   b. An anti-emetic minimum half an hour preflight even when patient has been NPO.
   c. Analgesia for pain relief can also reduce the anxiety for the patient.
   d. Ensure you have IV meds lest the patient should deteriorate.

5. Drainage
   a. Gastric drainage: A nasogastric tube (NGT) is essential in cases of ileus or intestinal obstruction and should also be inserted if on mechanical ventilation.[8] All patients, unless capable of protecting their own airway without crew assistance, particularly GI disorders / abdominal surgery, should have a NGT passed preflight in cases where flying time is 15min or more. It is advisable to aspirate all gastric contents preflight and enroute allow free drainage to a drainable collection bag.
   b. Urinary drainage: A Foleys catheter is indicated in long transfers, patients on diuretics or in cases where strict input and output monitoring is required.[8] Ensure sterile saline in the cuff.

c. Colostomy drainage: Apply clean dressings and empty collection bags prior to departure. Watch for gaseous collection in the bag.
d. Rectal drainage: This is ideal for patients with malaena stools and consideration for lower body access in flight is advisable.

6. Haemorrhage and wounds

a. Apply clean dressings prior to departure and ensure adequate dressing supplies for the duration of the transfer.
b. Suture lacerations to prevent further blood loss.
c. All wounds to be dressed to prevent contamination of the wound, crew and aircraft.
d. Active haemorrhage should be controlled as far as possible preflight.
e. Patients with gas gangrene should not fly at altitude if at all possible and must be transported with supplemental oxygen.

7. Musculo-skeletal injuries

a. Bivalve all fresh circumferential POP casts (applied within 24hrs of departure) or plaster on edematous limbs; it is ideal to make use of a POP back slab.
b. Apply fixed traction as G-forces may alter weight and turbulence will give rise to missile potential.

8. C-spine fracture

a. All trauma patients with injuries to the head, neck, chest or abdomen should be fully immobilized prior to flight (vacuum mattress is ideal for transfers longer than 15min).
b. NG and urinary catheters and IV lines should be inserted. Consider intubation for a patient with a high spinal injury.

9. Unco-operative patients

a. Combative patients can compromise the safety of the crew and in these cases soft wrist and/or leg restraints, sedatives or mechanical ventilation should be considered. The decision whether to transport ultimately lies with the pilot.

10. Critically ill patients

a. While every effort should be made to stabilise patients prior to transport, there will be some that are so critically ill, that this is not possible. A decision should be made whether to transport these patients at all.
b. This decision must be made by the ALS paramedic or the most senior practitioner doing the transfer and will depend on the following:
   - Whether a further period of stabilisation would improve the situation
   - The distance to the receiving hospital
   - The pathophysiology responsible
   - The probability that the patient will die in flight
   - The views of the receiving doctor
c. It may be preferable in these situations, not to transport the patient at the time.

11. Post-op patients

a. It is advisable where applicable and possible to undertake aeromedical transfer atleast 5 days after major surgery.

12. Cardiac patients

a. Require continuous monitoring.

13. Infectious diseases

a. Usually not accepted for commercial transfer.

b. The necessary special precautions should be taken, e.g. isolation if possible. Crews to take medication as currently prescribed and conduct self-monitoring for symptoms post flight.

14. COPD/TB
  a. In new cases watch for respiratory distress.

15. Decompression sickness
  a. It is preferable to recompress as soon as possible and if possible to transfer in a decompression chamber, otherwise fly at low altitude. Do not transport at an altitude more than 1000ft above injury-altitude.

16. Burns
  a. Circumferential burns should have an escharotomy
  b. Inhalation wounds should be managed as an airway threat preflight.

17. Post eye operation/Trauma
  a. Barotrauma can cause wound opening or separation of surgical incision due to entrapped gasses.
  b. Choroidal or retinal disease or injury patients should have supplemental O2 administerd above 4000ft.

Correct packaging of the patient is very important and involves the physical preparation of the patient for transfer and aims to minimise risk of disconnecting IV lines, tubes and equipment. ETT and venous access lines must be well secure and extension sets applied for hard to reach IV access sites. Staff must have easy access for administration of intravenous fluids or drugs and for suctioning.[16] Equipment required to deal with dislodged lines or tubes should be readily available. If possible, the patient should be positioned to provide maximum access. Sufficient space should be available at the head to allow monitoring and management of the airway.[3]

Any unused cross-matched blood or blood products must accompany the patient if there is an agreement between the hospitals for its use after departure from the referring facility. Finally the receiving physician must be informed of the estimated time of arrival.[3]

The transfer should be undertaken smoothly and not at high speed. The aim is to provide the same standard of care as in the ICU. In transit it can be difficult or impossible to do major procedures and the ideal transfer is when no intervention is needed once underway. This is the reason why timely stabilisation and attention to detail before moving the patient is essential. However the unexpected can occasionally happen and the crew should be adequately prepared for any such circumstances.[3]

Documentation and audit

Clear documentation is essential, not only as a permanent record for the receiving hospital, but also for audit and possible litigation purposes. This includes documentation of the assessment, evaluation and transportation of patient.[16] Documentation must include a referral letter, the hospital notes, imaging hard copies or digital media and results of all investigations.[3] In order to ensure safe, auditable and defensible prehospital medical retrieval, organisations must have Quality Assurance (QA) and Healthcare Governance (HG) frameworks in place. A named clinical lead is responsible for on-call acute advice and the ownership of appraisal, QA and audit.[17]

Pointers for in-flight and post flight care[11]

- Monitor vital sign trends
- Level of consciousness– changes are usually the earliest indication of deterioration
- Cardiac rhythms – monitor for both cardiac and non-cardiac caused changes

- Respiratory changes (compliance, TV, rate, nature) – monitor for tension pneumothorax / airway obstruction
- Circulation maintenance – BP, rate, rhythm, capillary refill, sustained tachycardia with hypotension may be as a result of continued volume loss
- Abdominal distension – continued haemorrhage, gastric dilation, NGT patency
- Neurovascular (motor) status in extremities – changes may indicate compromise of proximal fracture – check splint and limb alignment
- Behavioural changes – may be subjective or objective – rely on patients comments to provide vital information
- Temperature monitoring of neonates (even though in incubator) and critical patients is ideally necessary for flights longer than 15min

<u>Post flight procedures</u>[11]

- Comprehensive and thorough hand over to staff at the receiving medical facility
- Equipment: Ensure all your gear comes back with you after handing the patient over
- Follow up: In order to report on the patients progress post transfer. Did we play a positive role in the patient's overall condition?

MONITORING AND EQUIPMENT

Monitoring

Adequate monitoring during the transfer is vitally important. If the goal is to provide a similar level of care as in ICU, then similar monitoring capabilities as in ICU should be available.[5] All critical care patients in the pre-hospital arena should have a minimum standard of monitoring, similar to patients undergoing elective hospital anaesthesia:[17]

- Resuscitation and emergency airway kit readily available (oxygen supply, suction, self inflating bag and mask, airway adjuncts, advanced airway equipment, defibrillator)
- Continuous pulse oximetry and 3 lead ECG monitoring, non-invasive blood pressure measurement, respiratory rate or ventilator monitoring
- End tidal capnography
- Two reliable sites of peripheral venous access should be placed and secured
- Monitoring of intracranial pressure, pulmonary artery pressure or continuous arterial pressure if indicated

Equipment and medication

Safe transport requires essential and sufficient equipment and pharmaceuticals. Emphasis is placed on airway, oxygenation and circulation. During very short or very long transfers the crew may decide to deviate from this list depending on the patient condition and nature of illness.[8] All equipment and drugs should be checked daily and restocked. A checklist should be followed before and after each transfer and kit bags should be secured and dated where possible to make sure equipment stays present and stocks are up to date. 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.[17]

Equipment should be light and portable yet robust. Battery life of the monitoring equipment should be maintained in between transfers and spare battery packs should be available at all times. Oxygen and battery life of monitors should be calculated in accordance to the anticipated task time, with back-up in the event of delays or re-tasking.[17] Suction equipment with a back-up facility, should be readily available. Venturi suctioning consumes large volumes of oxygen and an electrical or hand held suction device avoids this problem but are often not as effective.[17]

A sufficient amount of oxygen should be available, making allowances for delays during the journey. When calculating the amount of oxygen, an FiO2 of 1.0 should always be used as this offers the capacity to increase oxygen delivery should deterioration occur. Twice the amount of calculated oxygen should be taken on the journey. The following equation can be used:[19]

Litres of oxygen required = 2 x [(minute volume + bias flow) x duration of transfer in minutes]

Transport ventilators must be small and light and have clear visual alarms. An external power source is ideal as oxygen driven ventilators can consume large quantities of gas. In this case oxygen flow may need to be adjusted. Non-invasive ventilation is not usually suitable for aeromedicine as the oxygen consumption is unpredictable and high, and patients needing NIV should usually be intubated.[17] Portable ventilators are recommended even for intra-hospital transfers. Studies have demonstrated alterations in blood gas values due to inconsistent ventilation. New generation transport ventilators have improved greatly and smooth transition from ICU ventilators is now possible. The use of manual resuscitator bags may be easy but it presents another set of problems. Practitioners are unable to control airway pressure or tidal volume (VT) and this can cause over or under ventilation and may exacerbate lung injury. Maintaining a stable PEEP can also be problematic and supporting spontaneous ventilation is difficult.[1]

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 take off 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.[17]

<u>Equipment and altitude</u>[11]
Increasing altitude, temperature and the stresses of flight may affect equipment. Here are some of the effects and what precautions to take to avoid equipment related problems:

1. Airway equipment

a. Suction unit
   - Back up unit available
   - Keep fully charged
   - Ensure you have adequately sized catheters and spares

b. ETT
   - Cuff type: Low-pressure high-volume
   - Fill cuff with sterile saline
   - Naso/orogastric tubes: due to gas expansion with increasing altitude, it is advisable to avoid the resulting vomiting and aspiration due to gastric distension and compromised ventilation. Gastric rupture has occurred in patients whose stomach was not properly vented (watch out that clamping during the loading/unloading of patients is not forgotten about)

c. Oxygen
   - Heat will cause contents to expand – check contents regularly and in extreme heat perhaps vent off excessive pressure manually
   - Flow rates and times on cylinders may vary with changes in ambient temperatures, necessitating advanced planning

- Cylinders should be mounted and secured as per regulations
- Crew should be cautious when handling portable cylinders during transport and loading/unloading procedures
- Fire precautions

d. ICD
- Replace all chest tube bottles (bulky, breakable) with Heimlich valves
- Due to the potential for exacerbating a pneumothorax, the chest drain should never be clamped during transport

2. Ventilation equipment

a. Ventilators
- Adjusting inspiratory and expiratory times, in conjunction with flow rate can compensate for changes in altitude, especially in unpressurised aircraft
- An adjustable inspiratory and expiratory ratio is also a desirable feature

b. PEEP valves
- The PEEP valve establishes a closed respiratory system, resulting in an 'enclosed space' in the pulmonary system. As altitude increases, gas inside the lungs expands, resulting in increased pressure and possible alveoli rupture

3. Circulatory equipment

a. Fluids: Colloids/crystalloid are susceptible to:
- Temperature extremes – fluid warmers may be needed
- Admin sets may break while loading and unloading (hook up on heli parts)
- Heat may alter IV fluids
- Expanding gas/bubbles in container and in the drip chamber
- Infusion pumps (inline air expansion may cause flow impedance, and audio alarms may not be heard), consider using a dial-a-flow

4. Patient monitoring

a. ECG monitors/defibrillators
- Artifacts and 60Hz interference from vibration may occur
- Lead attachment or cable-monitor connection may be affected by patient handling and/or vibration
- Ensure no crewmember is in contact with the patient or stretcher during defibrillation
- Heat can dry out monitoring/defib pads – replace if necessary

b. Dopplers
- Due to noise in the environment, dopplers may be used to augment assessment of pulses and fetal heart tones

c. NIBP
- Gas expansion in cuffs may give false readings
- Vibration and patient movement can alter readings

d. Pulse Oximeter
- Older portable units are affected by ambient pressure changes and would need to be recalibrated at altitude
- Poor perfusion may result in poor readings or no reading

e. Urinary catheters
- Gas in the bladder on ascent may cause leakage, return flow/reflux (also as a result of elevating the collection bag above the level of the bladder). This may result in infection
- Empty preflight and vent if necessary in flight and post flight

5. Immobilisation equipment

a. Space limitations (length, width and overhead clearance)

- Loading and storage of scoop stretchers, back boards and traction splints could be an issue

b. Weighted traction devices
   - These must be converted to fixed traction / immobilization preflight to avoid the hazard of a missile and altered weighting due to G-forces. If these are not possible then use a vacuum mattress
   -

Intravenous infusions

The essential need for each infusion should be rationalised in order to minimise the number of pumps for transfer. The more equipment and monitors attached to a patient during ingress onto and egress from the platform, the more likely something will be dislodged. This also assists in keeping weight, and thus fuel costs down. Syringe pumps should have visual alarms to identify occlusion or an empty syringe. Pressure bags will be needed for administering fluids at a fast rate due to limited height in the cabin.[17]

The following two tables contain lists of equipment and pharmaceuticals that should be available during transport of any critically ill patient.[1]

Table 1: Essential medications[1]

Type	Examples
Narcotic analgesics	Fentanyl, morphine, hydromorphone
Resuscitation medications	Atropine, epinephrine, calcium, sodium bicarbonate
Sedatives	Ketamine, midazolam
Anti-arrythmics	Amiodarone, adenosine, lidocaine
Anti-hypertensives	Labetalol, metoprolol, atenolol
Neuromuscular blockers	Succinylcholine, rocuronium, vecuronium
Reversal agents	Naloxone
Bronchodilators	Albuterol, ipratropium, methylprednisolone
Anti-microbials	Ampicillin, vancomycin, gentamicin, ceftriaxone
Anti-epileptics	Fosphenytoin, lorazepam, phenobarbital, diazepam
Intravenous fluids	Normal saline, lactated ringers, 10% dextrose, 5% dextrose, albumin
Intravenous medications	Dopamine, dobutamine, epinephrine, lidocaine, insulin
Anaphylaxis agents	Racemic epinephrine, cimetidine, diphenhydramine
Miscellaneous	Acetaminophen, activated charcoal, furosemide, heparin, mannitol, 3% saline, calcium gluconate, dextrose

Table 2: Essential equipment and supplies[1]

Type	Examples
Monitoring equipment	Electrocardiograph leads and cables, pulse oximetry probes and cables, thermometer, stethoscope, blood pressure cuff
Suction equipment	Suction catheters, Yankauer, suction tubing
Intravenous/intra-osseous equipment	Angiocatheters, arm boards, intra-osseous needles, tourniquets, tape, tegaderm, gauze
Chest tube/needle drainage equipment	Chest tubes, pleurovacs, syringes, stopcocks
Nasogastric/urinary equipment	Feeding tubes, nasogastric tubes, Foley catheters, syringes
Sterile field supplies	Betadine, chlorhexidine, alcohol wipes, sterile gloves, sterile drapes
Communication equipment	Cell phones, 2-way radios
Intubation equipment	Endotracheal tubes, nasal and oral airways, CO_2 detectors, stylets, laryngeal mask airways, tape, Magill forceps, commercial tube holders, tracheostomy tubes
Laryngoscopy equipment	Laryngoscope blades and handles, batteries, bulbs
Oxygen-related equipment	Nasal cannulas, oxygen tubing, flow meters, head hood, self-inflating bags, resuscitation masks, simple masks, venturi masks, non-rebreather masks
Aerosol equipment	Aerosol mask, tracheostomy mask, aerosol tubing, sterile water, nebulizers
Miscellaneous	Defibrillator pads, tape, needles, cervical collars, butterfly

MINIMISING RISK

Since the late 1970s, safety concerns have motivated several studies. One of the first demonstrated the beneficial effects of earlier transfer, resuscitation prior to transfer and ongoing medical care enroute. This applies to this day. In 1986, Ehrenwerth et al. concluded that critically ill patients could be transported safely with appropriately trained and specialised transport teams, haemodynamic stabilisation and effective monitoring.[27] Guidelines emphasise the principles regarding organisation, personnel and equipment. Still, high rates of adverse events continue to be published, many appearing to be avoidable and associated with non-adherence to guidelines.[2]

There is no shortage of advice or recommendations to prevent or decrease the impact of transport on patients. There are a variety of published guidelines provided by the Society of Critical Care Medicine, Study Group for Safety in Anesthesia and Intensive Care, American Association for Respiratory Care (AARC), Intensive Care Society and the Australasian College for Emergency Medicine. Most of these guidelines are however based on small observational or retrospective studies or expert opinion.[1] There is currently no mandatory regulatory oversight for transport teams. It is the responsibility of independent facilities to monitor and train their own transport teams.

A review of the literature reveals several suggestions for decreasing the incidence of adverse events. The first step in this process is bringing the ICU to the patient. It has been suggested that mechanically ventilated patients should be accompanied by at least 2 practitioners, one of them a critical care trained nurse and the other either a doctor or a respiratory therapist. The use of specialised transport teams focusing on patient stabilisation appears to be the most effective way to avoid potential life threatening events in the care of paediatrics during transport.[1] Enhanced monitoring capabilities provide vital information and allows earlier intervention. Airway equipment, a cardiac monitor with defibrillating capability, oxygen supplies, resuscitation drugs, intravenous fluids, battery operated infusion pumps, and a portable ventilator is considered minimium equipment.[1]

Preventive factors have also been suggested and checklists as well as in-transport monitoring tools have been suggested. Choi et al. reported that the use of transport checklist even in transporting between departments in the same hospital, decreased overall events rate from 9 to 5%.[28] Good crew skills/teamwork, meticulous preparation, regular patient and equipment checks, appropriate sedation, good communication, protocols and check lists, and diagnostic destinations that are easily accessed from the ICU are also associated with fewer incidents.[1,2]

OTHER SPECIAL CONSIDERATIONS

a. Pre-hospital rapid sequence induction (RSI)

There is increasing evidence to suggest increased survival rates and better functional outcomes for complex trauma patients (especially traumatic brain injuries) who receive a secured, definitive airway early in their management. Indications for aeromedical intubation include airway compromise, respiratory compromise, unconsciousness, agitated head injury patients and medical patients who cannot be managed safely without a definitive airway. It should be kept in mind that multi-system trauma patients undergoing RSI with manual inline stabilisation of the cervical spine have an increased incidence of difficult or failed tracheal intubation. At all times pre-hospital anaesthesia should adhere to the same principles as emergency in-patient anaesthesia.[17]

b. ECMO

Over a 15 year period, Cabrera et al reviewed the transport of 38 patients on ECMO. None of the patients had major complications and mortality during transfer was zero. However mobile ECMO is extremely risky and expensive. Transport of these patients should be considered very carefully. A portable device measures 30cm x 25cm x 43cm and weighs 10kg, and can provide pulmonary and/or circulatory support for up to 6hours.[29]

c. Obstetric and neonatal patients

Transport of laboring women is not ideal and women should deliver prior to aeromedical transfer where possible. Delivery during transport 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. Indications for rapid maternal transfer by air may include preterm labour, eclampsia, post partum haemorrhage, and sepsis. It may be prudent to suppress labour. The pregnant patient should be transported on her side and avoid strapping over the abdomen. Supplemental O_2 is indicated. 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.[17]

d. Psychiatric patients

Psychiatric patients may pose many challenges to safe aeromedical transfer. 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. Safe and effective transfer may require sedation or general anaesthesia. Patient consent should be sought for transport and if not achievable, the appropriate section of the National Mental Health Act should be consulted.[17]

CONCLUSION

Retrieval of critical patients involves bringing the mobile intensive care unit to the patient for facilitation of transfer to definite care. It can significantly improve the outcome of patients.[17] Patient transfer can have significant physiological effects on critically ill patients. Understanding the physiological impact that both land and air transfer has on the patient enables appropriate preparation for transfer and will reduce risk of patient instability and deterioration during transfer. It is vital to remember that the above principles not only apply to the patient but also to medical staff and equipment.[12] All staff involved in these transfers must be aware of the hazards and dangers. The importance of training and supervision and the need for meticulous planning and preparation cannot be over emphasised. Most physicians will not regularly be involved in patient transfers and this combined with the hazards of moving an unstable patient often in unfamiliar surroundings, make transferring critically ill patients very challenging.[19] Careful planning, monitoring, and resource allocation, including personnel appropriate for the transport, are extremely important to ensure patients remain as safe as possible.[1]

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