

A RETROSPECTIVE, DESCRIPTIVE STUDY OF PATIENTS EVACUATED
TO SOUTH AFRICA VIA AN AERO-MEDICAL PROVIDER FROM
NOVEMBER 2010 TO OCTOBER 2011

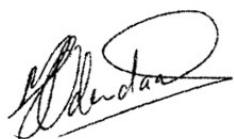
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Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the
degree of Master of Science in Medicine in Emergency Medicine

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Declaration

I, Salomé Marlize Odendaal, declare that this research report is my own work. It is being submitted for the degree of Master of Science in Medicine in Emergency Medicine at the University of the Witwatersrand, Johannesburg. It has not been previously submitted for any degree or examination at this or any other university.

A handwritten signature in black ink, appearing to read 'S. Odendaal', with a large, stylized loop at the end.

The 2nd day of August 2017

Abstract

Background. When the medical needs of an ill or injured patient exceed what is available locally, urgent transportation to a well-equipped medical facility becomes prudent in order to minimize morbidity and mortality. Aircrafts are frequently used for this purpose.

The aim. The aim of this study is to describe the patient profile of international aero-medical transportations (AMT) in sub-Saharan Africa.

Methods. All air ambulance patient transportations performed by a South African based dedicated AMT provider, from 1 November 2010 to 31 October 2011, were reviewed and analysed.

Results. Three hundred and six transportations were conducted of which 303 met the inclusion criteria. The patients' ages ranged from 2 days to 86 years (median age 43 years). The top 3 nationalities transported were from South Africa (25.1%), United States of America (9.9%) and Angola (26%). The top 5 medical categories were trauma (23.4%), cardiology (16.2%), infective diseases (11.2%), neurology (10.9%) and surgery (9.6%). Malaria, as a single disease entity, contributed to 10.2% of all transportations. Transportations were mostly done from Angola (32.3%), Zambia (11.9%) and Mozambique (9.2%). Thirty one patients (10.2%) received mechanical ventilation, 16 (5.3%) inotrope and/or vasodilatory therapy, 68 (22.4%) oxygen and 2 (0.7%) were transported within a patient isolation unit.

Conclusion. Transportation included neonatal, paediatric and geriatric patients with various medical conditions, some of whom required critical care procedures during AMT into South Africa. Therefore, the necessary skills training and appropriate equipment to care for critically ill patients and any possible complications should always be available during AMT.

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Abbreviations

AAP	Air ambulance provider
AC	Assistance centre
AMT	Air medical transport / Aero-medical transport
DRC	Democratic Republic of the Congo
FiO ₂	Fraction of inspired oxygen; the fraction of oxygen available in the immediate environment for inhalation
IPPV	Invasive positive pressure ventilation
NIPPV	Non-invasive positive pressure ventilation
PRF	Patient report form

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

1.1. Introduction

The phone rings. *“Welcome to your medical assistance company, you are speaking to Gerard*. How may I assist you? ... Oh, I am sorry to hear about your situation Mrs. Smith*. What is your contact number in case the line drops, please? ... Where are you currently? ... And your son’s name? ... Johnny* ... Thank you Mrs. Smith, please wait for me while I connect you to our medical team...”* A medical professional is conferenced into the conversation and information regarding Mrs. Smith’s son’s medical situation is obtained. There is an opportunity to speak to the treating doctor standing next to Mrs. Smith and she hands him the phone. After medical information is obtained and the treating doctor requests a transfer to another medical facility for Johnny as an upgrade of medical care, the phone is handed back to Mrs. Smith. The coordinator completes the call by obtaining further relevant logistical information. *“Thank you Mrs. Smith. As discussed, we will call you back within one hour with further information. Goodbye.”*

The information regarding Mrs. Smith and her son’s situation is evaluated, a risk assessment is done and this is discussed with the medical director and operations manager on duty. Johnny’s medical needs are exceeding the capability of the current local medical facilities available in the region of his current location. It is confirmed that an international aero-medical transportation to the nearest appropriate medical facility is the most appropriate course of action and in Johnny’s best interests.

**fictional names used*

Rapidly, the team tackles various different tasks such as confirming aircraft availability, confirming authorization to cover the costs, location of passports and proof of Yellow Fever vaccinations and finally the aero-medical transport provider is activated.

The medical flight crew are briefed regarding the medical condition. They test and pack medical equipment and medication while the pilots prepare for the flight and get the aircraft ready. Soon, everything is packed, safe and secured. Air Traffic Control confirms it is their turn for take-off. There is a smell of jet fuel. Sparkling runway lights are visible ahead. Pilots' silhouettes are created beside the hundreds of cockpit control lights. There is an increase in the engine's revolution. Senses heighten...and then the sudden thrust as the aircraft forces forward.

After hours of flight and a bumpy ground ambulance drive to the hospital, the medical flight crew finds Mrs. Smith and Johnny in the hospital. While the flight doctor obtains handover from the treating doctor, the flight nurse swiftly connects monitors to Johnny and obtains a set of vital signs. Like a well-oiled machine, the team works together to assess Johnny's medical condition, obtains all his reports, ensures relevant interventions are done, checks that his intravenous access is secure, he is connected to oxygen and is prepared and ready to go. As a single unit, he is skilfully lifted on to the ground ambulance's stretcher and transferred to the ambulance. After another bumpy drive through busy traffic, all arrive safely at the airport. Customs and immigration are cleared and Johnny is moved from the ambulance to the aircraft stretcher. After some further preparation, stabilization and ensuring that all is safe and secure again, the door is closed and the flight back to South Africa begins. Some

hours later, Johnny is handed over to a level one trauma centre and taken to the operating theatre.

Several organizations offer medical assistance to ill or injured travellers while abroad and provide medical evacuations or repatriations, depending on the patient's medical condition.¹ International SOS (Intl. SOS) is an international medical and travel security assistance company, which assists with managing the medical and security risks associated with overseas travel or assignment.² The above describes an example of International SOS's involvement in the precious life of a customer. The assistance is primarily provided to corporate and insurance companies that have purchased a membership program from Intl. SOS, but assistance is also provided to private individuals on a case-by-case basis.² All the assistance centres (AC) of Intl. SOS engage with various aero-medical transportation service providers for international transportation of any of their client's ill or injured travellers or expatriate members globally, when required.²

The researcher, being a former employee of Intl. SOS, was involved in overseeing various aero-medical transportations and thus a research question arose to understand the patient profile of those transported by an aero-medical transport provider in sub-Saharan Africa.

1.2. Literature review

The development of larger and faster passenger carrying aircraft brought cheap, affordable and accessible travel to millions of people throughout the world.³ The world-wide network of commercial airlines makes rapid travel between distant points on earth relatively easy and this coupled with increased travel activities for business and leisure across all age groups, transports an increasing number of people away from their home country to various and exotic corners of the earth.³⁻⁵ As business expands globally, organizations also require an increasing number of employees to travel and work abroad in order to support their international operations.⁶

The continuing increase in the average age of Western populations contributes to the average traveller's age rising.⁷ It is estimated that by the year 2030, half of all aircraft passengers will be above 50 years of age.⁷ The number of children travelling or living outside their countries of origin has also increased.⁸ Among leisure and business travellers, many of whom have significant past medical histories, there are those who become ill or injured while abroad some of whom may require medical transportation out of the area they visited.^{3,4}

Nearly all international travellers are able to complete their trips successfully with fewer than 0.5% of travellers requiring medical transportation out of the area they visited.⁴ However, when 1 to 2 billion people travel by air every year, even a small percentage of severe medical incidents translates into thousands of annual international medical transportations.⁴

Sand *et al.* state that increasing air travel has resulted in a significant increase in medical transportations.⁷ Studies indicate varying numbers of medical transportation: Chen *et al.* indicate 416 international patient transportations over a 2 year period according to data from International SOS Taipei in Taiwan, Daly *et al.* indicate 967 over a 4 year period by Emergency Medical Retrieval Service (EMRS) based in Scotland, Dewhurst *et al.* 483 over a 3 year period by a company in the United Kingdom (UK), Duchateau *et al.* 402 over a 1 year period as coordinated by Mondial Assistance France in Paris, Peiris *et al.* 410 over 2.5 years as coordinated by the Northern Territory Aerial Medical Service (NTAMS) in Australia, Peytremann *et al.* 162 over 2 years internationally among the United Nations High Commissioner for Refugees (UNHCR) field employees, Singh *et al.* 19 228 over a 2 year and 5 month by a provincial air-medical transport organization (Ornge) of Ontario in Canada, Suriyachaisawat and Surakam 302 over 1 year by the Aviation Medicine Department of Bangkok Hospital in Thailand and Tursch *et al.* indicate 356 over 1.5 years as coordinated by Med Call in Idstein, Germany.^{1,9-16}

1.2.1. Medical transportation

Blumen *et al.* divide transportation into two broad categories: intra-facility and inter-facility.¹⁷ Intra-facility transportation refers to the movement of a patient within the same facility.¹⁷ Wallace *et al.* agree with the categories as indicated by Blumen *et al.* and provides an example of intra-facility transportation as the movement of a patient from the ward to the imaging department or operating theatre.¹⁸ Inter-facility

transportation refers to the transportation of a patient from one medical facility to another medical facility.¹⁷ Mehra, however, divides transportation into three categories: primary, secondary or tertiary.¹⁹ Primary transportation includes search and rescue, transportation of skilled personnel to the scene of an accident, transportation of equipment and medical material to the scene of an accident and evacuation from the scene of emergency.¹⁹ Secondary transportation is intra-facility or inter-facility transfers and tertiary transportation includes inter-facility transfers to tertiary care centres, national or international repatriations, and transportation of donor organs and drugs.¹⁹

Daly *et al.* define “retrieval” as the transport of a patient from a medical facility to another for higher level of care, with transport performed by a team suitably qualified to deliver a standard of care equal or higher to that delivered at the receiving hospital.¹⁰ A secondary retrieval according to Daly *et al.* is the transportation of a patient from a medical facility without critical care facilities to one with critical care facilities.¹⁰ Both of these definitions are in keeping with Mehra’s secondary and tertiary transportation or Blumen *et al.* and Wallace *et al.* inter-facility transportation.^{17,18} There are many different views within the literature on the variety of definitions and classifications of transportation, therefore, for the purpose of this study, inter-facility transportation refers to transportation from one medical facility to another medical facility. Only inter-facility transportation will be further discussed.

Once inter-facility transportation is required, the appropriate timing of and mode of transportation have to be considered.^{4,11,17,20-22} Choosing the appropriate mode of transportation is not only subject to economic, logistical and clinical considerations

but, it is key to guaranteeing patient safety en route.^{16,18} Factors requiring consideration include: the inter-facility distance, the patient's medical condition, urgency, air transportation options versus other modes of transportation, weather conditions, the medical interventions necessary for on-going life support during transportation, financial cover and the availability of personnel and resources.^{4,11,17,18,20-23} Blackwell mention that before the advent of civilian ground ambulance services, the sick and injured were transported by any means available, including motorists, wagons, farm machinery, delivery carts, buses or taxicabs.²⁴ Today, inter-facility transportation can still be done by many different modes of transport but is commonly done by means of ground ambulances or alternatively aircrafts.²⁵ For the purposes of this report, only transportation via aircraft will be further discussed.

According to Wikipedia, Air Medical Transport (AMT) or medical evacuation usually refers to the use of military transport aircraft to carry wounded personnel²⁶, a definition seemingly taken from the World Heritage Encyclopaedia²⁷ but, the Free Dictionary describes aero-medical evacuation as the transportation of patients under medical supervision to and between medical treatment facilities by air transportation.²⁶⁻²⁸ For the purpose of this study, AMT refers to the transportation of an ill or injured patient under medical supervision by means of an aircraft.

Parsons *et al.* indicate that different types of aircraft are usually available for AMT: Commercial jet planes with pressurized cabins, light aircrafts and helicopters.²⁹ Gibbons *et al.* indicated in 1971 that it is not economically feasible to consider

pressurized aircraft for AMT.³⁰ Contrary to this, Blumen *et al.* mention in 2009 that various fixed-wing aircraft are available and used successfully for AMT.³¹ These fixed-wing aircrafts range from unpressurized light planes with single or twin piston engines to pressurized turboprops and jets.³¹ The type of fixed-wing aircraft used for AMT generally depends on the distance to be travelled, with single or twin engine propeller aircraft reserved for shorter flights, whereas jets may be used to transport across continents.³² Varon *et al.* and Mehra agree by summarizing that AMT is basically divided into two broad categories: 1) Fixed-wing or aircraft AMT and 2) rotor-wing or helicopter AMT.^{19,33}

Fixed-wing AMT tends to be considered for patient transportation where the inter-facility distance is more than approximately 300 kilometres (km).^{21,33} Many fixed-wing aircraft are capable of ranges in excess of 1 609 km, with some jets able to travel more than 3 219 km without refuelling.³⁴ An aircraft's range of flight is limited by the amount of fuel carried and used, which is a function of fuel tank capacity and useful load.³⁴ Fixed-wing air transportation is more subject to weather-related unavailability (e.g. snowing or icing) than ground transportation.³⁵ Weight restrictions, weather, noise and turbulence are applicable to fixed-wing transportation but are less of a factor when compared to rotary-wing transportation.^{17,22,31}

Fixed-wing aircraft speeds can exceed 400 kilometres per hour (km/h) but they are limited to travel between airports with appropriate runway length or runway conditions and refuelling facilities.^{19,22,31} As fixed-wing aircraft require airports or existing airfields to load and offload patients and with medical facilities rarely being located at the airports, ground transportation is needed at both the origin and destination ends

of a fixed-wing flight.^{19,35} The ground support should be able to fully support the patient, equipment and transport team.¹⁹

The AMT provider studied use only pressurized fixed-wing jet aircrafts. The choice and details of different fixed-wing aircrafts will not be elaborated on or discussed any further.

1.2.2. History of aero-medical transportation

On 5 June 1783 Joseph and Étienne de Montgolfier performed the first ballooning experiment at Annonay, near Lyons in France, where an unmanned balloon was filled with hot air.²⁹ Then, on 19 September a Montgolfier balloon transported a sheep, a duck and a chicken up to a height of 1 700 feet.^{3,19} This made way for the first manned ascent by the French doctor, Pilatre de Rozier, and the Marquis d'Arlandes in a balloon to an altitude of 2 700 feet on 21 November 1783.^{3,19,36} A Dutch military doctor by the name of De Mooy proposed that casualties might be evacuated by horse-drawn tethered balloons but there is no evidence that such a flight ever took place.³

Many authors, such as Allen *et al.*, Mehra, Parsons *et al.* and Gibbons *et al.* claim that the first documented AMT was the transportation of 160 wounded soldiers who were transported by hot air balloon from the besieged city of Paris during the Franco-Prussian War in 1870.^{19,29,30,33,34} Varon *et al.* and Martin indicate that this is incorrect.^{3,33} Contemporary records of the 67 balloons known to have left Paris during

the siege make no mention of the carriage of any sick or wounded.³ The origin of this belief is unclear, but may have resulted from an error in the translation of the original French reports.³ Many of the balloons were under contract to the French postal service and carried letters, government dispatches, homing pigeons, and passengers on governmental or war related business.³

On 17 December 1903, the American Wright brothers (Wilbur and Orville Wright), owners of the Wright Cycle Factory in Dayton, Ohio, piloted the first successful powered and heavier-than-air craft across the sand dunes at Kitty Hawk.^{3,36} The thought of AMT using heavier-than-air machines was initiated in 1909, when Captain George Gosman built an aircraft specifically for this purpose.^{33,37} However, it was not easy to convince the government to approve further development of Gosman's aircraft following its destruction in a crash, and it was never used to transport patients.^{19,33,37} Tremayne claims that the first AMT was in 1910 but it is not clear where this information originates from.³⁸ Developments in aviation and AMT were fuelled by World Wars (WW) I and II.³⁶

During WW I, wounded soldiers were transported using military aircraft in France.³⁹ According to Martin, the earliest recorded transportation of wounded casualties by aircraft took place during WW I, when Serbian patients were carried in an unmodified French fighter plane.³ In 1916, Dr Chassaing persuaded the French government to build an aircraft capable of carrying two stretchers.³ In 1917, the French aircraft Dorand ARII was used as the first fixed-wing AMT that carried patients.^{19,23,32,33,37} The first recorded British AMT took place in 1917 when a soldier in the Camel Corps in Turkey was flown to hospital in 45 minutes, thus avoiding a 3-day journey by road.³

In the same year, the Reverend John Flynn, a Presbyterian minister with the Australian Inland Mission, thought of combining aviation and medicine to produce a 'mantle of safety' across the outback of Australia.³ Over the next ten years, with the assistance of inventors, radio technicians, doctors, philanthropists and fellow missionaries, Flynn's dream became a reality.³

Initially the "ambulance airplane" industry grew, mainly in the military.^{32,33,37} Between the World Wars, both the British and French employed aircraft for the transportation of those injured due to colonial conflicts.³ In 1933 the Royal Flying Doctors Service was founded in Australia and began to operate in rural areas of Australia.³⁹ In 1933, the first British Civilian Air Ambulance Service was started, serving the Scottish Isles.^{3,19} Long distance high altitude AMT was pioneered by the Luftwaffe during the Spanish Civil War and WW II.¹⁹ It was WW II which heralded the rapid advancement and large increase in the use of AMT.^{3,33,37}

The military continued to dominate the growth and development of AMT in the immediate post-WW II period with a steady stream of conflicts and minor wars ensuring its interest.³ During the same period, other notable advances also had a marked effect.³ The development of rotary wing aircraft was of particular significance because of their ability to operate in confined spaces.³ A helicopter was first used in the Search and Rescue and casualty transportation role in Burma during the latter stages of WW II.^{3,32} Lt. Carter Harman, of the US Army Air Force, transported several wounded airmen near Mawlu in Burma on 23 April 1944.³

In 1950, the use of the helicopter for the front-line medical transportation of those injured during combat was authorized.^{33,37} The first real large scale transportation of wounded soldiers by helicopter occurred during the Korean war.^{3,19,30} The outstanding medical transportation system developed during the war in Vietnam owed much to the experience gained during the Korean conflict.^{33,37}

The Vietnam war was the definitive showcase for demonstrating the efficacy of helicopter medical transport in improving care for the injured.³ The use of AMT during the World Wars brought about dramatic reductions in patient morbidity and mortality.²³ The success of the military approach to casualty transportation during the Korean and Vietnam wars brought the aero-medical helicopter much public attention and kindled interest in their use of AMT in the civilian community.^{3,23,33,37}

The recent history of civilian fixed-wing AMT is difficult to trace, but the growth of international civil AMT has been driven by rapid advances in the technology and availability of mass transportation.³ A brochure for Air Ambulance Worldwide supports the notion that AMT is no longer a concept limited only to military missions.⁴⁰ A highly successful civilian model has been developed.²³ Gan *et al.* and Mehra, amongst others, agree that AMT is executed by both military air forces and civilian air ambulances using modern air platforms and sophisticated environmental control systems (such as temperature and cabin pressurisation controls).^{19,36} Additionally, AMT is no longer a rarity but has become an everyday event.^{23,37}

Thus, from 1903, when the American Wright brothers piloted the first successful powered and heavier-than-air craft to less than a century later, aircraft and air travel have become part of our daily lives, with AMT forming an integral part of modern emergency care systems.³ Furthermore, with the advancements in the field of aviation and medical technology, an intensive care unit (ICU) can be created in the sky.⁴¹ However, these technological advancements need to be supported by properly trained medical teams who are well versed with aspects unique to AMT, including the effects of aviation physiology.⁴¹

1.2.3. Transport stressors and aviation physiology

The key to successful AMT is planning for and responding to any deterioration in the condition that mandated urgent transport and to conditions induced by the aviation environment.⁴ Borne *et al.* and Blumen *et al.* document that any patient transportation, irrespective whether it is by air or ground, presents many unique challenges to the patient and the escorting medical crew such as noise, vibration and other transport stressors.^{17,42} Singh *et al.* advise that patients may deteriorate during transportation due to progression of the underlying disease, the physical stressors of movement and the transport vehicle, or the care delivered before or during transportation.¹⁴ Wallace *et al.* and Dewhurst *et al.* advise that additional reasons for risk and patient deterioration, which were not mentioned by Singh *et al.*, are that the patient often does not receive definitive treatment before transportation, remains physiologically unstable and transport vehicles are not conducive to active interventions.^{11,18} Wallace *et al.* and Dewhurst *et al.* add that the escorting medical

flight crew can also be faced with a different clinical situation on arrival than expected and no additional help may be available during transport.^{11,18}

Transportation via aircraft exposes the patient to well-described changes in the physical environment and these changes can affect the patient's physiological and pathological state, the medical flight crew and the medical equipment.^{11,33,43} It is important to understand the stressors of the aviation environment and their effect on the patient and medical equipment (aviation physiology) for successful AMT.^{11,14,20,30,31,41,43,44} These stressors are further discussed below.

Altitude and barometric pressure

Gan *et al.* write that aviation medicine traces its roots back to high altitude physiology where discomfort with mountain travel was documented by the Spanish army during the wars to conquer Mexico and neighbouring territories in the early 16th century.³⁶ In general, altitude refers to a distance measurement, usually in the vertical or “up” direction, between a reference datum and a point or object.⁴⁵ In aviation, it refers to the height of an aircraft with a reference datum of either mean sea level (MSL) or local ground level.⁴⁵ For the purposes of this study, further altitude references use MSL as reference data.

At any altitude, the barometric pressure is the weight of the air column, with a 1 cm² cross section, extending from that point up to the limits of the earth's atmosphere.²⁹ Air is compressible and therefore the atmospheric pressure, usually measured by a barometer in millimetres of mercury (mmHg), is proportionately greater at sea level

than at higher altitudes.²⁹ Barometric pressure progressively decreases with altitude from 760 mmHg at sea level to 140 mmHg at an altitude of 40 000 feet (ft.)^{32,33}

Fixed-wing aircraft can fly at altitudes of up to 43 000 ft.^{17,32,41,46} Modern aircrafts have systems which artificially control the cabin pressure within the passenger compartments and therefore compensate for the pressure changes with changing aircraft's altitude.^{34,46} Cabin pressures are adjusted equivalent to the barometric pressures found at certain altitudes above mean sea level and maintained as such during cruising.³² This is referred to as pressurization and is done by pumping air into the aircraft's cabin to maintain a pressure differential between the aircraft's cabin and the outside air.³⁴ The degree of pressurization is a function of how airtight the aircraft's "skin" is and of how efficiently and strenuously the compression equipment is operated.²⁹ It also depends on the type of aircraft and the aircraft's cruising altitude.²⁹ Thus, pressurized fixed-wing aircraft can fly at high altitudes while counteracting the negative effects of altitude within the cabin by means of pressurization.^{17,31,33}

There is some discrepancy in the literature reviewed about the range of cabin pressure or cabin altitude found at an aircraft's cruising altitude in pressurized aircraft: Essebag *et al.*, Teichman *et al.* and Joshi *et al.* indicate that cabin altitude ranges from 5 000 to 8 000 ft., Ehlers *et al.* indicate 6 500 to 8 200 ft., Stephenson 6 000 to 8 000 ft., Blumen *et al.* 7 000 to 8 000 ft. and Allen *et al.* and Parsons indicate pressures up to and equivalent to 8 000 ft.^{17,29,32,41,46,47} Irrespectively, pressurization generally does not result at mean sea level cabin altitude and therefore does not eradicate all pressure-change related problems.^{30,33} Thus, the patient, medical flight

crew and equipment will still be exposed to some pressure change during any flight.^{30,33} However, some aircraft can adjust their cabin pressure to a level almost the same as that at mean sea level, thereby limiting pressure-change related effects.²⁹ Some of the stressors experienced during flight are further explained by means of the applicable gas laws.

1.2.4. Applied physiology and stressors of aero-medical transportation

Dalton's law and aero-medical transportation physiology

Dalton's law states that the total barometric pressure at any altitude equals the sum of the partial pressures of all the gases present in the mixture.³¹ Oxygen constantly constitutes approximately 20.94% of dry air, but the partial pressure of oxygen in inspired air is proportional to the atmospheric barometric pressure; for example, the partial pressure of inspired oxygen (P_{iO_2}) drops from approximately 149 mmHg at mean sea level to approximately 108 mmHg at 8 000 ft. and to 20 mmHg at 40 000 ft., which is incompatible with human life.^{29,32} Thus, as pressure reduces with increase in altitude the percentage of oxygen constitute remains constant but, the quantity of oxygen becomes less with each breath resulting in fewer oxygen molecules delivered to the lungs, a decrease in the amount and rate of oxygen diffusion, and therefore less oxygen available for cellular metabolism and resulting hypoxemia.^{4,19,31,33,48}

Adjusting the fraction of inspired oxygen (FiO_2) to maintain the inspired partial pressure of oxygen throughout a flight is a clinically useful technique for preventing hypoxemia.³³ Pressurization of the aircraft cabin minimizes hypoxemia and eliminates the need for supplemental oxygen for flight crew and non-patient passengers.^{33,34} At cabin altitude of a pressurized aircraft, altitude related changes in partial pressure of oxygen (PO_2) are small and in most cases negligible.⁴⁶ Changes in PO_2 become more relevant when critically ill patients are transported at higher cruising altitudes or in patients with respiratory disease.^{34,43,46,48} Therefore, special considerations are warranted for patients who have anaemia, respiratory compromise or those in respiratory or cardiac distress.²⁹

In a healthy individual, PO_2 is adequate to maintain an oxygen pulse saturation (SpO_2) of over 90% at cabin altitude of a pressurized aircraft.⁴¹ Parsons *et al.* indicate that even in non-pressurized aircraft, because of the nature of the oxygen-haemoglobin dissociation curve, in healthy adults the oxygen saturation of haemoglobin at altitude levels up to 10 000 ft. will not fall much below 90%.²⁹ However, Varon *et al.* write that the physiological effects of hypoxemia can be detected in healthy individuals at altitudes less than 10 000 ft.³³ Withers *et al.* support that the SpO_2 decreases in healthy adults and children at cruising altitudes, however, he indicates that this desaturation does not result in clinically relevant hypoxemia unless there is an underlying disease process compromising respiratory or cardiovascular reserve.⁴⁹

A number of authors, including Joshi *et al.*, Allen *et al.* and Varon *et al.*, agree that people with respiratory disease or pre-existing hypoxia may require in-flight oxygen

supplementation as people with impaired respiratory function may be at risk of hypoxemia at commonly achieved cabin altitudes of pressurized aircraft.^{33,34,41} Essebag *et al.* refer to a study by Bendrick *et al.* of 24 patients with ischemic heart disease, indicating a mean saturation decrease of 5.5% at a mean cabin altitude of 6 900 ft. with 3 patients (12.5%) requiring supplemental oxygen for desaturation below 90%.³² Duchateau *et al.* indicate 29.1% patients require oxygen during medical transportation.¹

Various authors support that patients may require airway or ventilation support during transportation due to their clinical condition, as a study of Caldow *et al.* show a heterogeneous group of people with common factors of decreased level of consciousness and agitation requiring airway management.³⁹ In a study by Chen *et al.* approximately 8.7% of the patients received mechanical ventilation support during transport, Sand *et al.* show 10.3% during transport in their study on 504 transportations involving the Worker's Samaritan Federation in Germany and Singh *et al.* show 10.0% requiring assisted ventilation before transportation.^{7,9,14} Dewhurst *et al.* indicate 20% receiving mechanically ventilation and Tursch *et al.* 20.7%.^{11,16} Daly *et al.* show 50% being ventilated in a mixed medical and trauma critical care population.¹⁰ Le Cong *et al.* write that the use of non-invasive positive pressure ventilation (NIPPV) via face mask to improve oxygenation and ventilation in the acute respiratory failure patient group is a controversial topic in AMT but their experience was positive.⁴³ Le Cong *et al.* explain that any patient benefit of NIPPV, or lack of, can be determined very quickly and therefore the decision to intubate, if ultimately required, is not delayed excessively by a trial of NIPPV.⁴³

In general, physiological responses to hypoxemia include an increased rate and depth of respirations and an increase in cardiac output, mediated primarily through an increase in heart rate.^{31,32,46} Essebag *et al.* reference that the increase in cardiac output in patients during AMT was found to be proportional to the drop in oxygen saturation.³² Hypoxemia is also a stimulus for atrial arrhythmias and is associated with premature ventricular contractions.³² The potential for increased sympathetic nervous system activity in-flight is also an additional factor predisposing to arrhythmias.³²

Boyle's law and aero-medical transportation physiology

Robert Boyle (1627-1691) studied air bubble formation in the eye of a viper following decompression in a chamber, and formulated the famous Boyle's law.³⁶ Boyle's law states that the volume to which a given quantity of gas is compressed is inversely proportional to the surrounding pressure, with the temperature remaining a constant.^{29,31,32,34,46} Thus, as altitude increases and pressure decreases, volume increases.^{31,34,46} During descent, the opposite occurs.^{31,46} Boyle's law thus explains changes in gas volume as pressure changes with changing altitude.^{33,43} This may affect the patient, the medical flight crew and various medical equipment utilised by the medical flight crew during AMT.^{33,43}

The human body contains numerous cavities that are fully or partially closed and filled with gas or air, for example the inner ear, sinuses, pleural cavity and abdominal cavity.⁴³ Physiological effects may occur with changes in altitude from the expansion or contraction of gases (or air) within enclosed cavities of the human body.^{19,29,31}

Through pressurization, thus limiting the drop in cabin pressure that occurs with altitude, changes in trapped air volumes can be decreased or eliminated.³⁴ A change from mean sea level to an altitude of approximately 5 000 ft., air-filled compartments of the body will expand by a factor of 1.2.^{46,48} During a change from mean sea level to 8 000 ft. altitude will expand air-filled compartments of the body by a factor of 1.35.^{1,4,48} Parsons *et al.* indicate that this expansion from mean sea level to 8 000 ft. is 30% but most other references such as Essebag *et al.*, Stockman, Teichman *et al.*, Duchateau *et al.* and Joshi *et al.* agree that it will expand by approximately 35%.^{1,4,29,32,41,48}

In practical terms, the most significant physiological consequences relate to air trapped within the pleural space, obstructed bowel, peritoneal space, orbits, ears, sinuses and cranium of the human body.⁴³ Air trapped in the sinuses for example, may expand and cause discomfort.³³ Decreases in barometric pressure during ascent and flight cause air in the gastrointestinal tract to expand and increase pressure in the abdomen, often interfering with respiratory function.²⁹ This increase in intra-abdominal pressure can cause colic and potentially produce dehiscence in patients who recently underwent abdominal surgery.²⁹ Thus, in vulnerable patients, these volume changes can cause severe pain, dehiscence of surgical wounds, rupture of a hollow viscus, barotitis media, intracranial haemorrhage, irreversible ocular damage or provoke a tension pneumothorax.^{4,31,32,41,46,48} Flights with an increase in altitude can therefore be hazardous to somebody with a pneumothorax, intestinal obstruction, air in the cranium, gas gangrene, post traumatic emphysema or severe penetrating eye injuries.^{29,30}

These changes can also affect the functioning of medical equipment such as endotracheal tube cuffs, air splints and intravenous fluid administration.^{29,31,34} Air-filled cuffs may malfunction or injure the patient with changing altitude.³³ Endotracheal tube cuffs' pressure should be adjusted with changing altitude to avoid trauma.³² Le Cong *et al.* indicate that, contrary to previously suggested advice, filling the cuff with saline is now discouraged as research indicates that small bubbles left in the saline filled cuff can still cause significant pressure changes at altitude.⁴³ Air splint gas expansion at altitude can conceivably impair patient's limb circulation by pressure from the splint.³⁰ During the ascent of an aircraft, gas in a bottle of fluid will tend to expand.²⁹ This expansion will cause an increase in flow rate and therefore, plastic vaculitre bags are better than glass bottles and all intravenous lines are best placed on intravenous infusion pumps or syringe drivers.³² Plaster or fibreglass casts or splints should be split prior to a flight as air bubbles in the plaster may expand.^{29,43} Increased limb oedema can also occur at altitude and this combination may potentially lead to compartment syndrome.^{29,43}

Blumen *et al.*, Duchateau *et al.*, Joshi *et al.* and Teichman *et al.* agree that the major aviation stresses that altitude exposure imposes on human beings are hypoxia (as explained by Dalton's law) and gas or air expansion in body cavities (as explained by Boyle's law).^{1,4,17, 31,41}

Charles' law and aero-medical transportation physiology

On 1 December 1783, Jacques Alexandre Cesar Charles (1746-1823) made a balloon flight up to 10 000 ft. and described the first case of otitic and sinus

barotrauma, the effects as explained by Boyle's law, on himself.³⁶ He described Charles' law that notes that as temperature of a volume of gas rises, the volume of the gas increases, with the pressure remaining constant.³¹ This denotes the decrease of ambient temperature with increasing altitude.³¹ The ratio of altitude to temperature is fairly constant from sea level to approximately 35 000 ft. with temperature decreasing by 1 degrees Celsius (°C) for every 330 ft. increase in altitude.⁵⁰ Charles' law also denotes that an inflated balloon will shrink in cold temperatures and expand in warm temperatures. Likewise, air filled devices like air splints or endotracheal tube cuffs will expand or contract as the temperature increases or decreases.⁵¹

The human body temperature is generally constant with Charles' law having a limited effect on human physiology.⁵⁰ However, the risk of hypothermia or hyperthermia is increased when the patient being transported during aero-medical transportation is a newborn, with an even greater risk for a premature infant of low birth weight, or patients on medication such as sedatives, analgesics, some psychoactive and neuromuscular blocking medication, which interfere with the body's physiological temperature regulation processes.^{29,51} Temperature changes may also produce increases in metabolic rate and oxygen consumption or requirements.³¹

Henry's law and aero-medical transportation physiology

Henry's law states that the mass of gas absorbed by a liquid is directly proportional to the partial pressure of the gas above the liquid.³¹ Henry's law has specific relevance

in the patient group with dive related diseases such as decompression illness that must be transported by air.⁴³

In diving, as pressure decreases during a rapid ascent from depth it causes the gas, such as dissolved nitrogen, to come out of solution forming bubbles within the bloodstream, resulting in decompression illness or dysbarism with potentially catastrophic consequences.^{31,34,43} Altitude exposure intensifies diving-related decompression illness and increases the risk of arterial gas embolism.^{4,43} Patients with decompression illness can deteriorate rapidly with an increase in altitude of as little as 200 ft. above sea level.^{4,43} The use of sea level cabin pressure has become the mainstay of long distance AMT of patient's with dysbarism.^{34,43} In the aviation environment, sudden decompression of an aircraft at high altitude may similarly result in decompression illness in its occupants.³¹

Other stressors of aero-medical transportation

Additional stresses of flight include decreased humidity and dehydration, noise, vibration, disorientation, motion sickness, fatigue, effects of gravitational forces (G-forces), psychological fear, special limitations and radiation.^{18,19,29-31,34,41,43,47}

Humidity and dehydration

Humidity is of particular concern in fixed-wing operations because cabin air is taken from the ambient outside atmosphere and when warmed it may contain very little humidity.³³ Decreased humidity causes respiratory secretions to dry up which may

result in discomfort, atelectasis or blockage of tracheal tubes.^{33,41} Eye protection should be considered for the unconscious patient.³⁴

Noise and vibration

Cabin noise, especially in small aircraft, interferes with the medical flight crew's ability to assess and monitor the patient and masks the sound of air escaping from tubes or faulty ventilators.^{29,41} Noise also adversely affects the usefulness of a stethoscope and hinders communications within the cabin between medical crew and the patient.^{4,34} Modern aircraft still produce a substantial amount of noise.³³ The cabins of most aircrafts are quiet enough for conversation and patient evaluation but cabins of helicopters are so loud as to preclude auscultation of the lung sounds.³³

Vibration is a repeating and alternating form of motion.³³ The two major sources of vibration during AMT are from the aircraft power plant and turbulence from the air in which the aircraft is travelling.³³ Vibrations are transmitted to medical equipment in flight and may be a source of monitoring errors and malfunction.³³ During turbulence, a patient transported by means of a stretcher should be fastened to the stretcher and the stretcher fastened to the aircraft to prevent complications or injury.²⁹

Long-term exposure to noise and vibration may result in stress, fatigue, nausea, visual or vestibular disturbances, ear damage and deterioration in task performance.^{31,34} Hearing protection should be worn during aircraft operations by the patient and flight crew, which further affects communication and monitoring capability.^{31,34}

Gravitational forces

Occupants of an aircraft experience a change in velocity as the aircraft accelerates or decelerates.³³ A gravitational force (G-force), such as acceleration or deceleration, is a vector quantity with both magnitude and direction and is another form of a flight stressor.³³ Gibbons *et al.* write that short term forces of turbulence or manoeuvring will usually not constitute a problem for the properly restrained patient but special thought should be given to patients on weight traction.³⁰ Ehlers *et al.* and Joshi *et al.* however indicate that patients in the supine position experience intra-corporeal volume shifts (such as venous blood pooling or shifting of blood volume toward the lower extremities or head) during take-off or landing due to the effect of G-forces and this may have pathological consequences.^{41,46} Patients with labile haemodynamics or impaired autonomic function may have a resultant reduction in thoracic blood volume leading to lower cardiac output, which may cause pathological consequences for the patient, especially those with pre-existing cardiac conditions.^{41,46} A patient with a head injury could develop raised intracranial tension due to the effect of G-forces.⁴¹ For these reasons, patient positioning requires careful consideration.^{33,41} Healthy individuals will be able to mount a compensatory sympathetic response and avoid the pathological consequences.⁴¹

Limitations in space

Le Cong *et al.* comment that the AMT environment is all too often a restrictive and claustrophobic experience for many patients, which can lead to significant psychological stress.⁴³

Psychosocial stressors

AMT is a psychological stressful experience for many patients, since they are moved out of their familiar environment and away from family and friends.⁴³ Le Cong *et al.* state that the fear of flying is well reported in the literature and that it may be a cause of unexpected agitation.⁴³ Essebag *et al.* report that Demmons and Cook monitored anxiety levels of patients during AMT and found that anxiety was greatest in anticipation of the flight.³² Patients with little or no experience with flying were most nervous and anxiety levels decreased steadily during the flights.³² Most patients were, however, more anxious about their medical condition than the flight itself.³² Sometimes, a simple explanation and reassurance is sufficient, with appropriate education about the purpose of the AMT, the medical benefits of the transport and an adequate cabin safety briefing.⁴³

Radiation

Radiation exposure is known to increase with air travel.⁴⁷ Cosmic ionizing radiation, also known as cosmic radiation, is a form of ionizing radiation coming from outer space with a very small amount of this radiation reaching the earth.⁵² In general, the higher the latitude or the flight level, the greater the exposure.⁴⁷ At flight altitudes, passengers and crew members are exposed to higher levels of cosmic radiation than those at sea level.⁵² Radiation stress refers to the radiation dose and is usually 0.005 to 0.01 millisievert (mSv) per hour and the cumulative dose is negligible when compared to the annual maximum permissible dose of 1 mSv for pregnant flight crew in the United States of America (USA).⁴⁷ The pregnant air traveller would therefore

have to complete around 100 to 200 hours of flying to approach the permissible safe dose.⁴⁷

Regarding the stressors discussed above, the majority of healthy individuals can readily compensate for these stressors.¹⁹ A sick and injured patient is however at risk, depending upon the nature and severity of the medical condition.¹⁹

1.2.5. Safety of aero-medical transportation

The safety of AMT depends on both the aviation and medical aspects.³²

Medical safety considerations

The medical safety aspects of AMT relate to the patient's current illness or injury, the potential for exacerbation of the medical condition by physiologic or physical factors related to AMT, duration of travel, aero-medical stressors, the available medical technology and the qualification and experience of the available medical flight crew.³²

Blumen *et al.*, Warren *et al.* and Everest *et al.* refer to various studies that support that the transportation of the critically ill or injured patient is not without risks to the patient.^{17,20,44} Additionally, the legitimate concerns about flight stressors such as hypoxemia and gas trapping with altitude have remained a concern since the advent of AMT.³⁷ However, Varon *et al.* state that it is known that AMT can be accomplished with minimal risk.³³ Duchateau *et al.* agree that if a patient can be treated and/or stabilized prior to transportation, the risks associated with transport are lessened.¹

Technological support within the AMT environment has improved tremendously with advances in technology.³² Most intensive care facilities can now be packaged into the confines of an aircraft to almost replicate the critical care environment found in a hospital.^{17,32} Today, point of care technology allows analysis of blood gases and electrolytes during flight, and all forms of intravenous medications are at the disposal of the medical flight crew, allowing for a great deal of flexibility.³²

McGinnis *et al.* support that tertiary facility type critical care capabilities can be delivered to an injured or ill patient during transportation in addition to the unique ability of an aircraft to provide a rapid form of transportation.²² In 2006, the American College of Emergency Physicians (ACEP) and the National Association of Emergency Medical Services Physicians (NAEMSP) published that fixed-wing AMT are overall less desirable as a transport mode for severely ill or injured patients but extenuating circumstances may modify this relative contraindication to fixed-wing use.³⁵ Joshi *et al.* state that AMT with on-board intensive medical care monitoring and medical care is the preferred method of transportation of the critically ill.⁴¹ Dewhurst *et al.* refer to previous studies that indicated that high-risk AMT is safe, provided that appropriately trained personnel are used and Intensive Medical Care Units (ICU) facilities are available within the aircraft.¹¹

If patients with an acute myocardial infarction are to benefit from emergency thrombolytic therapy, angioplasty, and other interventions, they may require emergency transfer within hours.³³ Blumen *et al.* reference a concern regarding the transportation of cardiac patients because increasing altitude causes an increase in

heart rate and myocardial oxygen demand.¹⁷ Blumen *et al.* state that studies of patients with acute myocardial infarction and unstable angina revealed that complications such as hypotension, cardiac arrhythmias, and exacerbation of chest pain occurred during transportation of patients and that complications were more frequent when the patient was moved by AMT than compared to those moved by ground ambulance.¹⁷ Varon *et al.* state that AMT provides a safe means of transport for cardiac patients and should be considered for patients who require transfer to more specialized centres for additional diagnostic and therapeutic interventions.³⁷ Blumen *et al.* support this by also indicating that major in-flight events are uncommon in the cardiac population.¹⁷ Teichman *et al.* highlight that despite the high morbidity and mortality inherent in acute coronary syndromes, even patients with substantial acute coronary obstruction usually tolerate movement by AMT well.⁴

For a combination of medical, social, and economic reasons, cardiac patients with increasing acuity of illness are being transported over distances spanning the globe.³² In many communities, emergency AMT systems have become an integral part of the practice of cardiology and critical care medicine.³⁷ Daly *et al.* show in a mixed medical and trauma critical care population that 1.1% require electrical intervention during transportation.¹⁰ In their study, 6 patients (0.6%) required transcutaneous pacing.¹⁰ Their conclusion is that there is a small but significant incidence of electrical intervention required during aero-medical flight for critically ill patients.¹⁰ Essebag *et al.* refer to a helicopter based study by Vukov and Johnson where 7.8% of patients with acute myocardial infarction required either intravenous or external pacing during aeromedical transportation.³² Singh *et al.* indicate that 3.5% of their patients had hemodynamic instability, defined as those with a systolic blood

pressure of less than 80mmHg or a mean arterial pressure less than 60mmHg or required administration of vasopressors.¹⁴ Daly *et al.* comment that data from the USA suggest that the rate of cardiac arrest around the time of aeromedical transportation is 3.4 - 5.0%, with a requirement for defibrillation in around 0.8% of all aeromedical transportation missions.¹⁰

Various other medical conditions can be safely transported, for example, Teichman *et al.* indicate that patients with severe pulmonary disease have been safely flown for long distances at altitudes at which commercial aircraft are typically flown.⁴ Akl *et al.* mention that AMT of high-risk obstetric patients can be accomplished safely and in a timely manner, even in patients with advanced cervical dilatation.⁵³

Aviation safety considerations

AMT aircraft crashes are infrequent but well publicized.³⁵ AMT programs allocate both time and money in a continuing effort to maximize safety.³⁵ Teichman *et al.* indicate in an article in 2007 that statistics from the Flight Safety Foundation reveal an average accident rate of fewer than two per year for international fixed-wing AMT flights during the past decade.⁴

Joshi *et al.* state that there are no absolute contraindications to AMT.⁴¹ Smith writes that the practice of AMT is recognized as a vital component in the continuum of patient care.²³ The overall aim of AMT is to transfer the patient safely from point of origin to destination, without further deterioration in his or her condition.¹⁹ Tursch *et al.* mention that precise anticipation and stratification of transport-related illness

severity in the planning stage of AMT is crucial for mission success and patient safety.¹⁶ By using qualified and experienced medical crew with the appropriate equipment and with sufficient planning, adverse events can be reduced with little or no compromise to the patient's medical condition.^{4,11,17,18,20,21,44} AMT can transport patients safely and rapidly over long distances.²⁹

1.2.6. Reasons for aero-medical transportation

According to the World Health Organization (WHO), injuries are among the leading causes of death and disability in the world, with injuries being the leading cause of preventable death in travellers.⁵⁴ Road traffic crashes are common among travellers in foreign countries.⁵⁴ Vehicle related injuries are the leading cause of death in children who travel, with drowning the second leading cause of death in young travellers.⁸ More than 90% of people killed annually and 96% of child injury-related deaths due to road traffic related injuries occur in low and middle-income countries.⁵⁴ In many low and middle-income countries, unsafe roads, unsafe vehicles and an inadequate transportation infrastructure all contribute to the traffic injury problem.⁵⁴

The World Bank defines a country as a low, middle or high-income country according to its gross national income (GNI) per capita in United States dollars (\$) on an annual basis.⁵⁵ Low-income countries are those with a GNI per capita of \$1,045 or less in 2016 (e.g. Burkina Faso, Guinea-Bissau, Madagascar, Malawi, Sierra Leone, Uganda, Zimbabwe), middle-income countries are those with a GNI per capita of more than \$1,045 but less than \$12,736 (e.g. Angola, Botswana, Gabon, Ghana, Mauritius, Namibia, Swaziland, Zambia) and high-income countries are those with a

GNI per capita of \$12,736 or more (e.g. Australia, Japan, Sweden, the United Kingdom, the United States of America).⁵⁵

The decision whether or not to deploy AMT in medical emergencies is complex and determined by many factors, such as the circumstances of injury or illness, clinical condition of the patient, accessibility of locations by road, clinical resources at scene or in the area, proximity and resources of local medical facilities.³⁸ When everything is taken into consideration, McGinnis *et al.* advise that AMT provides beneficial rapid transport of patients with conditions requiring time-dependent definitive care.²² Wallace *et al.*, however, highlight that one must not focus only on the apparent speed of transport via air but to balance this against the organisational delays and time of transfer between aircraft and ground ambulance before and after air transportation, where applicable.¹⁸

Multiple authors, Blumen *et al.*, Warren *et al.*, Lamond, Teichman *et al.* and Duchateau *et al.*, are in agreement that inter-facility transportation occur mainly when the referring hospital lacks sufficient resources to meet the patient's medical needs, be it equipment, infrastructure, personnel or expertise.^{1,4,17,20,21} The patient's needs may be a requirement for further diagnostic, therapeutic, specialized care, critical care facilities or timely treatment that is not available at the referring hospital or even within the area.^{17,24,25,44} Teichman *et al.* additionally comment that inter-facility transportation may be required due to the non-adherence of a facility to universal precautions, poor general hygiene or to critical drugs being substandard, counterfeited or unavailable due to supply disruptions, government regulations or practice standards.⁴ Duchateau *et al.* highlight that another factor may be the

availability of paediatric care facilities as few paediatric care facilities are available in developing countries or they offer care that falls below first world standards.¹

Lamond and Blumen *et al.* mention that other contributing factors to interfacility patient movements are for continuity of care, related patient or family preference or the insurance plan or paymaster requirements.^{17,21} Blumen *et al.* and Dewhurst *et al.* share the opinion that appropriateness of lateral transfers between hospitals with similar capabilities is controversial in that it may expose the patient to risk and transportation stressors at an additional cost, frequently without convincing evidence of cost, resource or clinical benefits.^{11,17} Essebag *et al.* however state that returning patients to their own country of nationality or residence for treatment in their own language near their family and support system is very beneficial.³² For patients with travel insurance, if the anticipated cost of hospitalization exceeds the cost of AMT, insurance companies may prefer, mainly for commercial reasons, to transport patients back to their home countries and to their local health-care systems as soon as possible.³² In the study of Peytremann *et al.* it is mentioned that national employees were only transported if their lives were in danger.¹³

There is no consensus regarding the diseases requiring transportation. Teichman *et al.* indicate that the most common conditions requiring international medical transportation include neurologic and orthopaedic consequences of road trauma, acute coronary syndromes, infections unresponsive to available therapies, and pregnancy-related complications.⁴ Caldow *et al.* include trauma, seizures, ruptured oesophagus, meningitis and overdose patients.³⁹ According to Dewhurst *et al.*, the four leading diagnostic categories are trauma (35%), neurological (18%),

cardiovascular (18%) and respiratory (10%).¹¹ Duchateau *et al.* also find that the most common diagnostic categories are trauma (40%), cardiac disease (17%), neurological disorders (14%) and respiratory diseases (8%).¹ Peiris *et al.* indicate that 4 diagnostic categories accounting for 61% of transportations are respiratory disease (21%), obstetric conditions (15%), gastroenteritis (14%) and injury or poisoning (11%).¹² Mental health conditions contributes to 3.4% of the transportations.¹² Peytremann *et al.* indicate major causes for medical transportations as infectious diseases (17%), accidents (15%) and obstetric-gynaecological conditions (15%).¹³ Six of the infectious diseases are due to malaria and contributes to 4% of the total medical transportations, illustrating the importance of reinforcing preventive measures such as malaria prophylaxis.¹³ Psychiatric conditions represents 1.9% of transportations.¹³

Sand *et al.* indicate that the top diagnostic categories are trauma surgery (33%), internal medicine (24%) and neurology (15%).⁷ Psychiatric conditions attributes to 1.6% of medical transportations in their study.⁷ Singh *et al.* disease categories include cardiovascular (33%), neurological (14%), trauma (10%), surgical (10%), respiratory disease (7%), obstetric (7%) and other medical diseases (19%).¹⁴ Suriyachaisawat and Surakam shows that the top diagnostic categories in their study are cardiology (19%), neurology (18%), trauma surgery (14%), orthopaedic (11%) and cancer (9%).¹⁵ Accident and trauma constitutes 33% of all cases.¹⁵ Psychiatric conditions contributes to 1% of all transportations in their study.¹⁵ Tursch *et al.* indicate that the diagnostic groups are medical (31%), trauma related surgical (30%), cerebral haemorrhage (10%), ischemic stroke (8%), general surgical (6%), malignancy (4%), paediatric (4%), obstetric (1%) and other (7%).¹⁶

Duchateau *et al.* express that medical incidents occurring in sub-Saharan Africa demand extreme caution.¹ This is because sanitary conditions in many areas of sub-Saharan Africa are poor and travelling to this area is associated with increased health risks, including life-threatening diseases such as malaria.¹ Travellers from developed countries are also exposed to a wide range of specific infectious diseases and other health hazards in sub-Saharan Africa to which they are otherwise not generally exposed.¹

Since medical transportations are undertaken for various practical, clinical, financial and sometimes social reasons, as previously mentioned, it is done from and within almost any country, as Dutcheau *et al.* illustrate in their study with 6% of their studied transportations in America, 8% in Europe, 6% in Asia, 43% sub-Saharan Africa and 37% in North Africa.¹ Suriyachaisawat and Surakam finds in their study that most urgent medical transportations are from Thailand and Indochina countries such as Myanmar and Cambodia.¹⁵ Druckman *et al.* mention more than 200 countries in their study over 2 years, with medical transportation required from countries of all continents, involving countries such as Angola (4.5%), Nigeria (4.1%), Democratic Republic of the Congo (1.4%), Madagascar (1.4%), Equatorial Guinea (1.1%), Ghana (1.1%) and Mozambique (0.9%).⁶ Dewhurst *et al.* indicate 79% of the transportations are repatriations from countries within the European Union.¹¹ Sand *et al.* indicate 68% involving Europe, 17% Africa, 12% Middle East and 12% Turkey, amongst others.⁷

The ACEP and NAEMSP indicate that clinical situations for AMT in inter-facility transfers are best summarized as being present when: 1) patients have diagnostic and/or therapeutic needs which cannot be met at the referring hospital and 2) factors such as time, distance, and/or intra-transport level of care requirements which may render ground transport non feasible.³⁵

1.2.7. Demographics of patients requiring aero-medical transportation

The requirement for medical transportation can affect any age, as shown in a study of Sand *et al.* involving patients from 42 days of age to 96 years (median 66 years).⁷ Approximately 95% being adult (18 years of age or older) and 1% being 12 months old or younger.⁷ Dewhurst *et al.* indicate ages ranging from 1.5 to 90 years (mean 53 years).¹¹ Duchateau *et al.* have a median age of 47 years and Peiris *et al.* of 18.3 years, with children under the age of five years constituting 37.7% of those requiring transportation.^{1,12} Peytremann *et al.* show ages ranging from 25 years to 62 years (average 40.4 years).¹³ Singh *et al.* show a median age of 53 years but their study excluded patients younger than 18 years old.¹⁴ Suriyachaisawat and Surakam study's ages range from 1 day to 105 years (median 54 years).¹⁵ Tursch *et al.* ranges from 43 days to 95 years of age (median 65 years).¹⁶

Gender distribution of those requiring medical transportation differs within the literature: Chen *et al.* show 72% are male and 28% female, with a male to female ratio of 1:0.4.¹⁹ Dewhurst *et al.* show a male to female ratio of 1:0.75.¹¹ Peiris *et al.* gender representation is roughly equal.¹² Peytremann *et al.* show 58% are male and

42% female and Tursch *et al.* indicate 57% male and 43% females, both with a male to female ratio of 1:0.7.^{13,16} Sand *et al.* and Singh *et al.* both indicate 54% male and 46% females, with a male to female ratio of 1:0.85.^{7,14} Suriyachaisawat and Surakam show 66.5% are male and 33.5% female, with a male to female ratio of 1:0.5.¹⁵

Suriyachaisawat and Surakam show that the top 5 nationalities of patients requiring medical transportation at Bangkok Hospital are Thai (30.8%), Myanmar (9.6%), British (6.3%), German (6.0%) and Cambodian (5.3%).¹⁵ Australians represented 2.6% and nationalities from Africa 0.3%.¹⁵ Peytremann *et al.* have 64 nationalities with those from Africa representing 42% and Europe 28%.¹³ Expatriates from Europe, United States and Japan represented 36% of the medical transportations and 25% were national employees.¹³

1.2.8. Air ambulance versus scheduled commercial flight

There are various types of AMT programs such as hospital based programs (which mostly involve rotor-wing); non-hospital based (e.g. a consortium of hospitals or an independent corporation); Public Safety, Police, or State Services; and military resources.^{31,34} AMT can be arranged via scheduled commercial airline or medically configured aircrafts.³⁴

For long-distance transport that is elective, for example for economic and/or social reasons or where the patient is in a stable condition, transportation may be possible with a medical escort aboard a scheduled commercial aircraft.^{21,32} The medical

departments of commercial airlines place restrictions on patients travelling by air.⁵ In general, the patients should be mobile, able to look after themselves, should not be at risk of causing a flight diversion, should in no way be objectionable to the ordinary traveller or pose a risk to other passengers or to the aircraft.^{4,5} These restrictions are usually waived to a certain degree when medical flight crew accompany the patient in order to attend to their needs.⁵ Airline officials must be notified of the intention to medically accompany a patient and a full medical report has to be submitted in advance.⁵

Generally, an air ambulance is specifically designed to accommodate the aero-medical needs of people who are ill or injured or otherwise mentally or physically incapacitated, who may require emergency medical care in-flight, and who, in a doctor's opinion, cannot be safely transported on a standard scheduled commercial airline or flight.¹⁹ Elective long-distance transport of patients in less stable condition (e.g. early post-myocardial infarction, receiving mechanical ventilation, or receiving intravenous vasopressors or antiarrhythmic agents) and emergency long-distance transport is performed using fixed-wing air ambulance.³²

A benefit of air ambulance transportation, compared to commercial flight, is that patients can be collected at small airports that are often closer to the hospital of origin rather than larger airports accessible to scheduled commercial aircrafts.⁷ However, in cases of long-distance flights, air ambulance refuelling stops can be more frequent compared to scheduled commercial aircraft because air ambulance aircrafts generally have a shorter range.⁷ For potentially lethal communicable diseases for which no effective treatment is known, such as viral haemorrhagic fevers, an air

ambulance with an aircraft transit isolator can be used to transport a patient to a maximum biologic containment facility.⁴ Transport isolators are further discussed under patient preparation for transportation.

The air ambulance provider (AAP) studied in this study has an aircraft transit isolator and serves mainly sub-Saharan Africa and surrounding islands.

1.2.9. Patient preparation for transportation

As previously mentioned, the transportation of patients may be associated with risk and complications and these may range in severity from minor (e.g. removal of an intravenous line) to potentially life threatening (e.g. misplacement of an endotracheal tube).³² Meticulous preparation and packaging of a patient prior to transportation is essential to minimize the risk of transport-related complications.³²

In any AMT transport, there are usually two phases: the stabilization phase in which the patient is prepared for the flight, and the actual flight transport phase.²⁹ The space limiting design of aircrafts make the provision of care at ICU level challenging, so it is mandatory that all interventions and monitoring procedures (e.g. obtaining and securing intravenous access) that may be needed during the transportation should be performed before the flight within the departure hospital environment.⁴

Additionally, the patients should be evaluated with regards to the effects of pressure and other aviation stressors mentioned previously.³³

Patients with circular limb casts for fractures should have it split down to skin level before a flight if the underlying soft tissue is still oedematous, which is commonly the case in the first 7 to 14 days after surgery or injury.²⁹ Fixed traction rather than weight traction should be used during AMT.²⁹ Addressing the comfort of patients and alleviating anxiety are important components of care.⁴

Patient isolation units, otherwise known as transport isolators, may be used to isolate a patient within a sealed container under negative air pressure maintained by a high efficiency particulate air (HEPA) filtered ventilation system, where needed.^{56,57}

Transport isolators are the only available technical means of reliably maintaining airborne isolation during transportation.⁵⁶ The transport isolator's construction is light and durable and has working ports through which the medical crew can monitor patients and perform procedures.⁵⁷

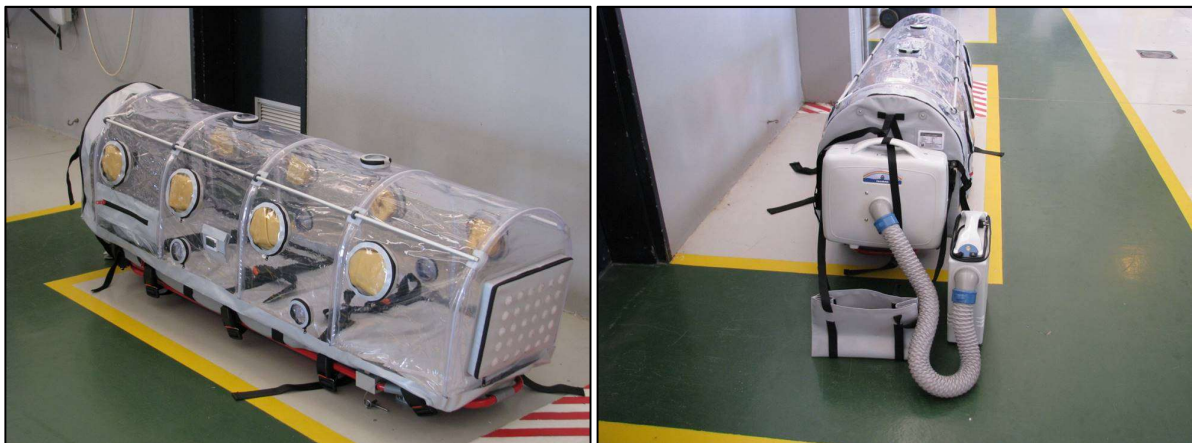


Figure 1.1: Transport Isolator.

IsoArk N 36-4. N.d. Photograph. Air Rescue Africa Photographic Library, Midrand.

Transport isolators can be used to safely transport patients with potentially lethal communicable diseases for which no effective vaccines, chemoprophylaxis, or specific therapies exist.^{4,56} These would include patients with an unknown disease

pending identification of the pathogen, patients with viral haemorrhagic fevers, and those suspected of being affected by a biological attack.⁵⁶ Transport isolators have been successfully used for AMT of patients with suspected Ebola fever, suspected and proven Lassa fever and patients with suspected severe acute respiratory syndrome (SARS) during the SARS outbreak in Asia.^{56,57}

After ground transport to the aircraft, the patient is transferred to the aircraft cabin while limiting any sudden pitching or movement of the stretcher.^{34,58} All transported patients should be adequately secured to the stretcher with safety straps to prevent sudden shifting of position during loading and flight.³⁴ There is a wide range of equipment developed and marketed to assist with loading and unloading of stretcher patients through narrow fixed-wing doors, such as stands, lifts, slides and sleds.⁵⁸ These devices significantly ease the loading procedure and assist with preventing excessive movement and potential injury to the patient or crew during loading and unloading of the patient.⁵⁸ The medical equipment and stretcher in turn should be adequately secured to the aircraft.³⁴

1.2.10. Crew requirements for aero-medical transportation

A variety of medical flight crew attend to patients during AMT.³³ There are no international standards regarding the qualifications of the medical flight crew.⁴ The medical flight crew configuration depends on each flight program and is based on the individual needs perception and available resources.⁵⁹ The minority of transport teams include doctors.³³ Bjoernsen states that whether flight doctors are required in flight during AMT remains an unresolved issue.⁵⁹ Varon *et al.* question whether the

presence of a flight doctor during flight improves patient outcome and this remains controversial.³³

Bjoernsen mentions that a Medline search frequently revealed poorly designed studies and a limited number of objective studies regarding the requirement of a flight doctor during AMT, but that a doctor's judgement and skills were needed in 25% of AMT missions.⁵⁹ He states that the flight doctor is an important but small part of air medical services.⁵⁹ Essebag *et al.* comment that the medical flight crew should include an intensive care trained flight doctor, nurse and/or paramedic.³² Mehra feels that the quality of medical care should not fall below that which could be available on the ground in an ICU.¹⁹ Warren *et al.* indicate that it is strongly recommended that a flight doctor with training in airway management, advanced cardiac life support, critical care training or equivalent, accompany critically ill patients.²⁰ Warren *et al.* further add that a minimum of two people should accompany a critically ill patient.²⁰

In summary, the needs of patients during AMT missions differ, and the medical flight crew should be selected according to the particular patient's medical needs.³³ The skills of the medical flight crew should include the ability to care for the patient's current condition and any reasonable foreseeable complications that could arise during transport.^{14,17,24,44} The choice of the medical crew configuration should not be based on economics or convenience.²⁹ Bjoernsen concluded that effective medical flight crew, irrespective of the configuration, are those with adequate training and on-going flight experience.⁵⁹

Crew configuration, equipment, medication and training requirements or other arguments within the field of AMT are not further elaborated on or discussed, as they do not relate to the purposes of this study. The AAP studied, has a minimum crew configuration of a flight doctor and a registered nurse or advanced life support paramedic.

As mentioned before, each contemplated patient movement requires an evaluation of the risks and benefits of the transport.^{17,20,34} When the appropriate benefit of the transfer exceeds the risks, this becomes key to preserving function and saving lives.^{4,17,20} Warren *et al.*, Lamond and Blumen *et al.* agree that the objective of moving a patient requiring critical medical care is to provide a higher degree of monitoring and medical care than the patient was receiving prior to transport as well as minimizing the risks.^{17,20,21}

The aim of this study is to analyse and describe the demographical data and disease profile of the patients transported internationally by an air ambulance provider over a one-year period within sub-Saharan Africa.

CHAPTER 2: METHODOLOGY

2.1. Aim and objectives

2.1.1. Aim

The aim of this study was to analyse and describe the demographical data and disease profile of patients transported internationally by an air ambulance provider (AAP) over a one-year period.

2.1.2. Objectives

- To describe the demographical data of the patient population transported by an AAP over a one-year period
- To describe the disease profile of the patient population studied
- To determine the percentage of the patient population receiving oxygen during transportation
- To determine the percentage of patients requiring endotracheal intubation and invasive positive pressure ventilation (IPPV) during transportation
- To determine the percentage of patient population receiving non-invasive positive pressure ventilation (NIPPV) during transportation
- To determine the percentage of the patient population receiving inotrope and/or vasodilator therapy during transportation
- To determine the percentage of patient population requiring transcutaneous or intravenous cardiac pacing during transportation

2.2. Design

The study was a quantitative, descriptive and retrospective study.

2.3. Patient population

All international patient transportations performed by a fixed-wing AAP over one year, from 1 November 2010 to 31 October 2011, were assessed. The AAP studied is an example of a non-military air ambulance using modern air platforms and sophisticated environmental control systems such as temperature and cabin pressurisation controls. The required clinical and demographic data for each patient transported was captured during transport on a document called a patient report form (PRF). All the PRFs for the air ambulance missions completed by this provider, where the actual time of departure from Johannesburg, South Africa, was after midnight 31 October 2010 and before midnight 31 October 2011, were included in the review.

Any missions where the medical flight crew were able to perform an initial assessment before patient transportation were included, irrespective of the initial location, nationality, age, or medical condition. Patients who died during any stage of the patient transportation but who had undergone an initial assessment and/or resuscitation performed by the AAP medical flight crew were included.

Aero-medical transportation missions flown on scheduled commercial airlines, any aero-medical transportation missions by the AAP where the patient was transported to countries other than South Africa and all local aero-medical transportation missions within the borders of South Africa by the AAP were excluded.

2.4. Permission

Written permission to access the information in the PRF's and the data management system within the Intl. SOS Johannesburg AC was obtained from the Medical Director Air Ambulance, overseeing the AAP, Dr. Steven E. Lunt. (Appendix 1)

2.5. Ethical approval

Ethical approval to conduct the study was obtained from the Human Research Ethics Committee (Medical) at the University of the Witwatersrand, Johannesburg. The research proposal was submitted and approved without any alterations. (Appendix 2)

2.6. Measurements

Once a PRF met the inclusion criteria, the case reference number for that particular mission according to the AC's data management system and the date the mission was performed was written on the correspondence sheet (Appendix 3) numbered from 1 to 350. The reference number of the first PRF, meeting the inclusion criteria,

and the date the respective mission was performed was written across number “1” on the correspondence sheet. The number on the correspondence sheet, number “1”, was then written on a datasheet (Appendix 4). The datasheet was then further completed according to the information available on the PRF. Thus, the number “1” was written on the first datasheet completed according to the information available on the first PRF listed as number “1” on the correspondence sheet. This was done in order to maintain confidentiality but enable the researcher to be able to reference the relevant PRF or case in the data management system, should further information or confirmation be required at a later stage.

Completion of the datasheet was according to the data available to the medical flight crew during their initial assessment and the interventions required according to the clinical condition of the patient and judgement of the medical flight crew during their initial assessment. Travel time from South Africa to the patient’s location could have contributed to the patient’s medical condition changing and therefore the data for this study was based on the medical flight crew’s initial assessment of the patient and not the information initially obtained by the AC and provided to the medical flight crew during their briefing for the mission.

Once the first datasheet was completed, the next PRF was reviewed according to the study inclusion criteria. If it met the inclusion criteria, the relevant reference number and the date the mission was performed were written on the correspondence sheet across number “2”. The next datasheet was taken, marked with a number “2” and completed with the information available on the PRF. The third applicable PRF’s reference number and date were written across number “3” on the correspondence

sheet, and so forth. This process was repeated until all the PRF's from all the transportation missions performed by the AAP from 1 November 2010 to 31 October 2011 were reviewed.

If any data variable listed on the datasheet was not available on the PRF or attached to the PRF, the relevant case was searched within the secure data management system within the Intl. SOS Johannesburg AC according to the case reference number on the correspondence sheet. If the data was available within this system, it was included onto the relevant datasheet. Any data not obtained from either the PRF or the case data management system was considered not to have been obtained during the mission or not available and then indicated as such.

2.7. Variables

The variables obtained were the patient's age, gender, nationality, country transported from, diagnosis and whether or not the patient received any of the following: oxygen, positive pressure ventilation (PPV), inotrope and/or vasodilator therapy or any form of cardiac pacing. If a patient required PPV, a distinction was made between whether it was invasive or non-invasive PPV. Inotrope and/or vasodilator therapy included any inotropic, chronotropic and/or vasopressor medication such as Dopamine, Dobutamine, Adrenalin or Noradrenalin. It also included vasodilatory medication such as Nitroglycerine. It did not include chronic oral anti-hypertensive medication or other medication with a vasodilatory effect but used primarily for another purpose, such as morphine used for analgesia.

2.8. Defining criteria and terminology

It was not always possible to have a confirmed diagnosis, mainly due to a lack of reliable diagnostic capability at the patient's location prior to patient transportation or this being unavailable to the medical flight crew. Where it was difficult to identify the most likely diagnosis in light of these limitations, the working diagnosis based on the medical flight crew's assessment and opinion was documented as the diagnosis on the applicable datasheet. For example, if a patient's main complaint was chest pain with a differential diagnosis of unstable angina, gastritis, oesophageal spasms or Tietze syndrome; but the working diagnosis of the medical flight crew was unstable angina, then unstable angina was the documented diagnosis on the datasheet for that particular PRF.

The diagnoses were then categorized within the following categories: allergic reaction, cardiological, congenital abnormality, gastro-intestinal, haematological, infective, malaria, nephrology, neurological, neurosurgical, obstetrics and gynaecology (O+G), orthopaedic, psychiatric, respiratory, surgical, trauma, urological and vascular surgery. For example, myocardial infarction or unstable angina was categorized as cardiological, bowel obstruction as surgical, severe gastro-enteritis with dehydration as gastro-intestinal, oesophageal spasm or gastritis as gastro-intestinal, idiopathic thrombocytopenic purpura as haematological, renal calculi as urological, dissecting abdominal aortic aneurysm as vascular surgery, meningitis as neurological, septic arthritis as orthopaedic, renal failure as nephrology, sepsis with multi-organ failure as infective, prune belly syndrome as congenital abnormality, etc. Where the diagnosis was due to underlying infection, it was rather categorized into

the system affected category than under infective. Only where the primary system affected or the source of infection could not be clearly identified, was it categorized as infective.

Cardiological included the conditions such as atrial myxoma, arrhythmias, acute coronary syndromes, congenital cardiac diseases, angina, chest pain, cardiomyopathy and congestive cardiac failure. Gastro-intestinal included gastroenteritis, hepato-renal syndrome, liver disease and hernias. Haematological included Idiopathic thrombocytopenic purpura (ITP) and anaemia. Infective included sepsis with multiple organ failure and two patients where viral haemorrhagic fever could not be excluded prior to the mission. Nephrology included renal failure and patients on dialysis. Neurological included meningitis, seizures, status epilepticus, transient ischaemic attack (TIA), stroke, blurred vision of unknown etiology, acute confusional state without convincing evidence of psychiatric disease, vertigo, encephalitis, febrile seizures, apnoea attacks and Guillain-Barré syndrome. Neurosurgical included intracranial haemorrhage, lumbago, cauda equina syndrome, intervertebral disc prolapse and cervical stenosis. Obstetrics and gynaecology included post caesarean wound sepsis, pre-eclampsia, threatening miscarriage, uterine malignancy, threatening preterm labour, premature rupture of membranes, pelvic abscess, hyperemesis gravidarum, ovarian torsion and haemolysis, elevated liver enzymes and low platelet count (HELLP) syndrome. Orthopaedic category included septic arthritis and malunion of femur fracture. Psychiatric included acute psychosis and bipolar mood disorder. Respiratory included lung mass, lower respiratory tract infection, chronic obstructive pulmonary disease, altitude sickness and spontaneous pneumothorax. Surgical included appendicitis, bowel obstruction,

cholecystitis, intestinal atresia, diabetic foot, snake bite, gastrointestinal bleeding and cellulitis. Trauma included all traumatic injuries and burns. Vascular surgery included abdominal aorta aneurysm and arterial thrombo-embolism.

A neonate was any patient less than 29 days old. A child was any patient less than 18 years old and an adult any patient 18 years old or older. Nationality was documented as the country of nationality as indicated on the patient's passport. In the event where a patient was transported by another aero-medical provider from a location, with a wing-to-wing transfer of the patient between providers to the AAP reviewed in this study, the patient's initial location country before any aero-medical transportation took place was documented as the country transported from. For example, if another AAP was used to extract the patient out of Somalia with a wing-to-wing transfer in Nairobi, Kenya, to the AAP reviewed, then it was documented that the patient was transported from Somalia and not Kenya. This was indicated as the country of origin of transportation.

If a patient received oxygen due to a clinical indication, it was documented that the patient received oxygen irrespective of whether the oxygen was provided by means of nasal cannula or mask or other means and irrespective of the flow rate. Patients receiving mechanical ventilation where there was no clinical indication to receive oxygen as far as could be determined but the ventilator's lowest setting for oxygen was at a fraction of inspired oxygen (FiO_2) of 0.4, it was documented that the patient received oxygen. All the patients breathing room air or where the relevant PRFs indicated that the FiO_2 was 0.21, it was documented that the patient did not receive oxygen.

2.9. Data analysis

All the information on the datasheets was inserted onto a Microsoft Office Excel™ spreadsheet. This information included paediatric patients and their ages were converted to age in years, where applicable, to standardize the information. For example, if the patient was 6 months old, it was indicated as 0.5 years of age, etc. The conversion from days or months to years was done by means of formulas within Microsoft Office Excel™.

Statistical processing and analysis was done by the researcher with the assistance of statisticians at the University of the Witwatersrand and a statistician from the Centre for Statistical Analysis and Research (CESAR), using functions and calculations within Microsoft Office Excel™, GraphPad InStat 3™, and STATA™.

The data analysis was performed according to the variable qualities. Age is a quantitative and continuous variable and was depicted by means of bar graphs to determine central tendency and spread of variation. The mean or median, depending on the distribution, the range and interquartile range (IQR) or standard deviations was determined and indicated. Age was further analysed according to ordinal categories by means of numbers and percentages and further in relation to gender by means of ratio, numbers, percentages and ranges.

Gender was depicted by means of a pie chart, numbers and percentages. The ratio was determined and written in decimal format rounded to tenths, with one number after the decimal point. Nationality was considered as the country of nationality of

each patient as it was indicated on their passport used during the transportation. Country of nationality and the country the patient was transported from were nominal categorical variables and illustrated by means of a figure, a table, numbers and percentages. The figure indicating the countries the patients were transported from was created by the researcher using Microsoft® Paint program. Diagnoses were analysed by means of categorizing into nominal diagnostic categories as previously indicated and demonstrated by means of bar graphs and percentages.

The FiO₂ of all the transported patients were illustrated by means of bar graphs, a median and IQR as well as divided into dichotomous categories, those who received oxygen and those who did not, and analysed by means of numbers and percentages. Invasive or non-invasive positive pressure ventilation requirements, inotrope and/or vasodilatory and cardiac pacing requirements, whether transcutaneous or intravenous, were dichotomous categories and analysed by means of numbers and percentages and illustrated by means of a table.

CHAPTER 3: RESULTS

3.1. Number of transportations

Three hundred and six transportations were performed during the study period, representing an average of one transportation every 1.2 days. Three of these 306 transportations did not meet the inclusion criteria and were excluded from further analysis. Therefore, 303 transportations were analysed.

3.2. Demographical data

Age had a partly skewed distribution to the left as shown in the graph below (Figure 3.1). The median age was 43 years, ranging from 2 days old to 86 years with an inter-quartile range (IQR) of 31 to 56 years.

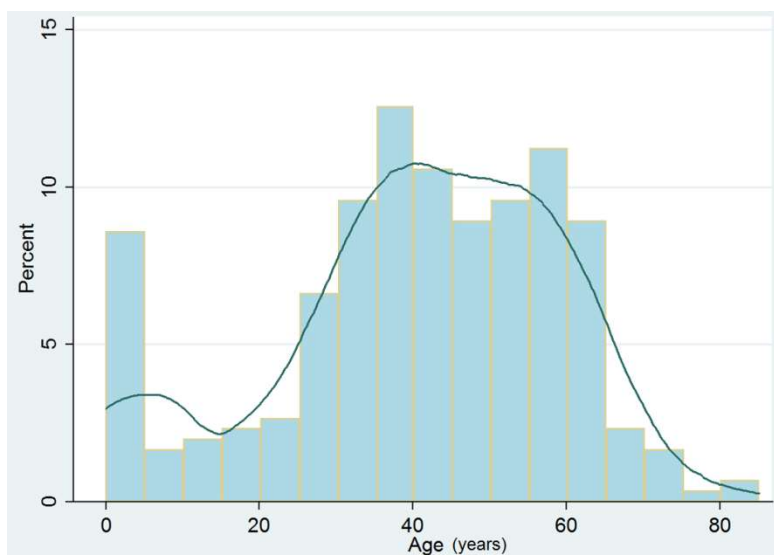


Figure 3.1: Age distribution.

The minimum and maximum ages of male and female patients are displayed in Table 3.1. Children were in the minority with 44 children (13.5%) aged less than 18 years old transported. The majority of the patients, 262 (86.5%), were adults aged 18 years or older. Three patients (1.0%) were neonates aged less than 29 days.

Table 3.1: Age according to gender (N=303)

	n (%)	Min	Max
Male	218 (71.9)	11 days	86 years
Female	85 (28.1)	2 days	78 years

n, frequency; %, percentage; Min, minimum; Max, maximum.

The male to female ratio was 1:0.4.

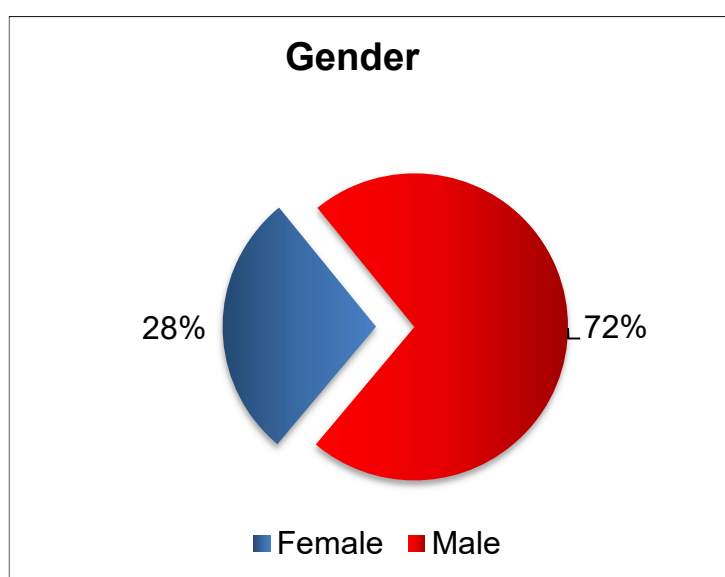


Figure 3.2: Gender distribution.

Fifty three different nationalities were transported over this period, with the majority of patients, approximately one out of every four, being South Africans (Table 3.2).

Table 3.2: Country of nationality of patients transported (N=303)

Country	N	%	Country	N	%
South Africa	76	25.1	Kenya	2	0.7
USA	30	9.9	Norway	2	0.7
Angola	26	8.6	Spain	2	0.7
United Kingdom	20	6.6	Uganda	2	0.7
Philippines	15	5.0	Botswana	1	0.3
DRC	8	2.6	Colombia	1	0.3
India	8	2.6	Egypt	1	0.3
Netherland	8	2.6	Germany	1	0.3
Nigeria	8	2.6	Ghana	1	0.3
Australia	6	2.0	Guinea	1	0.3
France	6	2.0	Ireland	1	0.3
Japan	6	2.0	Ivory Coast	1	0.3
Mozambique	6	2.0	Lebanon	1	0.3
Zimbabwe	5	1.7	Malaysia	1	0.3
Belgium	4	1.3	Mexico	1	0.3
Brazil	4	1.3	Peru	1	0.3
Canada	4	1.3	Romania	1	0.3
China	4	1.3	Rwanda	1	0.3
Gabon	4	1.3	Sierra Leone	1	0.3
Israel	4	1.3	Somalia	1	0.3
Portugal	4	1.3	Sweden	1	0.3
Greece	3	1.0	Switzerland	1	0.3
Italy	3	1.0	Tanzania	1	0.3
Malawi	3	1.0	Thailand	1	0.3
South Korea	3	1.0	Trinidad	1	0.3
Zambia	3	1.0	Venezuela	1	0.3
Burundi	2	0.7			

n, frequency; %, percentage; DRC, Democratic Republic of the Congo; USA, United States of America.

The 303 patients were transported from 27 different countries (Figure 3.3). The top 5 countries from which patients were transported were Angola (32.2%), Zambia (11.9%), Mozambique (9.2%), Nigeria (6.6%) and the Democratic Republic of the Congo (6.3%).

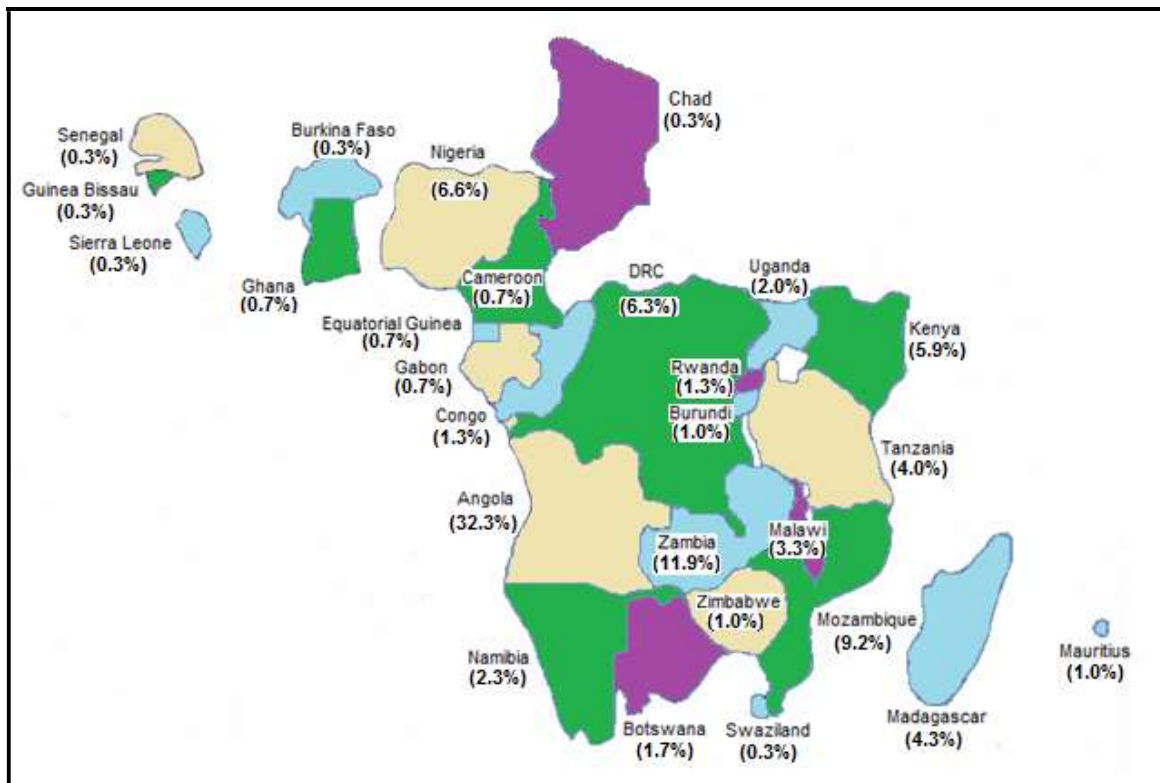


Figure 3.3: Country of origin of transportation.

Created by the researcher with Microsoft® Paint.

3.3. Diagnostic categories

The top 5 diagnostic categories were trauma (23.4%), cardiological (16.2%), neurological (10.9%), malaria (10.2%) and surgical (9.6%), as depicted in Figure 3.4. The categories requiring the least amount of transportation were allergic reaction (0.3%) and congenital abnormality (0.3%). Malaria and infective diseases combined contributed to 11.2% of transportations and was then the third most common diagnostic category requiring medical transportation. Two of the three patients within the infective category required transportation within a patient isolation unit. The congenital abnormality was a premature baby with suspected prune belly syndrome. There were no patients with dysbarism transported.

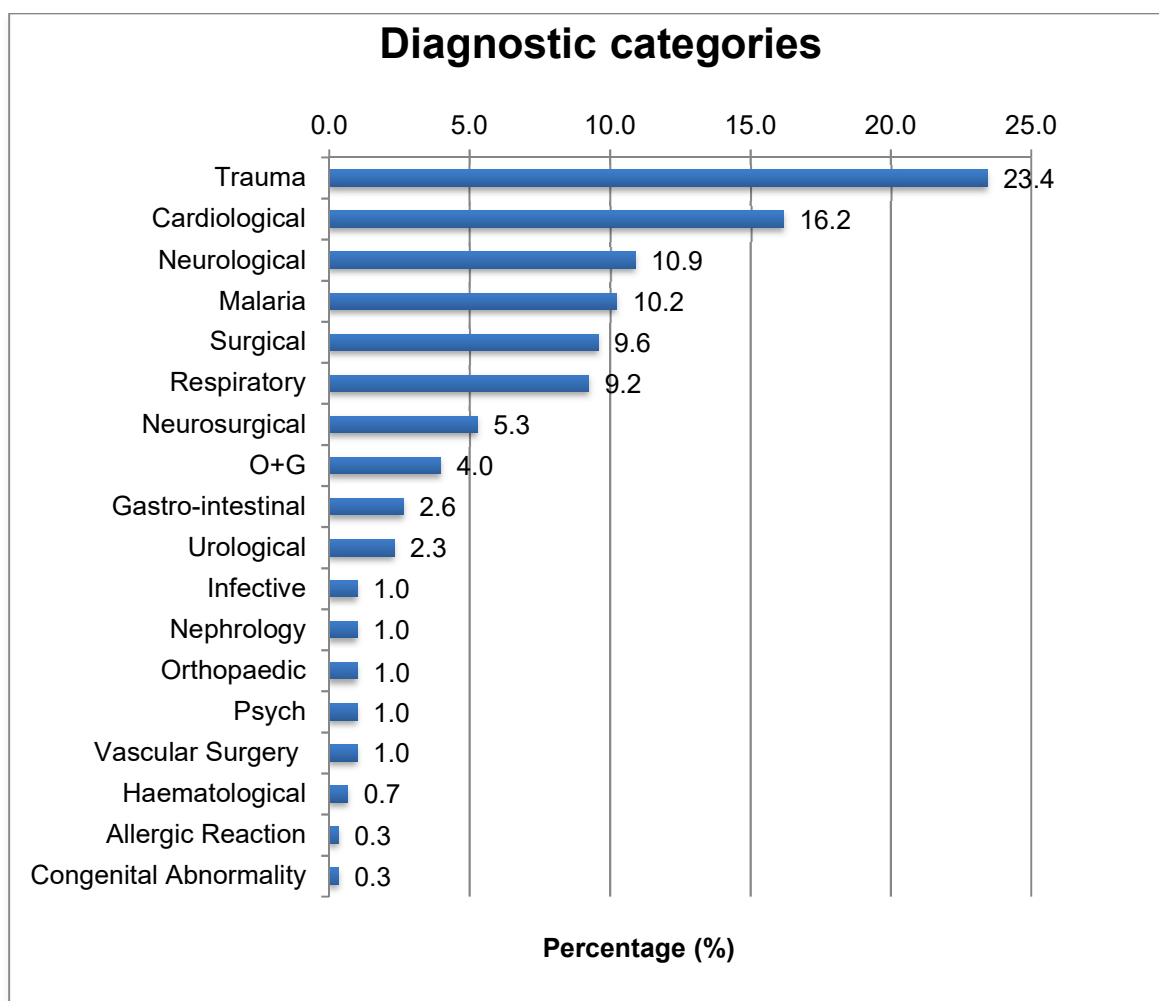


Figure 3.4: Percentage of patients transported per diagnostic category.
(O+G, obstetrics and gynaecology; Psych, psychiatry.)

3.4. Oxygen supplementation

The data on the fraction of inspired oxygen (FiO_2) was skewed to the left as illustrated in the graph below (Figure 3.5). This was confirmed by the statistical test for skewness ($p\text{-value} < 0.01$). The median FiO_2 was 0.21 with an IQR of 0.21-0.21, indicating that a minority of patients required supplemental oxygen.

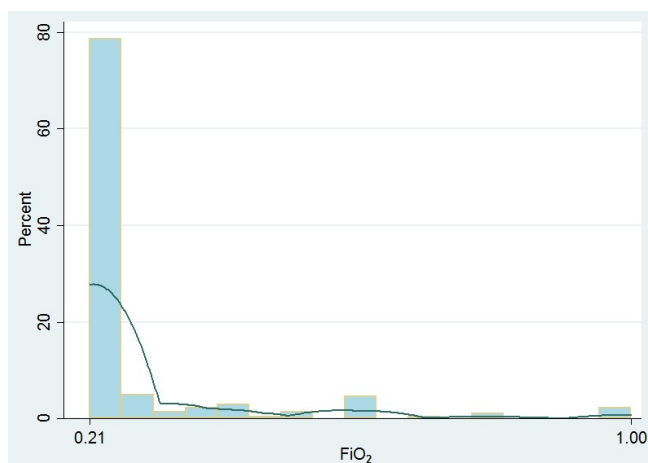


Figure 3.5: Fraction of inspired oxygen distribution.
(FiO₂, fraction of inspired oxygen)

Sixty-eight patients (22.4%) received oxygen supplementation during transportation. Two of these patients were neonates and 59 patients were adults. Oxygen supplementation was given to patients from the cardiological, respiratory, surgical, neurological, neurosurgical, malaria and trauma diagnostic categories. Seven (2.3%) of these 68 patients received 100% oxygen.

3.5. Ventilation, inotrope and vasodilatory therapy and transcutaneous or intravenous cardiac pacing

Thirty one (10.2%) of the patients required mechanical ventilator support (Table 3.3).

Table 3.3: Ventilation, inotrope and vasodilatory therapy and cardiac pacing

	n (%)
Endotracheal intubation and IPPV	26 (8.6)
NIPPV	5 (1.7)
Inotrope and/or vasodilator therapy	16 (5.3)
Cardiac pacing	0 (0.0)

n, frequency; %, percentage; IPPV, invasive positive pressure ventilation; NIPPV, non-invasive positive pressure ventilation.

Invasive positive pressure ventilation (IPPV) was more common than non-invasive positive pressure ventilation (NIPPV): 8.6% of the patients received invasive positive pressure ventilation as compared to 1.7% who received non-invasive positive pressure ventilation. Those receiving IPPV were within the same diagnostic categories as the ones receiving supplemental oxygen. Those receiving NIPPV were from the respiratory, trauma and surgical categories.

None of the patients transported received cardiac pacing, either transcutaneous or intravenous, during initial assessment (Table 3.3).

Four of the 16 patients receiving inotrope and/or vasodilatory therapy were from the cardiological diagnostic category with the rest from the malaria, neurosurgical, trauma, respiratory and vascular surgery category. Of the patients transported due to cardiological conditions, 8.2% received inotrope and/or vasodilatory therapy.

CHAPTER 4: DISCUSSION OF RESULTS

4.1. Number of transportations

Three hundred and six transportations were performed by the AAP over a one-year period. This was a greater number than the findings per year in the studies of Chen *et al.*, Daly *et al.*, Dewhurst *et al.*, Peiris *et al.*, Peytremann *et al.* and Tursch *et al.*^{9-13,16} This may be as a result of many of these studies focusing on small populations such as a remote indigenous community in Arnhem Land, Australia or only the field employees of a single company (UNHCR). Some studies focused on a small geographical area such as the international transportations in Taiwan and others looked at transportations in high-income countries such as Germany or the UK, where one can expect the risk and requirement for AMT to be less than in low or middle-income countries.

The findings in this study, showing more transportations per year in comparison with the other studies, could be due to covering incidents over a wider geographical area, namely the whole of sub-Saharan Africa. The AAP studied is a private, fee for service company with the client base of the assistance company being mostly oil and gas, mining, corporate companies and embassies. As a private, fee for service AMT provider, some transportations could also include transportations of local politicians, requesting transportation for political or other commercial reasons, rather than medical necessity.

An assistance centre may be called by a member, requesting medical transportation out of an area of sub-Saharan Africa prior to them being in a critical of life-threatening situation. Due to the limited resources, sanitary conditions and other factors previously mentioned, many of these members may be transported earlier after receiving a request in light of the threat of deterioration and/or limited ability to appropriately rule out a more sinister condition. For commercial and reputational reasons, employer companies or insurance companies request or cover early transportations in order to avoid legal proceedings, complaints or reputational damage. Therefore, the number of transportation may be higher when compared to studies conducted in developed countries as many transportations could be considered to be elective or “prophylactic” transportations rather than truly medical critically ill patient transportation.

4.2. Demographical results

4.2.1. Age

The median age of the studied population was 43 years and this supports the previously mentioned statement that the average traveller’s age is rising and that it is estimated that by the year 2030, half of all aircraft passengers will be above 50 years of age.⁷

The median age correlated well with the findings of other studies such as Duchateau *et al.* with a median of 47 years and Peytremann *et al.* with an average age of 40.4 years.^{1,13} It is understood that one cannot compare median with average age but

unfortunately Peytremann *et al.* only reported an average age in their publication reviewed.¹³ Duchateau *et al.* had a very similar study in that it was based on the medical transportations overseen by a medical assistance company and overlapped in the area covered, namely Africa.¹ Peytremann *et al.* studied only the transportations of field employees for the UNHCR, excluding relatives and those retired, thus excluding the very young and very old and only focused on the working age population.¹³ This may correlate with this study as the medical assistance company studied focus on business travellers and contract workers of international corporate companies, of whom the majority will be of working adults. The median age of 43 years may be relatively high due to the client population usually being local workers, contract workers, business travellers of corporate companies of the oil and gas and mining industries, including expatriates of various corporate companies and diplomats. The commercial and industrial environment worker force is generally predominated by adult males. Senior managers of many companies, visiting international operations, are usually of a higher age group. Expatriates working long-term contracts in a country often have their families staying with them, who may also be covered under the employer's insurance. Expatriates working shorter contract periods often travel without their families. Local national work force's families are usually expected to utilize local medical facilities. Families travelling into sub-Saharan Africa for leisure purposes may have small children but since leisure travel is usually for only a short time period, the risk of serious illness and injury requiring AMT is less than the worker contracted to remain in the area for a longer period.

The median of 43 years of age was less than the mean of 53 years found by Dewhurst *et al.*, 66 years by Sand *et al.*, 53 years by Singh *et al.*, 54 years by

Suriyachaisawat and Surakam and 65 years by Tursch *et al.*^{7,11,14-16} The older median age as found in these studies may be due to the AAP being involved in government services, including elective transfers, and non-urgent repatriations. This can contribute to a larger older population included for various injuries and illnesses as the risk for serious non-communicable illness increases with age.⁶⁰ Government based AAP in areas of good health care will also require a patient to meet certain clinical criteria to justify a transportation prior to accepting a mission. Any patient younger than 18 years of age was excluded in the study of Singh *et al.* and could also contribute to the higher median age.

The median age of 18.3 years of Peiris *et al.* is much lower than the findings of the other studies reviewed.¹² The studied population Peiris *et al.* was from a small, remote indigenous community and therefore a domestic environment including families with small children and expected higher proportion of children than the industrial environment covered in the researcher's study.¹² In the study of Peiris *et al.*, children aged less than 5 years old were reported to be 3.3 fold over-represented in transportations in comparison to the community component.¹² This large over-representation of very young patients may explain the outlier young median age in their study. One can speculate that the clinic in the area was likely better equipped for adults and that a lower threshold for transportation of paediatric patients existed, especially in light of how quickly children can deteriorate if not attended age-appropriately. Peiris *et al.* may be more equal in light of the over-representation of less than 5-year-old patient population and mainly involving governmental upgrade of care for a remote located indigenous population.

The AAP studied does not have any age exclusions for transportations and is fully equipped to safely transport ill neonates, with temperature regulated incubators, neonatal ventilators and a qualified neonatal ICU nurse. With the ages ranging from 2 days old to 86 years, the findings in this study correlated well with the age ranges from the studies of Suriyachaisawat and Surakam with a range from 1 day to 105 years, Tursch *et al.* from 43 days to 95 years and Sand *et al.* involving patients from 42 days of age to 96 years.^{7,15,16} Both Sand *et al.* and Tursch *et al.* were studies from organizations in Germany. It may be considered that there was appropriate neonatal care available in majority areas and that the risk of transportation of neonates outweighed the benefits. The lower end of the age spectrum for these studies may therefore not have included neonates.^{7,16} Suriyachaisawat and Surakam's study was in Thailand and the requirement to transport ill neonates from areas not appropriately equipped to manage neonates may have been a factor, contributing to the lower end of the spectrum to include an age as low as 1 day.¹⁵

The upper end of the age spectrum included ages up to 105 years. Even though this study did not include such a high age, it included up to the age of 86 years of age. If a patient's medical condition was considered to be transportable and the benefits of transportation exceeded the risk, the patient would be transported, irrespective of the age. End of life considerations would be taken into consideration but if the patient, the patient's employer, relatives or paymaster insisted on transportation, even if the capabilities of the receiving hospital are unlikely to change the overall prognosis or expected deterioration or demise, the patient would be transported as long as valid and informed consent for transportation was provided.

4.2.2. Gender

Seventy two percent were male, with a male to female ratio of 1:0.4, mirroring the findings of Chen *et al.* and Suriyachaisawat and Surakam's with 66.5% male and a male to female ratio of 1:0.5.^{15,19} The majority being male within the researcher's study correlates with the clientele mainly being adult male worker force in the industrial environment, as previously discussed under 4.2.1 (Age).

The study of Chen *et al.* obtained their data from the same medical assistance company but another assistance centre and may therefore have similar client considerations to this study.⁹ Suriyachaisawat and Surakam studied all transportations recorded by the Aviation Medicine Department of Bangkok Hospital and may involve more men than women due to Bangkok being the capital of Thailand with a lot of workers being seasonal migrants from remote areas of Thailand, without their families. The hospital provides care to the local domestic and industrial communities.¹⁵

The studies of Dewhurst *et al.*, Peytremann *et al.*, Sand *et al.*, Singh *et al.* and Tursch *et al.* showed a male to female ratio from 1:0.7 to 1:0.85, covering both domestic and industrial environments.^{7,11,13,14,16} Peiris *et al.* showed a roughly equal representation of male and female patients.¹² The majority of studies therefore found a male predominance being medically transported, with a higher male to female ratio in an industrial environment than a domestic environment.

4.2.3. Nationalities

The top 5 nationalities transported came from South Africa (25.1%), the United States of America (9.9%), Angola (8.6%), the United Kingdom (6.6%) and from the Philippines (5.0%). As South Africans were most common and since South Africa was the end destination of the studied population, this may be due to the recognized benefit of returning patients to their own country of nationality or residence for treatment in their own language near their family and support system.³² It may be related to their travel insurance anticipating cost of hospitalization or risk of remaining locally exceeding the cost of AMT with the preference to transport them back to their home country and to their local health-care systems.³² There are many South African companies expanding commercially into Africa; these include banks (e.g. Standard Bank), cellular companies (e.g. MTN) and many construction companies, with South African employees being deployed into Africa. There are also several international companies with their African base located in South Africa, deploying South African in Africa or having South African staff travelling from South Africa to their African operations. Many South Africans, covered by South African medical aids and insurances, travel into Africa for leisure purposes due to many areas being economical and nearby popular tourist destinations.

Many of the expatriate populations will often be evacuated by means of other AMT providers to Europe or other countries instead of South Africa, depending on their nationality and the distance to other first world countries. Patients in countries located in the Northern part of Africa would more likely be transported to Europe or United Arab Emirates or other countries. Expatriates of other nationalities may still be

transported to South Africa if injured or ill in countries close to South Africa or where AMT provider availability to South Africa exceeds availability of AMT to Europe or the Middle East, especially where the patient's medical condition requires the shortest and quickest possible solution to definitive treatment.

Americans from the USA were the second most transported nationality. The American nationalities may be related to many of the oil and gas companies with operations in Africa being American companies that frequently send American expat staff on business trips to Africa. These may be senior company staff required to temporarily live in Africa for the duration of a specific project. Africa may be foreign to visitors and they may therefore be more subject to injury or illness, for example being non-immune to malaria and at greater risk of rapid deterioration or complications. There may be a lower threshold for evacuation of USA citizens due to an organizations' duty of care obligations towards their American population and caution against legal prosecution. Companies have a responsibility to provide health care to the staff at the same level as their staff would receive in their country of residence when required.

Angolan nationality was likely under the top 5 related to the size and population of the country, the large amount of oil and gas companies' presence in Angola due to this being an oil-rich country and the well-developed relationship between the medical assistance company and local insurance companies in Angola. People from the Philippines were also quite common; likely due to the affordability of the Philippine worker force for international companies.

The top 5 nationalities differed from the findings of Suriyachaisawat and Surakam, who showed the top 5 nationalities of patients requiring medical transportation at Bangkok Hospital are Thai (30.8%), Myanmar (9.6%), British (6.3%), German (6.0%) and Cambodian (5.3%).¹⁵ This difference is likely due to the difference in geographical location of where the studied providers were based. The British were the fourth top nationality, representing 6.6% and 6.3% respectively between this study and that of Suriyachaisawat and Surakam. It is unclear why this finding was similar and may relate to both Africa and Thailand being popular and affordable holiday destinations for the British. Additionally, there are many British industrial and commercial companies with international operations in Africa, deploying British nationalities to their operations.

Almost half of the population transported (49.1%) were people from outside of Africa. Japanese, Europe and North America nationals constituted 32.3% of the transportations, which correlated well with the 35.8% in the study of Peytremann *et al.*¹³ African nationals contributed to 50.8% of the transportations in this study whereas Peytremann *et al.* reported 42% being of African decent and 0.3% in the study of Suriyachaisawat and Surakam.^{13,15} The similarity between this study and Peytremann *et al.* may be due to the patient population studied being very similar in that both groups were mainly the internationally deployed worker force with majority of incidents occurring in Africa – 59% of the reported events of the study of Peytremann *et al.* occurred in Africa.¹³ National employees in the study of Peytremann *et al.* were only transported internationally if their lives were in danger and a similar protocol is expected from the corporate clients using the AAP studied.¹³

The small contribution of African nationalities in the study of Suriyachaisawat and Surakam may be in that the majority of transportations in their study would be expected to be related to leisure travellers and local domestic communities and not as much for business purposes from Africa. Thai nationality represented only 0.3% of those transported in this study, where it represented 30.8% of the study of Suriyachaisawat and Surakam, indicating that the situation is almost reversed for African and Thai nationalities between the two studies. Thai being a lot more common due to the location of the study of Peytremann *et al.* being in Thailand whereas this study was in Africa.

4.2.4. Country of origin of transportation

Duchateau *et al.* indicated that medical incidents occurring in sub-Saharan Africa demand extreme caution due to sanitary conditions being poor in many areas and the accompanying increased health risks.¹ The 303 transportations were from 27 different countries. All 27 countries fall within sub-Saharan Africa and were low-income and middle-income countries. The top 5 countries were Angola (32.2%), Zambia (11.9%), Mozambique (9.2%), Nigeria (6.6%) and the Democratic Republic of the Congo (6.3%).

Dutchateau *et al.* illustrated in their study 6% of transportations in America, 8% in Europe, 6% in Asia, 43% sub-Saharan Africa and 37% in North Africa.¹ The difference is likely due to Duchateau *et al.* including non-urgent repatriations, likely involving medical escorted missions on commercial aircraft, and looking at all cases the medical assistance company supported where this study only focused on the

transportations performed by a South African based AAP. It would therefore mainly involve transportations within in the AAP aircrafts' range.

Suriyachaisawat and Surakam found the most urgent medical transportations were from Thailand and Indochina countries such as Myanmar and Cambodia.¹⁵ This is likely due to the location of their study focusing on the transportations by the Aviation Medicine Department of Bangkok Hospital. It would therefore also be limited to cases where the hospital is involved, the range of the aircrafts and geographical location. Druckman *et al.* mentioned more than 200 countries in their study over 2 years, with medical transportation required from countries of all continents, involving countries such as Angola (4.5%), Nigeria (4.1%), the Democratic Republic of the Congo (1.4%), Madagascar (1.4%), Equatorial Guinea (1.1%), Ghana (1.1%) and Mozambique (0.9%).⁶ Druckman *et al.* study reviewed 2 large databases involved in international transportations globally and was not limited by geographical location or a single AMT provider.⁶ There was no similarities between the percentage countries involved and this may relate to the differences in areas covered and study population sizes.

Dewhurst *et al.* indicated 79% of the transportations are repatriations from countries within the European Union.¹¹ This is likely due to the location of the AAP studied being based in the UK. Sand *et al.* indicated 68% involving Europe, 17% Africa, 12% Middle East and 12% Turkey, amongst others.⁷ These findings are different from the researcher's study as the study of Sand *et al.* involved air ambulance (77.6%) and scheduled transportations (22.4%) and focused on the transportations of a single organization and people residing in a single European country.⁷

4.3. Disease profile

Trauma was the leading diagnostic category requiring transportation. Timely access to care is important for patients with traumatic conditions and they often require management in a specialized trauma centre in order to limit trauma-related morbidity and mortality. Specialized level one trauma centres are unfortunately still rarely available in sub-Saharan Africa. Trauma is often associated with the requirement for blood transfusions with the limited availability of reliable blood products in some areas in sub-Saharan Africa being a contributing factor to the requirement of transportation.^{4,61}

As previously indicated, injuries are among the leading causes of death and disability in the world, the leading cause of preventable death in travellers and road traffic crashes are common among travellers in foreign countries.⁵⁴ Therefore, it is not surprising to see trauma-related conditions to be the most common diagnostic category. Trauma was also the category responsible for the majority of transportations in the studies of Dewhurst *et al.*, Duchateau *et al.*, Sand *et al.* and Suriyachaisawat and Surakam.^{1,7,11,15} Singh *et al.* however found trauma not to be a major reason for transportation in their study, as it only attributed to 9,7% of the transportations.¹⁴ It is unclear what the reason for the difference in findings is but difference in criteria for classification may have contributed where some may have been classified within the surgical or neurological group rather than the trauma group. Singh *et al.* may also have found a lower number of trauma patients since they excluded patients under the age of 18 years, thereby excluding paediatric trauma

where children are more susceptible to major and multiple injuries due to their body composition.

The top 5 diagnostic categories in the study of the researcher were trauma (23.4%), cardiological (16.2%), neurological (10.9%), malaria (10.2%) and surgical (9.6%). Malaria and infective diseases combined contributed to 11.2% of transportations and was then the third most common diagnostic category requiring medical transportation. Cardiological and Neurological conditions were amongst the top 5 categories in the studies of Dewhurst *et al.*, Duchateau *et al.*, Singh *et al.* and Suriyachaisawat and Surakam.^{1,7,11,15}

This frequency of cardiological conditions requiring AMT may relate to the increase in travellers' average age and many of the leisure and business travellers having significant past history such as diabetes, hypertension and ischaemic heart disease. Cardiological conditions are frequently time critical conditions, requiring specialist intervention and critical care within a level I ICU, which are unfortunately not commonly available in Africa. Baker mentioned that critical care remains rudimentary in low-income countries.⁵¹ Conditions such as acute myocardial infarction, which form part of the cardiological diagnostic category, are but one of the conditions that benefit from emergency thrombolytic therapy, angioplasty and other specialist intervention and therefore require emergency referral and transportation when these critical treatment modalities are not available at the patient's initial location.

Considerations similar to those for cardiological diagnostic category are also applicable to the neurological group (significant past history such as hypertension

and increase in average age). Acute stroke, which formed part of neurological diagnostic category, also benefits from emergency thrombolytic therapy and specialist intervention, which requires urgent transportation to appropriate medical facilities to improve overall outcome. Even though many patients are not within reach of a stroke unit for thrombolytic therapy within the required time frame, early and intensive rehabilitation in appropriate facilities are prudent to limit the morbidity and mortality of neurological conditions such as stroke and its complications.

Duchateau *et al.* mentioned the risk of life-threatening diseases such as malaria in sub-Saharan Africa.¹ Malaria is endemic in Africa. It was found to be the most frequent single disease entity requiring transportation during the researcher's study period. It was responsible for 10.2% of the transportations and the fourth most common overall diagnostic category. Malaria is of particular concern within non-immune expatriates or travellers, especially when not taking recommended prophylactic measures during their stay in endemic areas. The added risk may be substandard treatment supply resources in low-income countries. Non-immune patients have a higher risk of developing severe malaria and can deteriorate rapidly.

Dewhurst *et al.*, Duchateau *et al.*, Peiris *et al.* and Singh *et al.* found respiratory conditions to be amongst the top 5 categories but it was sixth in this study.^{1,11,12,14} One percent of the studied population were transported for psychiatric conditions. This correlated well with the findings of other studies. Psychiatric or mental health conditions contributed to 1% of all the transportations in the study of Suriyachaisawat and Surakam, 1.6% according to Sand *et al.*, 1.9% according to Peytremann *et al.* and 3.4% according to Peiris *et al.*^{7,12,13,15} Psychiatric conditions are not expected to

be frequently transported by air in light of the risks associated with a patient becoming violent within the limited space of an aircraft, resulting in possible damage or even crashing of an aircraft, especially if the patient is able to access the cockpit. Adequate deep sedation or restraint in an aircraft may also pose a risk to the patient. It is therefore preferred for patients with psychiatric conditions to be medically stabilized prior to undertaking any flight.

The categories requiring the least amount of transportation were allergic reaction (0.3%) and congenital abnormality (0.3%). This may be since allergic reactions should be able to be adequately managed globally and is either immediately life-threatening or adequately controlled within a reasonably short time. It should rarely be necessary to medically transport a patient internationally via AMT for an allergic reaction. Severe congenital abnormalities are rare and if severe, mostly not compatible with life. The number of patients requiring AMT due to these conditions was therefore expected to be low.

Two of the three patients within the infective category required transportation within a patient isolation unit. When transporting patients with potentially lethal communicable diseases an air ambulance with an aircraft transit isolator can be used to safely transport a patient to a maximum biologic containment facility.⁴ Indications for using a transport isolator, as in these two cases, include patients with an unknown disease pending identification of the pathogen.⁵⁶

4.4. Oxygen supplementation

Even though pressurized fixed-wing aircraft, such as those relevant to this study, can fly at high altitudes while counteracting the negative effects of altitude by means of pressurization, adjusting the fraction of inspired oxygen (FiO_2) by means of supplemental oxygen may be required to prevent hypoxemia in critically ill patients or those with anaemia, respiratory disease or respiratory or cardiac distress.^{17,29,31,33,34,43,46,48} Sixty-eight patients (22.4%) received oxygen supplementation during transportation. This finding correlated well with the 29.1% of patients receiving oxygen during medical transportation in the study of Duchateau *et al.*¹ Thus the majority of patients are not expected to require oxygen supplementation due to pressurization of aircrafts and they are therefore able to compensate adequately for the limited pressure changes experienced.

Essebag *et al.* referred to a study by Bendrick *et al.* where 12.5% of their patients required supplemental oxygen for desaturation below 90%.³² This study was on a very small study population of patients with ischemic heart disease. One can also conclude that not all patients with cardiological conditions would therefore require oxygen supplementation.

Oxygen supplementation was given to patients from the cardiological, respiratory, surgical, neurological, neurosurgical, malaria and trauma diagnostic categories. Oxygen supplementation is not limited to a single disease category and may be required for any patient and should be individualized according to the clinical parameters of a particular patient.

4.5. Mechanical ventilator support

As mentioned previously, most intensive care facilities can now be packaged into the confines of an aircraft and that tertiary facility type critical care capabilities can be delivered to an injured or ill patient during transportation.^{17, 22,32} This includes providing mechanical ventilator support.

4.5.1. Invasive positive pressure ventilation

Thirty one (10.2%) patients required mechanical ventilator support. This correlated well with other studies, such as Chen *et al.* with 8.7%, Sand *et al.* with 10.3% and Singh *et al.* with 10.0% requiring mechanical ventilation prior to transportation.^{7,9,14}

Invasive positive pressure ventilation was more common at 8.6% of the total patient population. The studies reviewed unfortunately did not differentiate between invasive positive pressure ventilation and non-invasive positive pressure ventilation when referring to mechanical ventilation.

Dewhurst *et al.* indicated 20% receiving mechanical ventilation, Tursch *et al.* 20.7% and Daly *et al.* as much as 50% in a mixed medical and trauma critical care population.^{10,11,16} They may have found a higher percentage of patient requiring mechanical ventilation due to both Dewhurst *et al.* and Tursch *et al.* study populations having a higher median and maximum age.^{11,16} Geriatric patients are more likely to require mechanical ventilator support due to a higher risk of complications and limited physiological reserve. They are also at a higher risk of non-communicable diseases such as stroke and myocardial infarction. There is a lower threshold for intubating

and ventilating geriatric patients with trauma due to their limited reserves and susceptibility to serious injuries from relatively minor impact, such as a hip fracture or intracranial haemorrhage from a fall. Some diseases are further progressed with age such as chronic obstructive pulmonary disease.

Daly *et al.* focused on a critical care population and one would therefore expect a higher percentage of critically ill patients, requiring critical care modalities such as mechanical ventilation.¹⁰ The number of patients being intubated and receiving mechanical ventilation may be lower in the researcher's study when compared with these other studies as occasionally, patients may be more likely intubated and supported with mechanical ventilation when they are in an area that is adequately equipped to provide critical care support with the necessary trained staff and monitoring capabilities. This environment and resources may not always be available in Africa. Not only critically ill patients are transported within Africa as previously discussed. Some may be medically transported out of an area early in the disease process or even prophylactically or even other commercial reasons and may therefore less likely require intubation and mechanical ventilator support.

The medical condition of the patient being transported, the level of care at the referring facility, the length of the flight and the risk of clinical deterioration during flight are all factors that may influence the decision on whether to intubate and ventilate or not. Given a finding of providing mechanical ventilation in 1 out of every 10 patients at least, or even one in every 2 at most, medical flight crew should be able to intubate and ventilate any patient, anywhere, on all their missions as the patient may deteriorate while awaiting arrival due to flight time from their base,

deteriorate during AMT due to disease progression or aviation stressors or the patient's condition may be worse than the initial medical report received. The patient with malaria may have cerebral malaria, the patient with chest pain may have congestive cardiac failure with pulmonary oedema, the patient with a headache may have a hypertensive crisis or subarachnoid haemorrhage or the patient with a rib fracture may have a flail chest.

Medical flight crew should therefore have adequate training and experience in airway management, ventilation strategies, critical care and aviation medicine, and they should be equipped with sufficient amounts of oxygen and portable, airworthy certified equipment required to intubate and ventilate a patient. Since AMT involves patients across all age groups, age appropriate equipment is required, for example neonatal ventilators and paediatric sized airway equipment.

4.5.2. Non-invasive positive pressure ventilation

Le Cong *et al.* argued that the use of non-invasive positive pressure ventilation (NIPPV) via face mask to improve oxygenation and ventilation in the AMT environment is acceptable in that the benefit of NIPPV, or lack of, can be determined very quickly and therefore the decision to intubate, if ultimately required, would not be excessively delayed by a trial of NIPPV.⁴³ In this study 1.7% of the patients received NIPPV. NIPPV can successfully be executed in the AMT environment in a subgroup of patients where it may be clinically indicated.

4.6. Inotrope and/or vasodilatory support

Sixteen (5.3%) of the patients transported received inotrope support in the form of Adrenalin, Noradrenalin, Dobutamine, Dopamine and/or vasodilatory therapy with Nitroglycerine or a combination of these drugs. Twenty five percent of these 16 patients had cardiological conditions with the other 75% of these patients being from the malaria, neurosurgical, trauma, respiratory and vascular surgery categories. Inotrope and/or vasodilatory therapy is commonly used for cardiogenic shock patients or those requiring blood pressure control or to assist with the management of patients with cardiological complications. It is therefore not surprising that 8.2% of all the patients within the cardiology category received inotrope and/or vasodilatory therapy.

None of the studies reviewed indicated how many patients received inotrope and/or vasodilatory therapy. Singh *et al.* indicated that they defined patients with hemodynamic instability as any patient who had a systolic blood pressure of less than 80mmHg or a mean arterial pressure less than 60mmHg or who required administration of vasopressors.¹⁴ They found 3.5% of their patient population to have had hemodynamic instability but did not specify how many of these received vasopressors and how many were managed appropriately with other therapy modalities such as intravenous fluids.

As for mechanical ventilation, justifying that medical flight crew require the right training, skillset and equipment to mechanically ventilate any patient when the need arises, the researcher has also shown the need to have appropriate equipment to provide inotropic and/or vasodilatory infusions to patients in the AMT environment. A

clinical significant number of patients received inotrope and/or vasodilatory therapy: 5.3% of all patients transported and 8.2% of patients within the cardiological category, the second most common disease category undergoing AMT. Appropriate infusion pumps not influenced or affected by vibrations, pressure changes or other stressors of the aviation environment during transportation are required in order to provide continuous infusion of these drugs in the aviation environment. It is important to note that infusion pumps are also required for the infusion of any intravenous therapy in order to assure that it is provided at the required pressure, dose and volume when given to a patient in the aviation environment.

4.7. Cardiac pacing

None of the patients transported required cardiac pacing, either transcutaneous or intravenous, during initial assessment. This did not correlate with the findings of Daly *et al.* or Vukov and Johnson, where pacing was required by 0.6% and 7.8% of the patients respectively.^{10,32} Daly *et al.* may have had a higher percentage than found within the researcher's study, since they evaluated patients from a critical care population over a longer period (4 years).¹⁰ Vukov and Johnson focused on helicopter transportations of patients with acute myocardial infarction.³² One would expect a higher number of patients requiring electrical interventions in these groups of patients due to their clinical conditions and disease processes.

None of the patients in this study received pacing (Table 3.3) and one reason may be that transportations were only reviewed over a one-year period. Additionally, data was mainly taken from the findings of the crew on their initial assessment prior to

transport and therefore patients who subsequently developed a need for cardiac pacing during transportation may have been missed. Even though none of the patients in this study received cardiac pacing, due to the fact that 16.2% of the transported population had cardiological diseases (the second most common disease category) and that other studies indicated that acute cardiac patients required the intervention, cardiac pacing capability is a mandatory requirement in order to safely transport cardiac and/or critically ill patients. The training and equipment to provide cardiac pacing may be rarely required, but it is a lifesaving intervention and when a critically ill patient requires it, an AMT provider need to be able to manage and support the patient appropriately.

CHAPTER 5: CONCLUSIONS

5.1. Conclusions

The researcher has shown that fixed-wing aircraft are available and frequently used for AMT. AMT can transport patients safely and rapidly over long distances. Taking into account that there are various AMT providers available globally, AMT has truly become an everyday event.

No patient is too young or too old for transportation. Patients of any age, nationality or disease entity may require AMT. According to the findings in the researcher's study and the literature reviewed, men are more frequently transported from commercial and industrial environments, whereas the male to female ratio are roughly equal when looking at transportations from a rural, domestic environment.

Trauma, cardiological, infective, neurological and surgical conditions most frequently require AMT. Malaria is the most common single disease entity requiring AMT within sub-Saharan Africa and this underscores the importance of adherence to malaria prevention strategies when visiting the area. Patient isolation units can be used to safely transport patients with potentially lethal communicable diseases for which no effective vaccines, chemoprophylaxis, or specific therapies exist and those with unknown diseases while awaiting identification of the pathogen. AMT is used to transport cardiac patients and patients with various medical conditions.

Aircrafts with the ability to artificially control the cabin pressure within the passenger compartments by means of pressurization makes altitude related changes in partial pressure of oxygen (PO_2) small and in most cases negligible, thereby negating the need for supplemental oxygen. However, adjusting the fraction of inspired oxygen (FiO_2) to maintain the inspired partial pressure of oxygen throughout a flight is still a clinically useful technique and necessary for some patients in order to prevent hypoxemia.³³ As per the findings of this study and the studies reviewed by the researcher, oxygen supplementation may be required in 12.5% to 29.1% of patients.

According to the studies reviewed, during AMT, 8.7% to 20.7% of patients receive mechanical ventilation, including NIPPV, with even as many as 50% among critical care patients. Up to 1.1% of patients may require electrical intervention, such as pacing or defibrillation.¹⁰ As many as 7.8% of patients may require cardiac pacing in those with acute coronary syndromes. In the researcher's study, 31 patients (10.2%) received mechanical ventilation and 16 (5.3%) received inotrope and/or vasodilatory therapy. This concludes that training, drugs and equipment to provide critical care procedures are justified in the AMT environment, irrespective of how often it may be used or the cost involved. Even though no patients required cardiac pacing in this study, it was required in other studies reviewed and is a life-saving procedure when needed. All critical care equipment should be taken on all AMT missions as one can never be sure what you may find on arrival.

Based on the illnesses and injury found in the study and equipment that may be required to treat at a critical care level, it is mandatory that all medical flight crew are adequately trained and adequately equipped to provide critical care for any life-

threatening illness or complication of injury likely to occur during transportation. AMT can be accomplished safely and in a timely manner and is a vital component in the continuum of patient care.

5.2. Limitations

Limitations to this study were that it only evaluated the data from a single provider based in South Africa over a short period of time, providing a small study population. The study is therefore not reflective of all air ambulance missions done out of sub-Saharan Africa as there are various AAP performing patient transportations within various countries and to many other destinations apart from South Africa.

Diagnostic categorization was done according to the researcher's opinion of most likely diagnosis based on the assessment and working diagnosis of the medical flight crew. The diagnostic category may potentially differ if assessed by different medical flight crew or researchers with different level of experience. There was no distinguishment made between trauma cases related to intentional and unintentional injury and whether it was work-related or not. It was not indicated whether the patients transported were considered to be expatriates or local nationals and whether or not the patients' purpose of travel was for business or leisure purposes.

The oxygen supplementation data only indicated the patients who received or required oxygen supplementation as per the medical flight crew's initial assessment and did not necessarily indicate all the patients who developed a requirement for oxygen in flight or during the mission. Additionally, some ventilators are unable to

provide less than a certain amount of oxygen supplementation, for example, the lowest FiO₂ ventilator setting being 0.4. Therefore, some patients who received ventilator support may have received oxygen supplementation even though there was no clinical requirement for oxygen.

Ventilation, inotrope, vasodilatory therapy or cardiac pacing requirements were recorded according to the medical flight crew's initial assessment and did not include any additional patients who developed a requirement in flight or during the mission. There was no distinction made between those receiving IPPV with regard to whether or not it was due to a requirement for respiratory support or another indication such as airway protection or energy conservation reasons.

The countries from where patients were transported from does not necessarily reflect the destinations visited by the AAP as some transportation missions required the assistance from other AAPs to transport a patient to a location accessible or closer to the AAP studied. This may have influenced some clinical findings as clinical variables may have been influenced by some treatment interventions provided by medical flight crew of the other AAP prior to the initial medical assessment of the medical flight crew of the studied AAP. This could for example have influenced oxygen, ventilation, inotrope, vasodilatory and cardiac pacing requirements data.

5.3. Future studies

Future studies should be considered with bigger population groups, subdivided according to age groups, for better analysis regarding significant associations and

difference according to age. Larger studies are required for a significant number of patients within all diagnostic categories for association analysis between diagnostic categories in order to determine if there are any association between diagnostic categories and the requirement of special interventions such as ventilation, cardioversion or other electrical interventions during transportation.

A study combining the findings of all AAP performing transportations in and out of Africa will provide a better description of demographics and disease profile of missions out of Africa. It may be beneficial to distinguish and assess the patient demographics and disease profile of business travellers versus leisure travellers to identify focus areas for companies deploying employees internationally.

AMT medical crew are often faced with a different clinical picture on arrival at the patient's bed compared to the medical report received before a flight. Studies evaluating this difference and how the difference relate to the transport time to the patient's location and the country the patient is being transported from, are needed. In addition to the previous, further studies assessing the difference in oxygen, ventilation, inotrope, vasodilatory or cardiac pacing requirements before, during and after transportation in relation to transportation time will provide valuable information in assisting with risk assessments and planning for patient transportations.

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Appendix 1: Permission to access records



Tel: +27 11 541-1350
Fax: +27 11 541-1058
e-mail: sosairrescueafrica@sos.co.za
web: www.international-sos.com

24-hour Emergency Contact Number
+27 11 541-1100

Albania
Algeria
Australia
Cambodia
Canada
China
Congo
Czech Republic
Estonia
France
India
Indonesia
Ivory Coast
Japan
Kazakhstan
Libya
Malaysia
Mali
Myanmar
New Zealand
Nigeria
Papua New Guinea
Philippines
Russia
Singapore
Slovak Republic
South Africa
South Korea
Spain
Switzerland
Taiwan (ROC)
Thailand
Ukraine
United Kingdom
USA
Venezuela
Vietnam

1 September 2011

Dr SM Odendaal
72 New Rd, Midrand
1685

Dear Dr Odendaal

Access to Air Rescue Africa Medical Flight Records

Intl SOS and Air Rescue Africa are happy to grant you permission to access records as per your request submitted. Please note that standard confidentiality of information rules will apply, with no mention of patient or client details being allowed.

Yours faithfully

A handwritten signature in blue ink, appearing to read "Steven Lunt".

Dr Steven Lunt
Medical Director

International SOS Assistance (Pty) Ltd.
72 New Road Midrand South Africa P.O. Box 4561 Halfway House 1685
Tel 27 11 541 1000 Fax 27 11 541 1060 Docex 25 Sandton Square Reg No 1985/003274/07
APA Vaissie (Chairman) (French) IM Cornish (Manager) NA Page A Jacobsz L Sobourin (French) FJC Truter T von Stryp (Financial)



Appendix 2: Ethics approval

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

R14/49 Dr Salome Odendaal

CLEARANCE CERTIFICATE

M111105

PROJECT

A Retrospective, Descriptive Study of Patients
Evacuated to South Africa via an Aero-Medical
Provider for the Year 2011

INVESTIGATORS

Dr Salome Odendaal .

DEPARTMENT

Division of Emergency Medicine

DATE CONSIDERED

25/11/2011

DECISION OF THE COMMITTEE*

Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 25/11/2011

CHAIRPERSON


(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Prof Efraim Kramer

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we **undertake to resubmit the protocol to the Committee. I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...

Appendix 3: Correspondence Sheet

Number	Case Number	Date Evacuated
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Etc.		

Appendix 4: Datasheet

Number: ☐

Age: _____

Gender: Male ☐ Female ☐

Nationality: _____

Evacuated from (Country): _____

Diagnosis: _____

FiO₂: _____

Positive Pressure Ventilation required: Yes ☐ No ☐

IPVV ☐ NIPPV ☐

Inotrope support and/or vasodilatory therapy: Yes ☐ No ☐

Cardiac pacing required: Yes ☐ No ☐