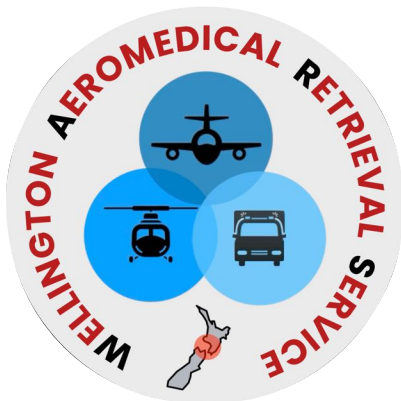


AN INTRODUCTION TO AEROMEDICAL TRANSPORT

Wellington
flight course



Course Manual v2025



**Wellington Aeromedical
Retrieval Service**
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Section One

Background

Objectives of the Introduction to Aeromedical Transport Training Course

- To introduce air medical personnel to the aviation environment
- To provide a thorough understanding of the importance of helicopter and fixed-wing safety, pre-flight briefing and dangerous goods and identifying and avoiding hazards in and around the aircraft
- To describe aviation physiology, how the gas laws effect air medical personnel and patients, and identify the appropriate treatments or interventions
- To provide an understanding of the stressors of flight on air medical personnel and patients, and to describe ways to prevent these adverse effects
- To introduce air medical personnel to the principles and preparation of a patient for air transfer
- To provide an overview of the varying speciality patient groups that may require aeromedical transport and discuss their flight and transfer preparation and management
- To experience emergency procedures during a crash landing in water, and discuss survival on the land
- To apply the knowledge gained during this course in practice through scenarios and simulation in the Wellington Regional Hospital (WRH) air ambulance simulator

Introduction to Wellington Regional Hospital's Flight Service

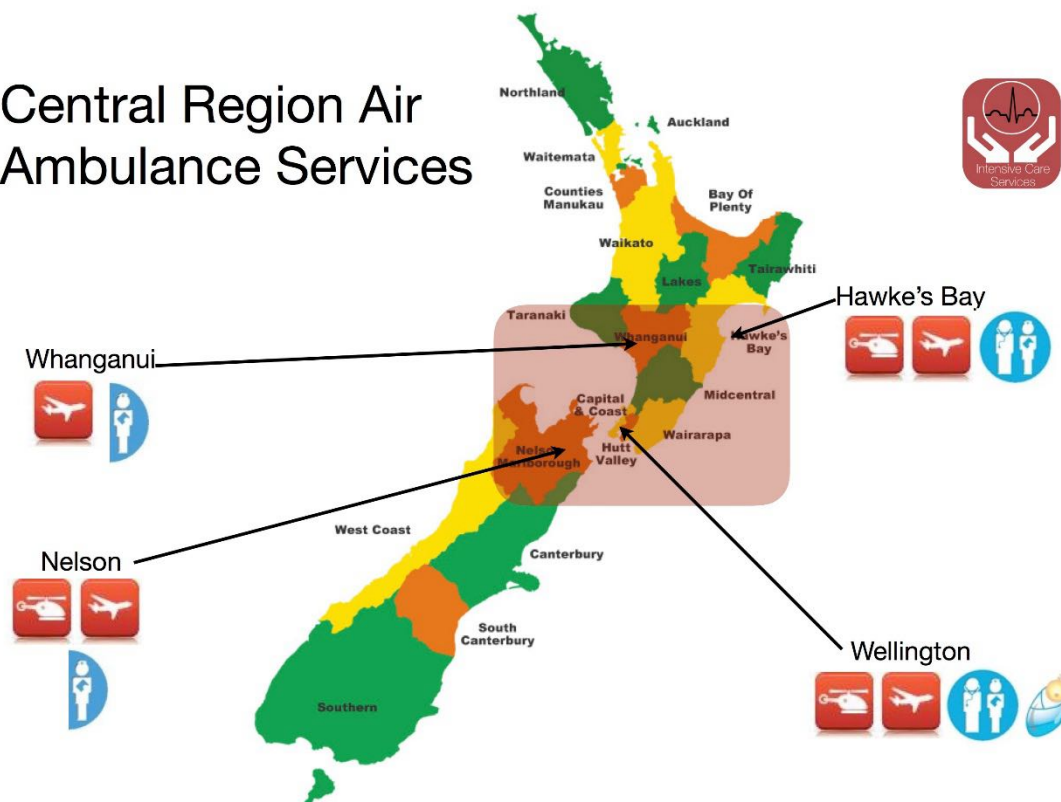
The WRH ICU Flight Service was established in 1994 and provides tertiary level ICU inter-hospital patient transfers. Retrievals are generally from Blenheim, Nelson, Masterton, Hutt, Whanganui, New Plymouth, Hastings and Palmerston North. The service primarily provides urgent access to tertiary services in Wellington. We also transfer patients directly to other hospitals for specialised services that cannot be provided in Wellington such as spinal injuries, hyperbaric, severe burns and paediatric oncology. The ICU flight team transfer approximately 1000 adult and paediatric patients a year with 80% of these in fixed wing aircraft, 15% by road and 5% in rotor-wing aircraft. The NICU team transfer around 400 infants a year; 60% in fixed wing aircraft, 35% by road ambulance and 5% in rotor-wing aircraft.

The population for the Central Region is over 1 million people. The on call ICU SMO and flight coordinator/flight nurse triage all referrals to determine the appropriate mode of transport and team composition based on time and skill requirements. Other factors such as weather and aircraft availability also affect out retrieval capabilities. If a patient cannot be retrieved in a timely manner then we will refer on to another service. The ICU specialist has overall responsibility for any patient we transfer once the team arrives at the referring hospital.

There is inherent risk associated with the inter-hospital transfer of patients that increases with their acuity. Many patients are acutely ill and all require significant clinical expertise in a challenging environment far removed from the support that is immediately available in a hospital. International standards, aligned with policy statements from all three relevant Australasian medical authorities (the Colleges of Intensive Care, Emergency Medicine & Anaesthesia), dictate that only specialist teams should be used for the interhospital transport of patients; this is the role that the WRH Flight Service fulfils.

There are a number of other flight services within our region who provide secondary transfer services.

Central Region Air Ambulance Services



Introduction to Aeromedical Retrieval Services in New Zealand

Inter Hospital Transport (IHT) exists to move patients between different hospitals to meet their medical or nursing needs. This is particularly the case when the patient requires an intervention not available at smaller centres such as cardiac angiography and neurosurgical intervention. Needs could include specialist interventions, imaging, other investigations or there could be logistical reasons such as repatriation back to a hospital of domicile.

IHT networks around NZ have developed over a number of years, often based within tertiary and secondary centres or by privately owned operators. Specialised services have become more centralised in large tertiary hospitals and thus the reliance on IHT teams to bring regional patients to them. National services such as PICU and ECMO are based in Auckland and have their own specialised retrieval teams. Regional services transfer ICU, HDU and ward level patients. For sicker, acutely unwell patients, retrieval models are used where clinical expertise is taken to the patient, bringing a higher level of care. This has been the preferred model of IHT for paediatric and adult ICU/HDU and NICU teams for several decades.

Within New Zealand there are tertiary flight services based in Waikato, Wellington, Christchurch and Dunedin, these include ICU and NICU teams. Specialist PICU, NICU and ECMO retrieval services are based in Auckland.

A number of smaller regional hospitals have secondary flight services and are able to transport lower acuity patients and those returning to their home hospitals. These are most often nurse only flight services – Whanganui, Nelson, Hawkes Bay, Tauranga and Gisborne. Hawkes Bay and Whangarei have the capability to undertake acute and ICU level transport when appropriate resources are available.

Patients can be categorised as:

 Time and skill critical patients	Complex unstable patients needing acute transfer for a time critical intervention.	Usually require an ICU or specialised transport nurse and doctor team.
 Time critical patients	Patients needing transfer for a time critical intervention.	Usually require ICU or specialised transport nurses +/- ICU doctors. Critical care paramedics may be used.
 Skill critical patients	Physiologically unstable patients needing advanced levels of support and care.	Require ICU or specialised transport nurse and doctor team.
 Routine stable patients	Stable patients transferred for elective intervention or repatriation.	Require flight or transit nurse.

Aeromedical retrievals are divided into three categories:

- **Primary retrievals** – Emergency pre-hospital care and air transport by Critical Care Paramedics (CCPs) utilising rotor wing aircraft; these are also part of the national acute trauma network and utilise staging practices to transport patients meeting specific criteria directly to tertiary centres

- **Secondary retrievals** – Inter-hospital transfers (IHTs) from non-specialised centres to larger centres with specialist services e.g. neurosurgical, interventional cardiology, and complex obstetrics. Usually performed by flight nurse +/- flight doctor teams
- **Tertiary retrieval** – IHTs between two similar types of hospitals with specialist services e.g. from Wellington Hospital to Auckland City hospital for ECMO.

95% of patient transports by air are IHTs. Prehospital services predominantly use road and rotary wing aircraft. IHT services mostly use fixed wing aircraft, however rotary is preferred for time-critical IHT work due to the direct hospital-to-hospital transfer rather than requiring a road component to travel to/from the hospital/airport at either end. This is often a significant contributor to delay as it relies on the availability of local ambulance vehicles to transport the crew, equipment (including stretcher) and patient. In smaller centres, particularly out-of-hours, this may be the only ambulance in the region meaning it is unavailable for prehospital work during this time. Ambulance co-ordination centres may also triage such work as lower priority than undifferentiated patients in the community even though the patient waiting in hospital may have a time critical condition.

Modes of transport

	Rotor wing aircraft – often reserved for time critical or urgent transfers within 250km. Provides the advantage of door-to-door time savings as there is no road ambulance component. Availability is affected by weather and cloud base.
	Fixed wing aircraft are typically used for longer IHTs >250km. They are pressurised and provide a more stable transport environment than rotor-wing aircraft. Transfers tend to be longer and require a road ambulance for transports between airfields and hospitals.
	Road ambulances provide transport between hospitals or airfields and hospitals. They may be used in poor weather conditions when aircraft are unable to fly. They are however affected by vehicle availability (also used by pre-hospital services) and traffic.

Flight standards

Flight team members may be classed as clinical support crew (regularly fulfil the role) or medical passengers (infrequently fulfil their role) and must adhere to guiding principles in the aeromedical industry in addition to Health and Safety laws and local policies.

New Zealand Aeromedical / Air SAR Standard v4.0 2024

Some key points include:

- *The care available to the patient during transport should not be less than that available at the location/facility the patient is collected from.*
- Clinical Support Crew and medical passengers must have the required experience, training and current competency to care for the patients on board.
- All Clinical Support Crew shall receive safety training for environments and service delivery relevant to where they will be responding. Refer minimum training requirements for their specific roles specified in current version of NZS 8156, and Table 4 – Minimum education and training requirements for aeromedical and air-SAR activities (non-pilot personnel) as applicable.
- All Clinical Support Crewmembers shall participate in activities that maintain the skills and competencies for their specific roles required to operate as a Crewmember, as prescribed in NZS 8156

New Zealand Standard 8156 is the over-arching document for ambulance, paramedicine and patient transfer services.

The College of Air & Surface Transport Nurses (COASTN) is a group within NZNO that provides national representation of over 400 flight nurses. They provide **Standards of Practice** and a **Skills and Competency Framework** for their members, as well as helping co-ordinate national education and providing an annual conference.

IC-10 Guidelines for transporting critically ill patients (2024) from the Colleges of Emergency Medicine, Anaesthetists and Intensive Care (ACEM, ANZCA, CICM) provide guidelines to support patient transfers that minimise risk and maximise safety.

NZ Health and Safety at Work Act 2015. Aims to reduce rates of workplace injury and death. Ensure your service complies with H&S legislation and mitigates risks as far is reasonably practicable e.g. provision of flight PPE – appropriate footwear, uniforms, the required standard of training and education.

Consent for Treatment

Staff are expected to comply with legal requirements under the **Code of Health and Disability Services Consumers' Rights 1996** (Rights 5, 6 and 7 for informed consent).

Informed Consent

The patient must make a fully informed choice and informed consent prior to being transported to another hospital; do they have adequate understanding of information provided and opportunity to consider and discuss options?

- ◆ Ensure the patient is competent to give consent
- ◆ If the patient does not have capacity to give consent is there another person legally able to do so e.g. child's legal guardian, adult with an EPOA.

When consent cannot be obtained

When the patient is not competent to make an informed choice or consent and no person is entitled to consent on their behalf. Such circumstances may include: unconsciousness, reduced GCS, shocked, use of illegal drugs.

Under Right 7(4) of the Code of Rights services can be provided to adults and children without consent if they are in the best interests of the patient and needed to preserve their life or health. They must take into account:

- ◆ any previously expressed views about care and treatment or
- ◆ the views of others interested in the welfare of the patient e.g. NOK, whanau, GP or carers

Treatment must be no more than what a reasonable patient would expect to receive in all the circumstances. Interventions are not justified even in an emergency if contrary to known wishes of the patient e.g. advanced directives

Refusal of Treatment

- ◆ Competent patients may decline transfer and life-sustaining treatments even if it will result in injury or their death. Their choices must be fully informed and respected.
- ◆ Ensure information provided and refusal is documented in clinical notes.

Restraints

May be indicated if a patient's behaviour poses danger to self or others. A competent patient can consent to the use of restraints, such as in an aircraft where it is a legal and safety measure.

References:

Health & disability Commissioner. *Code of Health and Disability Services Consumers' Rights 1996*. Wellington Hospital. (2019). *Policy: Informed consent – adults and children 1.2706*

Section Two

Safety

Helicopter Safety

- *Watch the Pilot*
 - Follow his/her directions, proceed when the pilot indicates
- *Approach from the Front*
 - The pilot cannot see you at the back and the tail rotor is lethal
- *Approach from the Downhill Side*
 - On a slope, approach and leave the helicopter on the downhill side
- *Blinded by Dust*
 - Crouch and wait until you can see again and re-establish contact with the pilot
- *Board a Hovering Helicopter*
 - Do this slowly, one person at a time
- *Secure all Clothing and Equipment*
 - These can be caught in the rotor wash
 - Carry all long objects horizontally

NO SMOKING OR VAPING IN OR AROUND THE AIRCRAFT

Safety around helicopters

APPROACHING OR LEAVING A HELICOPTER



Do not approach without receiving a visual signal from the pilot. Never leave without a visual or spoken instruction to do so. Stay where the pilot can see you at all times.



Crouch while walking for extra rotor clearance. Secure any loose articles such as hats and ensure your pockets are zipped up. Never reach up or chase after anything that blows away.



On sloping ground always approach or leave on the downslope side for maximum rotor clearance.



If blinded by swirling dust or grit, STOP - crouch lower, or sit down and wait for assistance.



Never approach or leave a helicopter when its engine and rotors are running down or starting up.



Carry long objects horizontally below waist level - never upright or on the shoulder.

TAKE-OFF, LANDING, AND LOADING OPERATIONS



Clear helipad of loose articles. Secure your gear from the effects of rotor wash.



When directing the pilot for landing, stand with back to wind and arms raised.



When transporting personnel, loading staff should ensure that:

- ✓ passengers are briefed on approaching and leaving the helicopter
- ✓ they are grouped together and positioned to one side of the landing zone
- ✓ they protect their eyes against blowing dust and particles
- ✓ each person looks after their own gear
- ✓ they are ready to board in turn as soon as the pilot gives the signal, and they are escorted to the helicopter.

Fasten and adjust your seat belt on entering the helicopter and leave it fastened until the pilot signals you to get out.



When directing the pilot by radio, remember they may be too busy to give a reply.



Te Kaitiaki Take Kōwhiri
New Zealand Government

Revised October 2022

Fixed Wing Safety

- *Pilot*
 - Follow his/her instructions
- *Approach*
 - Be aware of
 - Other personnel in and around the aircraft
 - The positions of support vehicles
 - Other aircraft.

Never enter, exit or conduct activities around a running engine

- *Restraints*
 - Patients must be restrained with the approved stretcher fittings and maintained during the flight
 - Crew must remain buckled up during take-off and landing and when not administering nursing care
 - Advise pilot if moving around cabin
- *Communication*
 - Be familiar with the equipment
 - Refrain from talking during taxi, descent, ascent, landing and high-density air traffic operations
- *Equipment*
 - All equipment must be secured and stowed
- *Danger*
 - Fuel
 - Oxygen
 - High exhaust temperature
 - Jet blasts
 - Loose objects, such as clothing and equipment

NO SMOKING OR VAPING IN OR AROUND THE AIRCRAFT

Pre-Flight Briefing

Pre-flight briefing of persons on board an aircraft is a legal requirement, (CAA Reg 91.211, Dec 1977). This is generally delegated to the crew, if not, then the flight nurse should carry out the task.

Before boarding consider:

- Sensible clothing of patient and staff, warm not nylon
- Effects of flying when recovering from minor cold, ear, sinus infection
- No alcohol prior to flight
- No smoking during the flight
- Ensure luggage is not overweight, no hazardous materials, e.g. matches, lighter fluid, aerosol cans
- Lithium batteries
- If no toilet on board, ensure comfort stop before leaving
- Cell phones turned off or on flight mode

Discuss implications of the environment:

- Noise level, ear protection, communication
- Effects of turbulence, seatbelt secure
- How to unblock ears if they feel full or are painful

Approaching the aircraft:

- Approach on direction of the pilot or crew
- Be aware of other aircraft and vehicles in the vicinity
- Avoid the propeller area at all times
- Escort all patients and relatives to the aircraft
- Instructions on the use of steps, handholds, stretcher loading
- No loose clothing or blankets
- If blinded by dust, crouch down and wait for assistance

On board

- Instruction on how to fasten and release seatbelt. To remain fastened throughout the flight
- Instruction on emergency exits and how they operate
- All loose equipment to be stowed away and secured, no items should obstruct the exits
- Location of emergency oxygen and how it is activated
- Location of life jackets for all person on board and how they operate, not to be inflated until out of the aircraft
- Location of vomit bags
- Briefing card to read

Pilot and medical crew

- Use of electronic equipment, cell phones
- Any patient specific requirements e.g. Cabin altitude pressurisation, long roll out on landing, priority flights, appropriate PPE
- Rate of ascent and descent
- Implication of turbulence
- Heating/air conditioning needs
- Possibility of diversion due to weather, suitability facility
- ETA

Pre-flight briefings are often hurried through or ignored, but it is a legal requirement. It must be part of the flight nurses' professional responsibility to ensure that all on board are informed about the environment they are in and have as much safety information as is practical, in order to give

them the best possible chance of survival should anything go wrong. It is too late once an emergency happens.

Dangerous Goods

Articles listed below are considered dangerous goods particularly when flying and when in a non-pressurised space, such as the nose locker.

Patients/Relatives

Patients/relatives luggage should be checked for the following, removed and stowed in the pressurised cabin:

- Compressed gases, such as Butane gas in camping cylinders
- Corrosives such as acids, alkalis, mercury and wet cell batteries, which contain mercury
- Explosives, including guns, ammunition including blank cartridges, fireworks
- Flammable liquids and solids such as lighter fuel, matches, paint thinners, fire lighters
- Oxidising materials, such as bleaching powder, peroxides
- Poisons and infectious substances, such as insecticides, weed-killers and live virus materials.

Retrieving patients who have been involved in a chemical spill, petrol spill:

- Care must be taken to remove as much of the chemicals as possible before loading into the plane, due to the confined space.

Medical Crew

As medical crew, we should be aware that some of the drugs and equipment we carry come under the label of dangerous goods because of their ability to cause damage to the aircraft in some form if inappropriately used or spilled.

- Drugs, such as calcium, potassium, paraldehyde if spilled can be corrosive to aircraft materials
- Oxygen – danger of fire
- Mercury, such as that in thermometers and sphygmomanometers is corrosive to aluminium
- Administration of blood under pressure during flight without careful monitoring may result in spillage.
- Body fluids, such as blood, vomit and urine, pose an infection control risk, are corrosive to the plane and their smell can be difficult to remove.

Dangerous goods

KEEP YOURSELF SAFE. ASK YOUR AIRLINE.



LPG bottle



Lighter fluid



'Strike anywhere'
matches



Fireworks



Corrosives
and poisons



Blue flame and
single-action
lighters



Batteries and
powerbanks



Camp stove



Ammunition



E-cigarettes,
lighters and
safety matches



Aerosols



Chainsaw and
other tools

Items like these can be dangerous in the air. They might be prohibited and taken off you before you board. Some items might be allowed if packed correctly. Avoid prosecution. **Ask your airline for advice.**

Travelling with batteries?

KEEP YOURSELF SAFE. ASK YOUR AIRLINE.



Portable electronic devices

- If in checked baggage ...
Turn device OFF

✓ Carry-on
✓ Checked



E-cigarettes/vapes

✓ Carry-on
✗ Checked



Spare or loose batteries

- 20 per person
- Under 100Wh
- Individually protected

✓ Carry-on
✗ Checked



Large batteries

- Over 160Wh
- Exemptions apply

✗ Carry-on
✗ Checked

Batteries like these can be dangerous in the air. They might be prohibited and taken off you before you board. Some batteries might be allowed if packed correctly. Avoid prosecution. **Ask your airline for advice.**

Annual competency requirements for Flight Nurses (Clinical Crew)

New Zealand Aeromedical / Air SAR Standard v4.0 2024: Minimum education and training requirements, p.33-35.

Name:

Aircraft safety briefing

	Date	Fixed wing	Date	Helicopter
Specific aircraft orientation				
In-flight procedures				
Role specific equipment orientation				
Safety in and around aircraft • Safe areas • Approaching vehicles • Loose objects				
Day and night flying protocols				
EMS and general communications • Use of headsets • Procedure when unable to communicate • Cell phones				
Aircraft evacuation procedures • Exits • In the dark • Smoke filled cabin				
Emergency equipment • Life jacket drill • Life raft • Survival kit • Crash axe • Fire extinguisher				
In-flight and ground fire suppression				

In-flight emergency procedures				
• Crash • Water ditching • Depressurisation • Turbulence • Engine outage • Autorotation • Violent patient/relative				
Emergency landing procedures				
NVG cabin protocols		NA		
Management of oxygen supplies				
Use of emergency locator beacons				
Patient loading and unloading				
Refueling procedures with patient on board				
Hazardous materials recognition				
Aviation terminology				
Flight following				

Signature of Pilot/Crewperson

FW _____

Heli _____

Other training requirements

Role specific equipment orientation		
Human factors/CRM/Threat & error management		
Physiological effects of altitude		
Stressors of flight		
Survival training		
HUET (3 yearly)		
Audit and review processes		

AM I FIT TO FLY? REMEMBER THE

I'M SAFE

✈ CHECKLIST

I



ILLNESS

Free of illness
and symptoms

M



MEDICATION

Safe medication only

S



STRESS

Managing stress well
at home and at work

A



ALCOHOL AND DRUGS

Free of alcohol and
drugs and their effects

F



FATIGUE

Rested and
sleeping well

E



EATING

Fed, watered,
and ready to go



Ta Kāwanatanga o Aotearoa
New Zealand Government



CIVIL AVIATION AUTHORITY
OF NEW ZEALAND
Ki te huarua, huarua te huarua

courtesy of the Civil Aviation Authority of New Zealand

It's Only A Cold!

By Dr. Dougal Watson

So your throat is sore, your nose running and your head throbbing as if to burst. You can't help speaking with a characteristic nasal twang causing friends and colleagues alike to comment or ask "Got a cold have we?" Between coughs and sniffles you're forced to reply "Yair but it's not a problem. It's only a little cold, I should be over it in a couple of days!"

This is a familiar story around most homes and workplaces and indeed a cold usually isn't much of a problem. The situation could be very different if, however, you plan to travel in an aircraft while suffering from this usually inconsequential ailment.

I'd like to tell you a little bit about colds, what they are, what they do to your body and most importantly how these effects can alter your suitability to pilot an aircraft. This should allow you to make an informed decision, the next time you've got a cold, concerning your fitness to fly.

A cold is proper cause for taking the responsible action of voluntarily and temporarily grounding yourself from flying. I've suffered the pain and distress of bilateral haemotympanum (that's bleeding into the eardrums of both ears, the stage before perforation or rupture of the eardrums) during an aerobatic spin sequence when, unknowingly, I was brewing a cold. I've also seen usually stout military aircrew reduced to tears of pain during descent because having a cold rendered them unable to clear the pressure in their facial sinuses. Although a minor ailment to most folk, a cold is a potential disaster to aviators (and those that fly with us).

What Is A Cold?

A cold is an infection, caused by any one of a hundred or so related rhinoviruses. It usually takes one or two days for a cold to incubate or brew once you've 'caught' it.

The first symptoms you notice are usually tiredness and irritability along with a tickly, scratchy throat, blocked or runny nose and a mild headache. The runny nose (rhinorrhoea) usually increases over the next couple of days and then settles rather rapidly as the whole illness resolves. Bouts of sneezing may also occur. A fever is unusual during the common cold. A small number of people (around 1-2%) will develop bronchitis at the same time and have a cough that produces quantities of sputum (phlegm).

Most of us use the word 'cold' in reference to any illness or infection of the nose, throat, ears and lungs that involves a runny nose or mild cough. Many other viruses are also able to cause diseases similar to the common cold. The illness caused by these other viruses is often more severe than a common cold and may involve quite marked cough, fever, sore throat or even pneumonia.

The common cold, along with any of the above mentioned viral upper respiratory tract infections, is often more severe in children.

You won't be surprised to hear that colds are more common in the Winter and Autumn. Nobody is certain why this is the case, but it may have something to do with the increased time we all spend indoors close to other people during the colder months. For the purpose of this article I'm not going to distinguish between all of these related but different illnesses. I'm simply going to use the word 'cold' to denote any or all of the above – after all, they have similar relevance to aviators.

What Happens During the Infection?

The offending virus usually gains access to your body through the lining tissues of your upper airways, especially the nose or throat. It invades the cells there and sets about doing what viruses do best, trying to produce more of its kind and send them forth into the world to infect other cells and produce even more viruses. To do this the virus must hijack machinery and equipment within the cell. This machinery is reserved for the cell's privileged use and the hijacking may set off alarms and alert the body's defence (or immune) system.

As the virus multiplies the cell may rupture and millions of new viruses spill into the bloodstream or nearby tissues. This release of new viruses may also alert the immune system's equivalent of 'customs and immigration', ever watchful for viruses without visas. The release of new viruses causes the cell to die and the immune 'homicide squad' may also be called. The alerted immune system then mobilises to seek and destroy all viruses, bits of viruses and hijacked infected cells. This is usually achieved rapidly and the illness rarely lasts much longer than a few days. This response almost invariably results in swelling of the infected areas as the battle rages between the immune system and the infecting virus.

Once a virus has been vanquished, the immune system 'remembers' it and is able to recognise its closer relatives for a time. It is still possible for a not-so-closely-related virus to cause another cold soon afterwards and the memory eventually fades so that the same virus may again cause a cold some time in the future.

You can spread a cold to others because as you breath out virus particles may leave your nasal area in the air or within tiny fluid droplets. If someone near you breaths in some of the virus particles, the whole process may start afresh in their nasal passages.

How Can A Cold Affect Flying?

The two features of a cold that are most important to aviators are the overflow of new viruses into the bloodstream and the swelling of nose and throat tissues. The first of these, the release of new viruses from their host cell into the body is often called the 'viraemic phase'. This viraemic phase usually results in the headaches and general feeling of tiredness, lethargy and unwellness that is usually associated with a cold.

Anything that makes you feel tired and unwell is a distraction from flying and may well impair your decision making abilities at a critical moment. The viraemic phase of a cold is no exception and our mental and physical performance is always impaired. As aircrew we can ill afford any impairment of our performance that may affect our safety and that of the craft we fly and those that choose to fly with us.

As the tissues lining the nasal area swell the tiny openings to the ears (eustachian tubes) and the sinuses (ostia) become narrowed and may close over. Closure of these small tissue lined tubes makes ear and sinus pressure equalisation difficult or impossible. Inability to equalise our ears and sinuses during ascent or descent may result in pain and tissue damage. The term barotrauma (as in barometer) is used to refer to these pressure related tissue damage.

The pain of sinus and ear barotrauma can be of crippling intensity leaving the sufferer unable to devote attention to the task of flying. The tissue damage, which could include rupture of the eardrums or the filling of a sinus with blood, may adversely affect our short and long term 'fitness to fly'. It's really not worth the risk.

What Can You Do?

The first action for an aviator with a cold is the simplest, but often the most difficult. When you have a cold you are most certainly not fit to fly. It's as simple as that; the risks are just not worth it. To fly whilst suffering a cold a professional aviator would be exposing his passengers, cargo and employer to an added, avoidable risk while a sports aviator exposes himself, his passengers and his craft to the same unnecessary risks.

As an air passenger you are still exposed to the same risks during a cold. It is unlikely, though, that as a passenger you could cause the wreck of an aircraft or the injury of others. Should you choose to travel by air as a passenger while you've got a cold there are a few things you might find useful knowing.

There is no cure (yet) for the common cold! Our immune system is the only avenue we have for ridding our body of the cold virus. To function at its peak our immune system must be maintained by a sensible and well-balanced diet. Large doses of vitamins or mineral supplements do not cure the common cold. The body also requires adequate rest for its immune system to remain in peak condition.

Antibiotics do not cure colds! Viruses are immune to antibiotics. It is only when the cold is likely to become complicated with a second, overlapping bacterial infection that antibiotics have any place at all in the management of colds. Anyone healthy enough to maintain an aircrew licence is extremely unlikely to suffer any bacterial complications of a common cold.

It is only if the cold symptoms are sufficiently severe that medication has any place in treatment of a cold. Even then the only effect that medicine will have is some relief of the symptoms. Medication can't cure or dispel a cold. Aspirin or Paracetamol will help to relieve a headache or sore throat and may settle a mild fever. Decongestants will reduce some of the swelling of the nasal lining tissues and may make it easier to equalise the ears or sinuses. It may also be possible to relieve an irritating cough with a cough mixture or tablets.

Conclusion

- A cold is an upper respiratory tract infection caused by any of a large number of viruses.
- There is no cure for a cold, the body's immune system must be allowed to fight the infection.
- Adequate rest and a sensible diet are the best ways to help your immune system.
- Flying with a cold is just not worth the risk.

This article was originally published as: **"It's Only A Cold!"** in the AOPA (Australia) Magazine, Vol. 44, No. 9, September 1991.

Section Three

Flight Physiology & Stressors of Flight

Aeromedical Transport – ‘Do it on the Ground not in the Air’

Objectives

Describe the significance of gas laws in aeromedical transport and understand the effect of altitude.

Demonstrate knowledge of the stresses of flight.

Demonstrate how to safely prepare a patient for transport.

Discuss in-flight and post-flight care.

Flight Physiology

In-depth knowledge of flight physiology together with adequate time spent preparing the patient is essential to provide optimal patient care in the aeromedical environment.

Normal physiological responses to change altitude are further complicated when transporting an already compromised patient.

It is not simply a case of using any aircraft and whatever medical staff might be available.

STRESSORS OF FLIGHT “GHOST BAN”

G-Forces
Humidity - Dehydration
Oxygen – Hypoxia
Shakes - Vibration
Thermal
Barometric Pressure
Activity & Fatigue
Noise
+
Third Spacing

Altitude Physiology and the Stresses of Flight

(Adapted from: Blumen, I.J., & Rinnert, K.J. (1995). Altitude physiology and the stresses of flight. *Air Medical Journal*, 14(2), 87-100. and EPICCNZ e-learning program induction in critical care (2024), Health New Zealand Te Whatu Ora)

Introduction

Aspects of transport medicine provide the air medical crew member with many unique challenges. This is especially true with respect to considerations related to altitude and flight physiology. An in-depth understanding of flight physiology, stresses of flight and self-imposed stress is essential for the air medical crew to provide optimal patient care in the unique aviation environment. This objective is intensified since the normal physiological responses to a changing altitude are further complicated when transporting an already compromised patient. In addition to having a direct influence on the patient and the flight crew, some medical equipment also may be affected.

The stresses of flight create a significant challenge to those providing medical care to the critically ill or injured. In general, the terms *stresses of flight* is commonly used to identify the conditions and physiological affect that the air transport environment may place on the patient and the flight crew. In addition to these stresses, there are a series of *self-imposed stresses* that can further influence crew performance, patient outcome and overall safety.

Altitude physiology and the stresses of flight will have their greatest impact during fixed-wing transport. However, it is important to realise that rotor-wing transport is not immune to these stresses.

The crew must anticipate and prevent potentially serious complications by vigilant patient monitoring and the initiation of appropriate treatment.

History

The effects of altitude on the human body have been noted for centuries. In 1783, the first, manned hydrogen balloon ascended to an altitude of 9,000 feet.¹ During this two hour flight, the solo pilot began to experience the physiologic affects of his new environment, which included a drop in temperature during ascent and a feeling of sharp pressure in one ear as he descended. Ten years later, a physician pilot and his passenger documented the first *objective* physiological changes at altitude. On the ground, the pilot's pulse was counted to be 84 beats per minute, and at altitude the pulse now was measured to be 92 beats per minute.

The dangers of high-altitude travel were demonstrated in 1804. At an altitude of more than 20,000 feet, the crew experienced vomiting, frostbite of their hands and feet and loss of consciousness. It also was observed that the flame in their lantern went out. Nearly 60 years later, two Englishmen ascended to 31,000 feet in a balloon. During this ascent, numerous physiologic changes were observed.

At 19,000 feet, the pulse increases to 100 beats per minute. At 19,500 feet, breathing was affected, palpitations were perceived, hands and lips turned blue, and the crew experienced difficulty reading on-board instruments. "Sea-sickness" was experienced at 21,500 feet; and at 28,500 feet, there was extreme muscle fatigue and a period of insensibility lasting seven minutes.

Background

Before directing our attention toward the *stresses of flight*, it is important to have the background knowledge pertaining to the atmosphere, the physical gas laws and cabin pressurisation. A general understanding of these three topics helps illustrate how the human body responds to the atmospheric changes and begins to explain several of the stresses of flight.

The Atmosphere

The air medical crew must possess knowledge of the earth's atmosphere and awareness of the effects that altitude can have on human physiology. This information will provide the essential foundation for the adaptations necessary for optimal patient care in the air medical environment.

The atmosphere is composed of a variety of gases. Up to an altitude of approximately 70,000 feet (21,319 metres), these gases exist in a uniform percentage. Nitrogen gas has the largest percentage (78.08%), followed by oxygen (20.95%). Argon, carbon dioxide, hydrogen, neon and helium – all in very small percentages – represent the remaining gases in the atmosphere.

The atmosphere can be characterised several ways. It may be described by the *layers* that are included within the atmosphere or by the *physiological zones* that predict the effects of altitude on the human body. Many of these predictable effects are based on atmospheric properties that can be observed at any given altitude. Atmospheric pressure or barometric pressure is the force or weight exerted by the atmosphere at any given point. Temperature and volume changes also will be observed at the varying altitudes. Altitude-related properties are shown in Table 1. The graphical relationship between altitude and barometric pressure is represented in Figure 1.

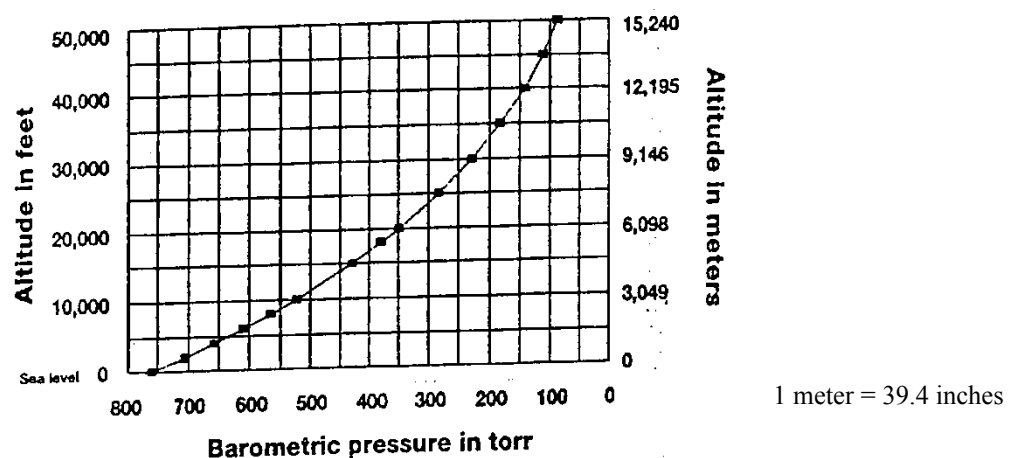


Figure 1: The relationship between altitude and barometric pressure

Table 1: Altitude-related Properties in the Earth's Atmosphere

Altitude		Barometric Pressure		Temperature		Gas Expansion Rate
feet	metres	torr	PSI	°C	°F	
0	0	760	14.70	15.0	59.0	1.0
1,000	305	733	14.17	13.0	55.4	
2,000	610	706	13.67	11.0	51.8	
3,000	914	681	13.17	9.1	48.4	1.2
4,000	1,219	656	12.69	7.1	44.8	
5,000	1,524	632	12.23	5.1	41.2	
6,000	1,829	609	11.78	3.1	37.6	1.3
7,000	2,134	586	11.34	1.1	34.0	
8,000	2,438	565	10.92	-0.9	30.4	
9,000	2,743	542	10.51	-2.8	27.0	1.5
10,000	3,048	523	10.11	-4.8	23.4	
11,000	3,353	503	9.72	-6.8	19.8	
12,000	3,658	483	9.35	-8.8	16.2	
13,000	3,962	465	8.98	-10.8	12.6	
14,000	4,267	447	8.63	-12.7	9.1	
15,000	4,572	429	8.29	-14.7	5.5	1.8
16,000	4,879	412	7.97	-16.7	1.9	
17,000	5,182	396	7.65	-18.7	-1.7	
18,000	5,486	380	7.34	-20.7	-5.2	2.0
19,000	5,791	364	7.04	-22.6	-8.7	
20,000	6,096	349	6.75	-24.6	-12.3	
21,000	6,401	335	6.48	-26.6	-15.9	
22,000	6,706	321	6.21	-28.6	-19.5	
23,000	7,010	308	5.95	-30.6	-23.1	
24,000	7,315	295	5.70	-32.6	-26.7	2.7
25,000	7,620	282	5.45	-34.5	-30.1	
26,000	7,925	270	5.22	-36.5	-33.7	
27,000	8,230	258	4.99	-38.5	-37.3	
28,000	8,534	247	4.78	-40.5	-40.9	
29,000	8,839	236	4.57	-42.5	-44.5	
30,000	9,144	228	4.36	-44.4	-47.9	3.3
32,000	9,754	206	3.98	-48.4	-55.1	
34,000	10,363	188	3.63	-52.4	-62.3	
36,000	10,973	171	3.30	-56.3	-69.3	5.4
38,000	11,582	155	3.00	-56.5	-69.7	
40,000	12,192	141	2.72	-56.5	-69.7	
42,000	12,802	128	2.47	-56.5	-69.7	
44,000	13,411	116	2.24	-56.5	-69.7	
46,000	14,021	105	2.04	-56.5	-69.7	

Table 1: Altitude-related Properties in the Earth's Atmosphere

48,000	14,630	96	1.85	-56.5	-69.7	
50,000	15,240	87	1.68	-56.5	-69.7	8.7

Layers of the Atmosphere

The Troposphere

The troposphere is the closest atmospheric layer to the earth. In general, this layer extends to an altitude of approximately 30,000 feet at the north and south poles, but only 6,000 feet above the equator. This difference is due to the rising of heated air. In the troposphere, the temperature will decrease approximately 2°C for every 1,000 feet increase in altitude. In addition, a significant change in barometric pressure will start to be seen. Helicopter transport and a considerable amount of fixed-wing transport is performed within this layer.

The Stratosphere

The stratosphere extends from about 35,000 feet to about 80km above sea level. The temperature now has achieved a constant -56°C, while barometric pressure continues to drop in the initial portion of this layer. No turbulence is experienced in the stratosphere. The majority of jet aeroplanes will routinely travel within this layer at 35,000 feet to 45,000 feet altitude.

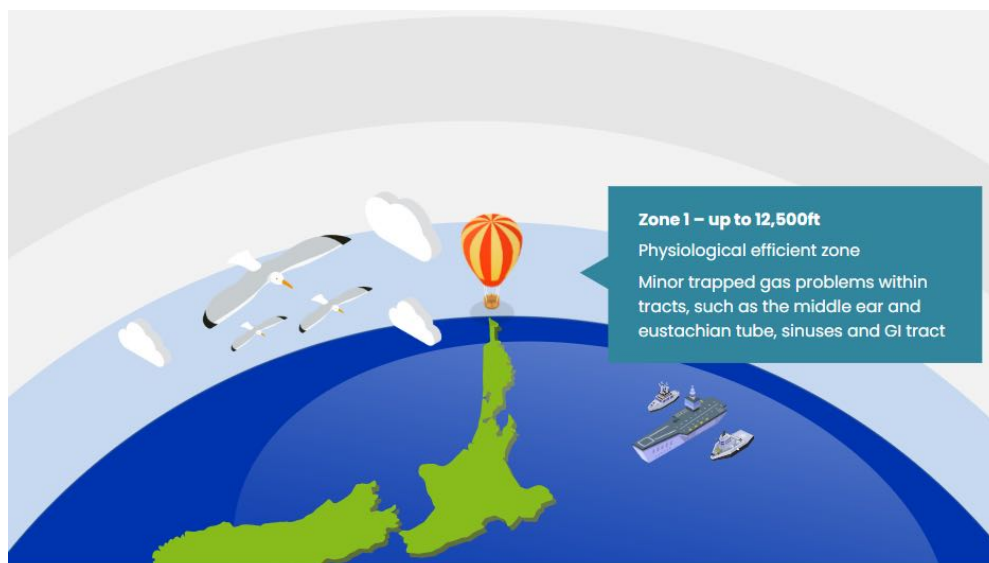
The Ionosphere

The ionosphere ranges from 80km to 960km above the earth and forms a protective shield from ultraviolet radiation. From 960km to 1,200km above earth is the *exosphere*, which represents the vacuum of space.

Physiological Zones of the Atmosphere

There are four physiological zones that compose the earth's atmosphere. These zones are characterised by the pressure changes that take place within the altitude boundaries and the physiologic effects on the human body.

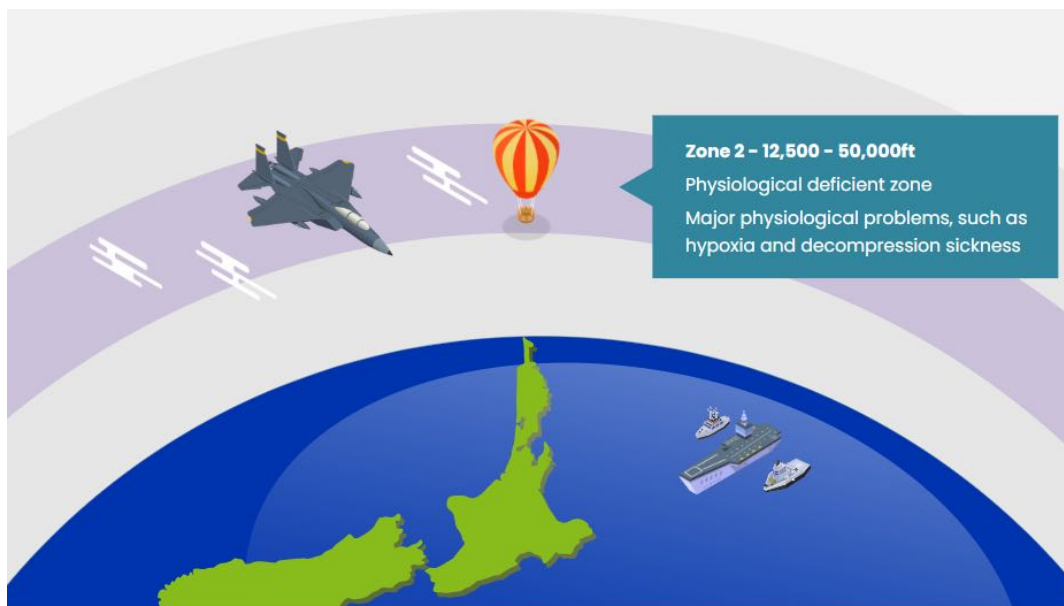
The Physiological Zone



The physiological zone, or the efficient zone, extends from sea level to approximately 12,000 feet. Within this zone, the barometric pressure decreases from 760 torr to 483 torr (torr = mmHg). This is

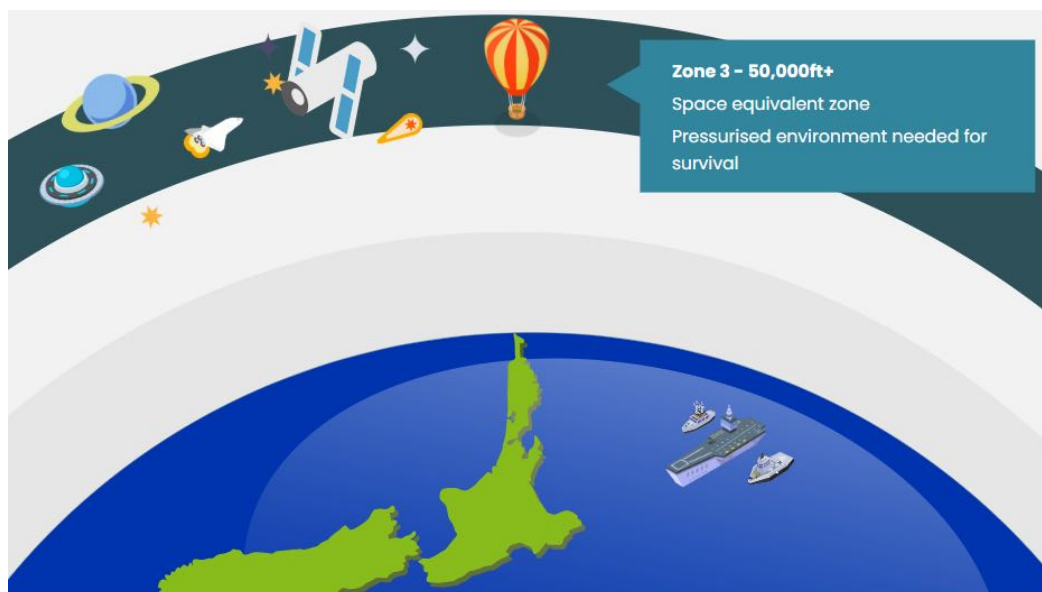
the most acceptable zone for normal physiological function unless an individual acclimatises to a higher altitude or supplemental oxygen is used. With prolonged exposure, only minor problems may occur, especially if an individual continues to ascend, exerts him or herself, or stays too long.

The Physiological Deficient Zone



A dramatic drop in barometric pressure and temperature is seen in the physiological deficient zone where the barometric pressure drops from 483 torr to 87 torr. Normal physiological function will be impaired seriously at the upper limits of this zone if there is no appropriate intervention. Most commercial and private aviation occurs in this zone and the physiological zone.

The Partial Space Equivalent Zone & the Total Space Equivalent Zone



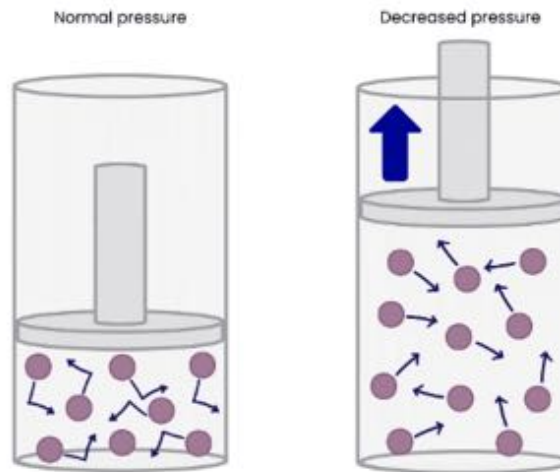
The partial space equivalent zone and the total space equivalent zone represent the final two physiological zones of the atmosphere. The partial space equivalent zone extends from 50,000 feet to 192km, where a pressurised environment is mandatory to compensate for the barometric changes that can affect the body. The total space equivalent zone, extends from 192km above sea level and beyond. Weightlessness occurs within this zone, which represents “true space.”

The Physical Gas Laws

With an understanding of the characteristics of the earth's atmosphere, knowledge of the gas laws helps explain the various physiological changes that may be experienced at different altitudes in the aeromedical environment.

Boyle's Law

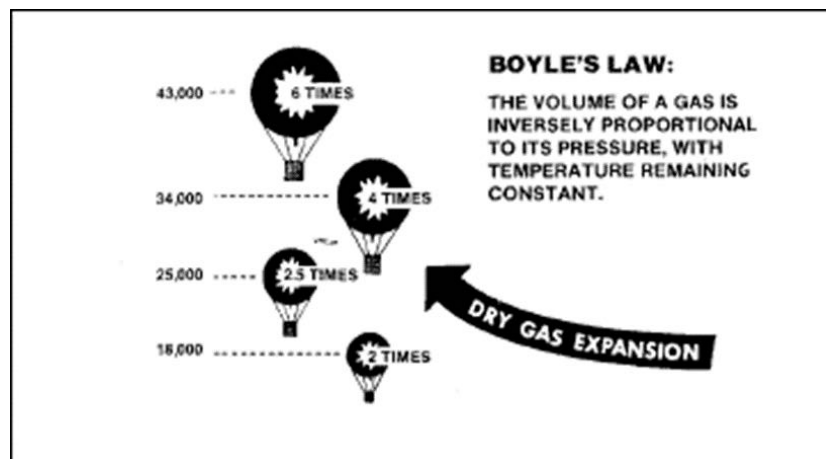
Boyle's Law relates to the expansion of gases. It states that the volume of a given gas varies inversely as its pressure.



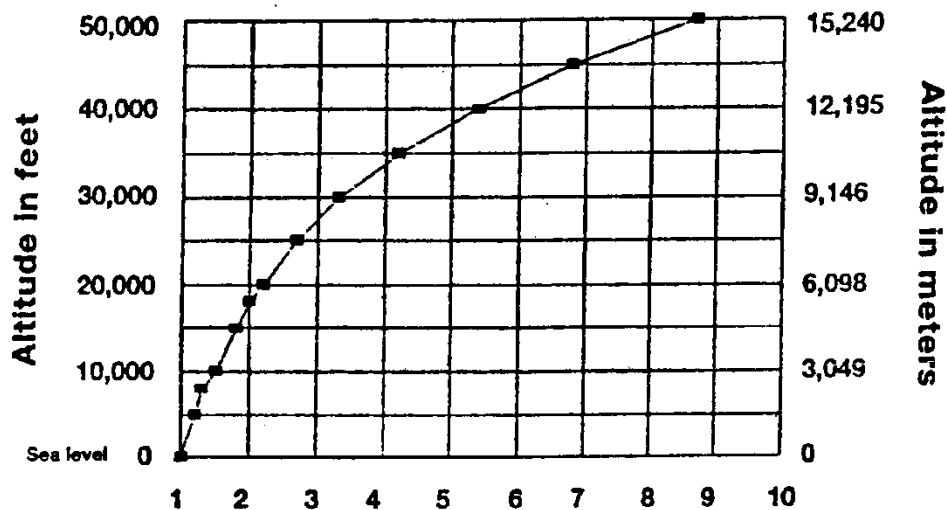
As an aircraft ascends in altitude, barometric pressure decreased and gas expands. As the aircraft descends from altitude, the reverse will be true. (See Figure 2)

Figure 2:

Boyle's Law



At the altitudes that helicopters usually fly (up to a few thousand feet above sea level, except in mountainous regions), the amount of gas expansion will be relatively small (10% to 15%). At 8,000 feet above sea level, the gas expansion will be 30%. This height is an important consideration for unpressurised aircraft and also represents the approximate cabin altitude for many pressurised aircraft flying at 35,000 feet to 40,000 feet. The relationship between altitudes and gas expansion is depicted in Figure 3.

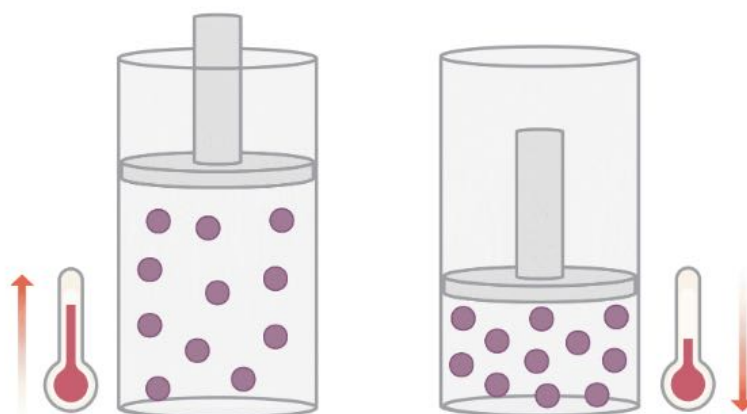


Clinical and transport considerations

- Pressurised aircraft minimises these effects
- Affects respiratory rate & depth
- Intravenous flow rates
- Expansion of gases in hollow organs, such as stomach causing nausea/vomiting, intestines, middle ear, sinuses and a closed pneumothorax
- Other potential spaces include pneumocephaly, pneumointestinalis and subcutaneous emphysema.
- Sinus pressure due to head colds/blocked sinuses
- Endotracheal tube cuff expansion
- Increased pain

Charles' Law

At a constant pressure, the volume of a gas is directly proportional to its absolute temperature. Increases in temperature makes molecules move faster. Greater force is exerted leading to volume expansion and vice versa.



Transport consideration: Gas cylinders will read low when cold such as at increased altitude, while volume remains unchanged.

Table 2: Summary of Gas Laws

NAME OF LAW	CONSTANT	VARIABLE
Boyle's	Temperature	Pressure & Volume are inversely proportional
Charles'	Pressure	Volume proportional to Temperature
Gay-Lussac's	Volume	Pressure proportional to Temperature

Dalton's Law

Dalton's Law of Partial Pressure describes the pressure exerted by gases at various altitudes, stating that the total pressure of the gas mixture is the sum of the individual or partial pressure of all the gases in the mixture. Mathematically, Dalton's Law can be represented as:

$$P_t = P_1 + P_2 + P_3 \dots P_n$$

When P_t is equal to the total pressure; and $P_1 \dots P_n$ represents the partial pressure of each gas in the mixture containing "n" gases. Within a mixture of gases, each gas will exert a pressure equal to its own percentage of the total gaseous concentration. At sea level, where the total barometric pressure is 760 torr, the percentage of oxygen is equal to 20.95%. The partial pressure of oxygen (PO_2) at sea level can be calculated as:

$$PO_2 = 20.95\% \times 760 \text{ torr} = 159.22 \text{ torr}$$

From sea level to 70,000 feet the percentage of each gas within the atmosphere remains constant.

Table 3: Atmospheric Composition at Sea Level & 10,000 Feet

Gas	Percentage within the Atmosphere	Partial Pressure (torr)	
		At sea level	At 10,000 feet
Nitrogen	78%	593	408
Oxygen	21%	160	110
Other gases	1%	7	5
Total in the atmosphere	100%	760	523

As the altitude increases and the total barometric pressure decreases, the partial pressure of the gaseous components will decrease, exerting less pressure. At an altitude of 10,000 feet, the atmospheric pressure is 523 torr (Table 3). The percentage of oxygen *remains* 20.95%, but the partial pressure of oxygen will decrease:

$$PO_2 = 20.95\% \times 523 \text{ torr} = 109.56 \text{ torr}$$

The decrease in partial pressure at altitude is an important consideration for oxygen delivery into the body. A pressure differential is required for oxygen to cross the alveoli into the bloodstream. As a result of this decrease in the partial pressure of oxygen, less oxygen is transferred to the body. In addition, as altitude increases and pressure decreases, gas expansion causes the *available* oxygen to decrease as gas molecules move farther apart in a given volume of air. Therefore, less oxygen is available to enter the lungs with each breath. The net result of these pressure changes and the gas laws is hypoxia. (See Figure 4)

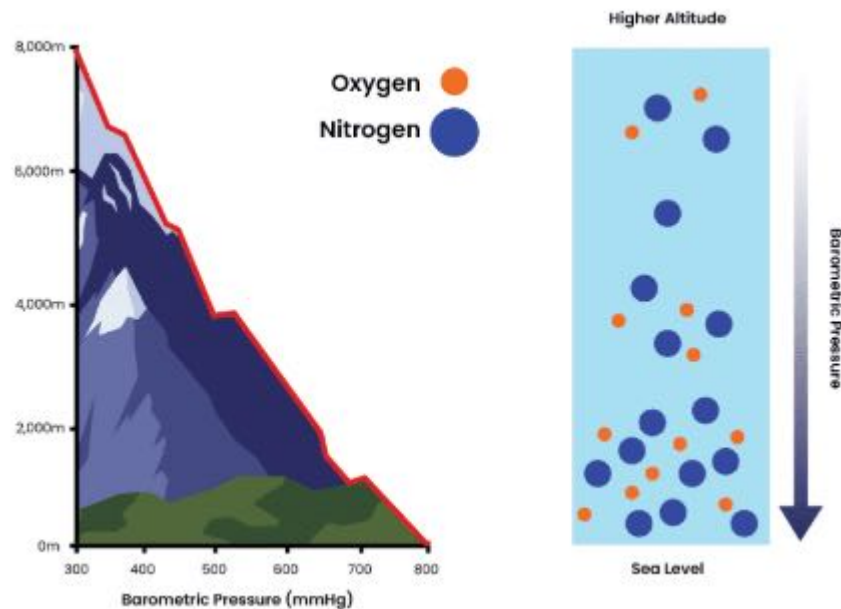


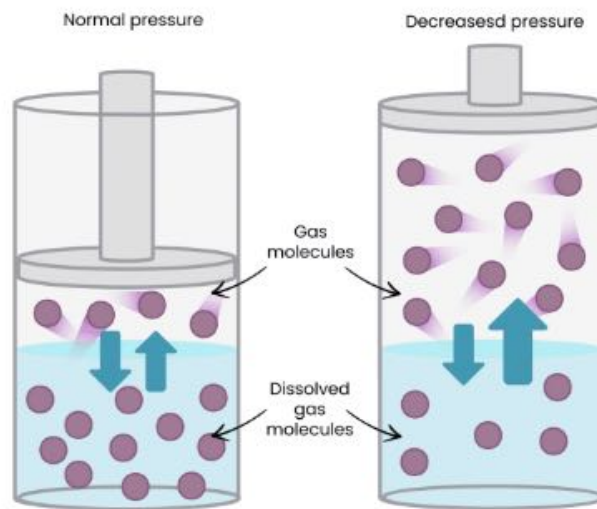
Figure 4: Dalton's Law

Clinical & transport consideration

- Total atmospheric pressure is reduced at altitude, so is the oxygen available for respiration as oxygen molecules are further apart resulting in hypoxia
- Look for signs of hypoxia or compensation such as tachycardia and tachypnoea

Henry's Law

Henry's Law explains the solubility of gases within a liquid. This law states that the weight of gas dissolved in a liquid is directly proportional to the partial pressure of the gas above the liquid. The amount of gas that will dissolve in a liquid is determined by the partial pressure and solubility of the gas.



A carbonated beverage bottle is a common example of Henry's law. The gas above the liquid creates an equilibrium with the gas dissolved in the liquid while the cap is on. When the cap is removed, the pressure decrease in the gas above the soda allows the gas bubbles within the liquid to be released. The *bends*, a decompression sickness, is another example. A scuba diver ascending too quickly can cause nitrogen gas bubble formation in their blood.

Clinical and transport considerations

- Risk of subcutaneous emphysema, expansion of a pneumothorax, gas embolism, decompression sickness
- Observe for difficulty breathing or changes in speech, cough, chest pain, increasing pain, tachycardia
- Rarely a concern if normal cabin pressure is maintained or under 25,000 feet

Cabin Altitude

The first protection against the influences of a changing altitude is the creation of an artificial atmosphere or cabin altitude. In a pressurised fixed-wing aircraft, compressed air is pumped into the cabin to maintain a cabin altitude significantly less than the flight altitude. There are three factors that work together to maintain a constant pressure within the aeroplane:

- the amount of compressed air that can be introduced based on the aeroplane's fuselage construction
- a known leak rate of air from the aeroplane
- controlled outflow of air

The amount of pressurisation in the aircraft often is set by the pilot. Therefore, the cabin altitude may vary as the flight altitude changes. In most pressurised aircraft a cabin altitude of approximately 8,000 feet can be achieved while flying at an actual altitude over 40,000 feet.

A malfunction of the pressurisation equipment or aircraft structural damage from a cracked window or foreign object may result in a loss of cabin pressure or decompression. The effects of a decompression will depend on several factors; total cabin volume, size of the structural defect in the hull, flight altitude, and the pressure differential between the flight altitude and the cabin altitude.

During a rapid decompression, there is a loss of pressure, within one to three seconds, through a large defect. This results in an explosive noise, a rapid temperature drop and flying debris towards the hole. The aircraft will fill with fog due to moisture condensation in the expanding cabin

atmosphere. Crew members, patients and equipment that are not properly restrained may be tossed about the cabin or even pushed out if they are near a large cabin defect.

Hypoxia is the most important clinical consequence of rapid decompression at high altitude. Oxygen tension in the blood will drop very quickly. Depending on the altitude, a person's effective performance quickly may be compromised. In a rapid decompression, supplemental oxygen must be applied first to the pilot and the medical crew and finally to the patient.

Another significant event caused by rapid decompression will be the rapid expansion of air within an enclosed space. All catheters, chest tubes and nasogastric tubes then should be unclamped.

Stresses of Flight – GHOST BAN

To have a better understanding of the impact the stresses of flight can have on both the patient and the medical crew, it is important to appreciate the link between “stress” and work performance. Stress results from perceived imbalance between a demand and the ability to meet that demand. Stress can cause fatigue and suboptimal work performance.

Familiarity with the stressor reduces the *physiological* impact of the stress and that consistent practice or familiarity with the task reduces the *behavioural* impact of the stress. These conclusions may be expanded to relate to many of the “routine” functions undertaken in medicine and air medical transport. Patient simulations in advanced cardiac life support, advanced trauma life support, emergency medical services disaster drills and downed aircraft drills are designed to familiarise the participants to the “task” being practised. Similarly, a thorough knowledge and understanding of the stresses of flight may prevent related complications during either helicopter or fixed-wing medical transport.

There are two types of stresses associated with the aviation environment and air medical transport. They are the “stresses of flight” and “self-imposed stresses.” These stresses are cumulative and may lead to significant compromise. GHOST BAN is an acronym commonly used to describe the stressors with third spacing an additional stress.

Gravitational forces
Humidity (dehydration)
Oxygen (hypoxia)
Shakes/vibration
Temperature
Barometric pressure
Activity & fatigue
Noise



Gravitational Forces

During routine flight operations, G-forces will not impact significantly the patient or the crew. However, an understanding of gravitational forces will explain how such forces may be relevant to aeromedical crew and patient positioning with the aircraft, as well as to safety and survival.

One ‘G’ represents the force that an individual exerts when seated and is a result of gravitational force imposed on the body. G-forces are applied to the body on ascent and descent and during a change in speed or direction. Acceleration is the rate of change in velocity and is measured in Gs. During any sudden or excessive change in direction or speed an individual or object will be subject to the effects of gravitational forces.

Newly Type-Certified rotor-wing aircraft must meet or exceed the following loads: 16 Gs forward, 20 Gs downward, 8 Gs sideways and 4 Gs upward. Load requirements for seating in fixed-wing aircraft are 9 Gs forward, 6 Gs downward, 3 Gs sideways and 3 Gs upward.

During deceleration (landing) an unrestrained or improperly restrained person in a forward-facing seat may be injured or ejected from his or her seat. In contrast, a rear-facing seat may provide better restraint during crash deceleration.

In theory, patient positioning within the aircraft may enhance or minimise the effect of G-forces during take-offs (acceleration) and landings (decelerations). For patients with cardiac disease, myocardial perfusion is improved during acceleration by positioning the patient with their heads

towards the back (aft) portion of the aircraft. As negative G-forces are increased, pooling of blood occurs in the upper part of the body. In head-injury victims or fluid-overload patients, it may be desirable to augment positive G-forces, which would pool blood in the lower extremities. This is accomplished by positioning the patient with his or her head toward the front (fore) portion of the aircraft. In a head-injured patient, this may reduce the risk of a transient increase in intracranial pressure during takeoff.⁶

Humidity & Dehydration

As altitude increases and air cools, moisture in the air decreases significantly. As a result, pressurised aircraft draw in dry, outside air creating an extremely dry, pressurised cabin. In addition, dry medical oxygen will predispose the patient to dehydration.

Signs of dehydration - include thirst, dry mouth, dry mucous membranes, thicker respiratory secretions, sore throat, hoarseness and dry or scratchy eyes.

Clinical considerations - To prevent dehydration during air medical transport, fluid intake (oral or IV) must be monitored carefully and patients should receive humidified medical oxygen. These recommendations are especially important during long transports. Patients who exhibit signs of dehydration should be managed aggressively before exposing them to further circulatory changes at altitude.

Oxygen (Hypoxia)

There are numerous types of hypoxia, all of which may complicate air medical transport. Regardless of the cause, hypoxia represents an oxygen deficiency in body tissues sufficient to cause impairment of physiological function¹⁵.

There are four physiologic classifications of hypoxia that can be described based on their various etiologies^{16, 17}.

Hypoxic hypoxia - also referred to as *altitude hypoxia*, is caused by an inadequate gas exchange at the alveolar-capillary membrane. The combined effects of the physical gas laws explain the etiology of this type of hypoxia at altitude. An inadequate supply of oxygen to the blood results in an oxygen deficiency to the tissues. Common causes include an airway obstruction, ventilation/perfusion.

Hypoxic hypoxia represents the most common and most serious cause of hypoxia encountered at altitude. This may become apparent above an altitude of 10,000 feet. If there is no compensatory mechanism or treatment, the blood oxygen saturation will drop precipitously. At sea level oxygen saturation of 98% will drop to 87% at 10,000 feet and at 22,000 feet will be only 60%¹⁶. The effects of the various altitudes on PAO₂ (arterial oxygen) are listed in Table 4.

Hypemic hypoxia – Caused by a reduction in the oxygen-carrying capacity of the blood, also termed *anaemic hypoxia*. Blood loss, anaemia, drugs, dyshemoglobinemias, excessive smoking and carbon-monoxide poisoning are common causes.

Table 4: Effects of Altitude on Oxygenation

Altitude (feet)	Barometric Pressure (torr)	PAO ₂ (torr)	PaO ₂ (torr)	PaCO ₂ (torr)	Oxygen Saturation
0	760	159.2	103.0	40.0	98%
1,000	733	153.6	98.2	39.4	
2,000	706	147.9	93.8	39.0	
3,000	681	142.7	89.5	38.4	
4,000	656	137.4	85.1	38.0	
5,000	632	132.5	81.0	37.4	
6,000	609	127.6	76.8	37.0	93%
7,000	586	122.8	72.8	36.4	
8,000	565	118.4	68.9	36.0	
9,000	542	113.5	65.0	35.4	87%
10,000	523	109.6	61.2	35.0	
11,000	503	105.4	57.8	34.4	
12,000	483	101.2	54.3	33.8	
13,000	465	97.4	51.0	33.2	
14,000	447	93.6	47.9	32.6	
15,000	429	89.9	45.0	32.0	84%
16,000	412	86.3	42.0	31.4	
17,000	396	83.0	40.0	31.0	
18,000	380	79.6	37.8	30.4	72%
19,000	364	76.3	35.9	30.0	66%
20,000	349	73.1	34.3	29.4	
21,000	335	70.2	33.5	29.0	60%
22,000	321	67.2	32.8	28.4	
23,000	308	64.5	32.0	28.0	
24,000	295	61.8	31.2	27.7	
25,000	282	59.1	30.4	27.0	

Stagnant hypoxia – Caused by poor circulation in the body causing oxygen deficiency e.g. inadequate cardiac output that cannot meet tissue requirements, occlusion of a blood vessel, venous pooling, arterial spasm or long periods of positive-pressure breathing.

Histotoxic hypoxia - There is adequate oxygen on hand, but the body tissues are unable to utilise the available oxygen. Carbon monoxide poisoning, cyanide poisoning, alcohol ingestion and narcotics may result in this form of hypoxia.

Signs and Symptoms of hypoxia

During aeromedical transport, the most threatening factor of hypoxia is its insidious onset. Medical crew may be involved in flight activities and may not notice the early onset of signs or symptoms in the patient or themselves. No one is exempt from the effects of hypoxia, though the onset and severity of symptoms may vary with individuals. Some individuals may tolerate a few thousand feet more altitudes than others. However, all patients and crew members will begin to experience symptoms of mild hypoxia if exposed to a high enough altitude.

Regardless of the cause of classification of hypoxia, the symptoms are generally the same. However, there are many factors that may influence an individual's susceptibility to hypoxia. Many predisposing medical illnesses will be exacerbated at altitude, including pneumonia, chronic obstructive pulmonary disease, acute asthma, pneumothorax, heart attack, shock and blood loss. Physical activity, physical fitness, metabolic rate, diet, nutrition, emotions and fatigue influence one's threshold for hypoxia. A physically fit individual normally will have a higher tolerance to altitude-related problems, while increased physical activity will raise the body's demand for oxygen and cause a more rapid onset of symptoms. Alcohol ingestion may promote histotoxic hypoxia. Smoking produces carbon monoxide, reducing the blood's capacity to combine with oxygen. An individual's metabolic rate will increase with exposure to temperature extremes, increasing oxygen requirements and, therefore, reducing the hypoxic threshold.

Respiratory Response

4,000 – 5,000 feet - An increased rate and depth of respiration (increased ventilation) is the initial respiratory system response to hypoxia. Minimal response to hypoxia.

8,000 feet (approx.) - Arterial oxygenation saturation drops to 93%.

22,000 feet - Maximum response occurs. Minute volume (respiratory rate multiplied by tidal volume) will approximately double. A change in tidal volume is responsible for the majority of this increase, rather than an increased respiratory rate.¹⁶ Hyperventilation will result in a reduction of the partial pressure of carbon dioxide (PaCO_2), causing respiratory alkalosis and a shift of the oxyhemoglobin dissociation curve to the left. The result will allow an increased binding of oxygen with haemoglobin for transport to the tissues, but a decrease in the amount of oxygen released at the tissue level for a given saturation.

One of the effects of hypoxia on the respiratory system is to promote significant vasoconstriction of the pulmonary vascular bed. This will result in an elevation of the pulmonary arterial pressure and a subsequent increased workload on the right side of the heart. Providing supplemental oxygen acutely may relieve the hypoxia, but simultaneously may decrease alveolar ventilation. A respiratory acidosis may develop, again promoting pulmonary vasoconstriction and further increasing the pulmonary artery pressure.

An important consideration during air medical transport deals with medications that the patient may be given. Central nervous system depressants may inhibit the respiratory response to hypoxia that normally occurs at altitude. This emphasises the need to recognise the early symptoms of hypoxia, to properly monitor the patient and to aggressively treat patients who are hypoxic.

Central Nervous System (CNS) Response

A common threshold for the onset of cerebral hypoxia is a PO_2 between 50 to 60 torr¹⁶. Higher oxygen partial pressures also may be associated with hypoxic effects, based on an individual's predisposing medical condition(s), social factors, physical condition and activity level. The potent vasodilatory effects of hypoxia will overcome the hypocapnic vasoconstriction and result in an increased cerebral blood flow.

Hypoxia results in a decreased ability to function. The initial CNS signs and symptoms that may be observed include hyperactivity, restlessness, excitation, talkativeness and euphoria. The progressive effects of CNS hypoxia are directly proportional to the severity and duration of the hypoxic events. As CNS hypoxia persists, a patient or crew member will exhibit worsening mental confusion, impaired judgement, decreased attention span, impaired memory, depression, deterioration of visual field and/or depth perception, inability to interpret various other sensory input (e.g. sound, taste) and, finally, unconsciousness. Eventually, cerebral activity will cease and death will follow.

At higher altitudes, an individual's performance can be compromised greatly as a result of hypoxia. *Effective performance time* (EPT) refers to the amount of time an individual will be able to execute critical functions in an oxygen-deficient environment¹⁰. This applies to pilots, as well as medical crew members, when subjected to the same oxygen-deficient environment. Both patient care and safety of the transport could be compromised seriously if the crew is unable to initiate preventative or corrective action in flight.

As with the variable onset of symptoms, there are several factors that can influence EPT. Effective performance time will decrease at higher altitudes, with a faster rate of ascent, and with increased physical activity. In addition, the use of tobacco, ingestion of alcohol or certain medications and fatigue will shorten the EPT. The most dramatic effect on EPT is rapid decompression. The sudden loss of the artificial cabin altitude (pressurised aircraft) will result in an oxygen-deficient environment quickly. The EPT for an individual exposed to the varying altitudes is shown in Table 5.

Table 5: Effective Performance Time

Altitude (feet)	Effective Performance Time
18,000	20-30 minutes
22,000	5-10 minutes
25,000	3-5 minutes
28,000	2.5-3 minutes
30,000	1-2 minutes
35,000	30-60 seconds
40,000	15-30 seconds
45,000	9-15 seconds

Cardiovascular Response

Compared to the respiratory and central nervous systems, the cardiovascular system is relatively resistant to hypoxia. The cardiovascular response to hypoxia may be observed in two stages. An initial increase in cardiac output will be caused by escalation in the heart rate and selective vasoconstriction. This increase in the heart rate will begin at an altitude of about 4,000 feet and will achieve a maximum rate at approximately 22,000 feet¹⁶. As a result of the increase in cardiac activity, the cardiovascular system will require more oxygen. The myocardium, which is already hypoxic, will then respond with a decreased heart rate, hypotension and arrhythmias.

Physiologic Stages of Hypoxia

Having described the signs and symptoms of hypoxia, it is possible to describe the physiologic responses that can be anticipated at different altitudes. There are four physiologic stages of hypoxia.

Indifferent Stage

Illustrates the physiological findings that are seen between sea level and an altitude of 10,000 feet. The individual is usually unaware of his or her symptoms and there may be no perceived impairment. Oxygen saturation usually will reach between 90% to 98%, if there are no significant predisposing medical conditions. Heart and respiratory rates will increase in response to the hypoxia. At approximately 4,000 feet to 5,000 feet elevation, there may be an onset of visual disturbance, including blurred vision and tunnel vision. At 5,000 feet, night vision may be reduced by 10% and by 10,000 feet night vision can decrease by as much as 28%¹⁶.

Signs and Symptoms at different stages

Physiologic stage	Altitude (feet)	Signs & symptoms
Indifferent stage	Sea Level – 10,000	↑ HR ↑ RR and depth SaO ₂ 90 – 98% Blurred / tunnel vision
Compensatory stage	10,000 – 15,000	↑↑ HR & RR ↑ cardiac output, ↑ Systolic BP Fatigue, Nausea Dizziness, headache Night vision ↓ up to 50% Apprehension, irritability ↓ Co-ordination Poor judgement
Disturbance stage	15,000 – 20,000	SaO ₂ 70-80% Headache, amnesia, ↓ LOC possible Nausea, vomiting, air hunger weakness, numbness, tingling, decreased sensation (e.g. touch and pain) and impaired visual acuity ↓ coordination, speech and handwriting. ↓ reaction time, worsening short-term memory, slower thinking Over-confidence, depression, aggressive behaviour, belligerence, euphoria
Critical stage	20,000 – 30,000	SaO ₂ 60-70% Hyperventilation, Respiratory failure Cyanosis ↓ LOC Seizures Coma, Death

Compensatory Stage

Occurs between an altitude of 10,000 feet to 15,000 feet. This stage of hypoxia may be easily overlooked. There will be a more significant increase in respiratory rate and heart rate, as well as an increased systolic blood pressure and increased cardiac output. Oxygen saturation of an uncompromised person will be between 80% and 90%. Night vision now will be decreased as much as 50%. An individual may begin to experience subjective symptoms including nausea, dizziness, listlessness, headache, fatigue, air hunger, apprehension, and hot and cold flashes. Following a 10 to 15 minute exposure at 12,000 feet to 15,000 feet, CNS symptoms will be evident. Impaired coordination, increased irritability, poor judgement and decreased efficiency all may be seen.

Disturbance Stage

Individual compensatory mechanism and physiological response can no longer compensate for the oxygen deficiency, and individuals usually become aware of their hypoxic symptoms. These symptoms typically are associated with exposure to an altitude of 15,000 feet to 20,000 feet and an oxygen saturation between 70% to 80%. Some individuals, however, may have a loss of consciousness without ever experiencing any subjective symptoms.

The most common subjective symptoms include headache, nausea, vomiting, air hunger, amnesia and decreased level of consciousness, which is most common with children. Objectively symptoms may be noted pertaining to the senses, CNS, personality traits and psychomotor function. The senses will become diminished and an individual may experience weakness, numbness, tingling, decreased sensation (e.g. touch and pain) and impaired visual acuity. A decay in psychomotor function may be seen by a deterioration in coordination, speech and handwriting. Delayed reaction time, worsening short-term memory and slower thinking all correspond to impaired mental functions. Individuals may show evidence of altered personality traits, exhibited by over-confidence, depression, aggressive behaviour, belligerence and euphoria. Cyanosis may be noted, but should not be relied on as a prominent clinical indicator of the disturbance stage.

Critical Stage

The most serious stage of hypoxia. Objective findings now may include an inability to remain upright, jerking of upper limbs, seizures, rapid unconsciousness, coma and death. These findings correspond to an altitude of 20,000 feet to 25,000 feet and an oxygen saturation between 60% to 70%.

Clinical Considerations

In air medical transport, the primary “treatment” for hypoxia should be directed toward prevention. Recognition of subjective and objective symptoms should become the second priority. It is essential to use all of the appropriate and available resources to closely monitor the patient during transport, including physical exam, pulse oximetry and end-tidal CO₂.

Whether hypoxia is secondary to altitude or any other etiology, supplemental oxygen remains the cornerstone of treatment. The goal of oxygen therapy is to increase the alveolar concentration of oxygen, decrease the myocardial workload and decrease the demand on the pulmonary system.

The oxygen adjustment equation can be used to calculate the FiO₂ required at any given cabin altitude or destination altitude as follows:

$$\frac{\text{Current FiO}_2 \times \text{Current Barometric Pressure}}{\text{Destination Altitude Barometric Pressure}} = \text{FiO}_2 \text{ required}$$

For example, a patient is currently receiving an FiO₂ of 44% at a referring hospital at sea level. This patient will be transported in an aircraft at a cabin altitude of 7,000 feet. The new required FiO₂ necessary to achieve the same oxygen saturation will be:

$$(0.44 \times 760 \text{ torr}) \div 586 = 0.57$$

These calculations are useful during air medical transport. However, their use may seem less important when using pulse oximetry. When monitoring the patient with pulse oximetry, crew members tend to rely on monitor readings to alter therapy but this may not reflect adequately the patient's oxygen requirements as shown in the use of the oxygen adjustment equation.

If supplemental oxygen is applied at an appropriate FiO₂, and hypoxia is still evident, the medical crew must consider the possible etiologies: a malfunction of the on-board oxygen system, deterioration in the patient's condition, patient intolerance of a change in barometric pressure, or another etiology for the hypoxia must be diagnosed and treated accordingly.

Additional steps in the treatment of hypoxia should include reducing the altitude of the aircraft or increasing the cabin pressurisation. Whenever possible, it is recommended that the medical crew monitor the cabin altitude and communicate with the pilot any specific altitude limitations or requirements. Descending to a lower altitude will effectively increase the partial pressure of oxygen. Flight altitudes below 10,000 feet may be most preferable. Increasing the artificial cabin altitude by raising the cabin pressurisation may also be beneficial when this is possible mechanically. At times, a combination of all of these treatment alternatives may be necessary for optimal patient care.

Shakes/ Vibration

Vibration is inherent to all transport vehicles and may interfere with patient assessment and some routine physiological functions. The most common sources of vibration during air medical transport are the aircraft engines and air turbulence. During helicopter transport, vibration is most severe during transition to a hover or during turbulent weather conditions. In fixed-wing transport, vibration increases during high-speed, low-level flight and during cloud penetration in turbulent weather.

Physiological effects - Aircraft vibration may interfere with invasive and non-invasive patient monitoring. In-flight vibration also has been shown to cause dysfunction of activity-sensing pacemakers¹⁸. Exposure to moderate vibration results in a slight increase in metabolic rate and is similar to a startle reaction or mild exercise. Low frequency vibration may promote the onset of fatigue, irritability, shortness of breath, motion sickness, chest pain or abdominal pain, and blurred vision. Vibration may interfere with body thermoregulation, and its effects may be aggravated by either hot or cold temperatures. In the hypothermic patient, vibration may worsen the patient's condition. In a hyperthermic patient, aircraft vibration may cause circulatory vasoconstriction. This could override the body's compensatory cooling mechanism, impairing the ability to sweat.

Clinical considerations - Little can be done to eliminate or decrease the amount of vibration in the aircraft but effects can be minimised by avoiding or reducing direct contact with the airframe. Padding should be placed on any part of the airframe that may come in contact with the individuals on board e.g cushioned seats and stretcher pads. Direct contact with the bulkhead of the aircraft should be avoided by placing blankets or other cushions appropriately. Patients and crew members should be restrained properly at all time to minimise the effects of vibration.

T Thermal Considerations

Helicopter and fixed-wing transport can expose the aircraft, crew and patient to temperature extremes that may result in clinical and operational complications. These temperature extremes may be due to inherent seasonal changes, geographic considerations or altitude variation.

The effects of thermal exposure can be magnified by other stresses, including vibration, dehydration, and alcohol and drug intoxication. In addition, climatic temperature variations can create air turbulence that can impact negatively on the aircraft, crew or patient.

Physiological effects - Exposure to extremes in temperature – hot and cold – will result in an increased metabolic rate, causing increased oxygen demand and consumption. This may further compromise an already hypoxic patient. In addition, prolonged exposure results in impaired performance, motion sickness, headache, disorientation, fatigue, discomfort and irritability.

Clinical considerations - Many factors can exacerbate or mitigate exposure to temperature variation, such as air circulation, duration of exposure, condition and type of clothing and physical condition. Whenever possible, the air medical crew should take steps to prevent potential complications related to thermal stress. The aircraft cabin should be kept at a comfortable temperature, minimising exposure to the ambient environmental extremes. To prevent hypothermia, appropriate layers of clothing or blankets should be used to limit heat loss. In addition, wet clothing or moist dressings should be removed. Prolonged exposure to high temperatures may require increased oral or intravenous fluids to prevent dehydration. The use of increased ventilation, cool water mist or moist dressings may be of benefit.

B Barometric Pressure

The effects of a changing altitude during air medical transport may be related directly to the physical gas laws. The impact of barometric pressure changes can affect the medical crew, patient and equipment in many ways. Trapped gas will expand by 30% at 8,000 feet, and 50% at 18,000 feet.

With respect to the body's physiologic response to changing pressures, there are several types of "injuries" that can develop. These injuries can result in actual tissue damage or may cause only pain to the individual. There are three distinct terms often used when discussing the effects of barometric pressure. Dysbarism represents the general topic of pressure-related injuries. Barotrauma refers to the injuries that are a direct result of the mechanical effects of a pressure differential. The complications related to the partial pressure of gases and dissolved gases are called *decompression sickness*.

There are three mechanisms by which barometric pressure affects the body. The first follows Boyle's Law, dealing with gas within an enclosed space and changes in ambient pressure. If air is unable to escape, a positive pressure develops that may result in a rupture or the compression of adjacent structures. The second mechanism follows Henry's Law when gas dissolved in blood is released. The third mechanism applies to barometric changes in an underwater environment (e.g. scuba diving) and addresses abnormal tissue concentrations of various gases.

Barotitis Media

Barometric pressure changes resulting in disturbances of the middle ear. The tympanic membrane separates the middle ear from the outer ear. The eustachian tube, which forms a connection between the middle ear and the external atmosphere by way of the nasopharynx, usually functions as a one-way valve. This allows gas to escape, but not return to the middle ear. Gas will expand in the middle ear behind the tympanic membrane as altitude increases. During ascent, gas normally will escape through the eustachian tube every 500 feet to 1,000 feet, or when there is a pressure differential of approximately 15 torr to 20 torr. This will allow for the equalisation of pressures between the middle ear and the surrounding atmosphere.

As altitude decreases, the gas within the middle ear contracts, creating a negative pressure within the middle ear, pulling the tympanic membrane inward. Under normal circumstances, the eustachian tube will not allow the passive movement of air back into the middle ear. However, the eustachian tube can be opened actively allowing equalisation with the middle ear by using positive pressure originating from the nasopharynx or by using the jaw muscles.

Under normal situations, pressure in the middle ear is equalised without incident. However, equalisation may be compromised if the eustachian is obstructed by swelling of the mucosa, the presence of polyps, previous trauma, allergies, upper respiratory infection, a sinus problem or smoking. Therefore, flying is not recommended for crew who are symptomatic of any of these conditions.

Barotitis media can affect both the crew and patient if they do not equalise pressure successfully. A fullness in the ears may occur as equalisation takes place during ascent. A conductive hearing loss may occur as result of decreased vibration of the eardrum. Severe pain, tenderness, vertigo, nausea, tinnitus, perforation of the eardrum and bleeding can occur during either ascent or descent if pressures are not equalised. Typically, individuals will become symptomatic when the pressure differential approaches 100 torr. The severity of symptoms will depend on the individual's initial condition, rate of ascent or descent and individual compensatory mechanisms.

Air medical crew should be familiar with the early symptoms of barotitis media. Treatment is directed toward the equalisation of pressure between the middle ear and the atmosphere. Ideally, attempts should be made to equalise pressures before the symptoms become severe. Equalisation may be accomplished by yawning, swallowing or performing the valsalva manoeuvre. The Frenzel manoeuvre is another suggested treatment - forcing closed the glottis and mouth while contracting the superior pharyngeal constrictors and the muscles of the floor of the mouth. The use of a topical vasoconstrictor nasal spray may be beneficial when used 15 minutes before descent. These nasal sprays also may be helpful if used 15 minutes before take-off. If there is concern for barotitis, sleeping patients should be awakened five minutes before descent, so they can swallow more frequently. Infants can be given a bottle during take-off and landing to achieve similar results. While swallowing may reduce the likelihood of barotitis media, it may increase the incidence of gastrointestinal (GI) distress after take-off due to increased air in the stomach.

A slow descent from altitude – 500 feet/minute – is recommended to minimise the onset of symptoms. If the descent is too rapid, the pilot may have to increase altitude again to allow equalisation of pressure in the middle ear before attempting to descend again.

If pain persists after a flight, decongestants and analgesics may be used. Individuals who remain symptomatic should refrain from further altitude exposure until all signs and symptoms have resolved. Erythema of the tympanic membrane resolves within one to three days, while it will take two to four weeks when there is blood behind the tympanic membrane. A perforated tympanic membrane should be allowed to heal before flying again. This may take several days to weeks.

Barotitis Externa or external ear squeeze

The external auditory canal is normally a patent, air-filled cavity that communicates with the surrounding environment. If the external canal is obstructed, the enclosed air space will be subject to the increased ambient pressure during ascent to altitude, resulting in *barotitis externa*. This obstruction can be due to cerumen, earplugs or other foreign bodies. For this reason, tightly fitting earplugs are not recommended during take-offs, landings or significant changes in altitude.

Barosinusitis or sinus squeeze

Air normally can pass in and out of the sinus cavities without difficulty, resulting in minimal effects, if any, as a response to barometric pressure changes. However, if a person has a cold or sinus infection, the lining of the mucous membrane may become swollen. As a result, air may be trapped that will expand as altitude increases. Failure of the air-filled frontal or maxillary sinuses to equilibrate results in pain or pressure above, behind or below the eyes. Pain may persist for hours and may be accompanied by a bloody nasal discharge or epistaxis. The ethmoid and sphenoid sinuses rarely contribute to this type of barotrauma.

Treatment is similar to the treatment of barotitis media - including the use of a vasoconstrictor nasal spray and returning to a lower altitude.

Barodontalgia or tooth squeeze

Air trapped in dental fillings, caries, abscesses or crowns may result in a severe toothache. It's often associated with recent dental extraction, dental fillings, periodontal infection, periodontal abscess or tooth decay. While this is a rare problem, the pain can be severe. Treatment is directed toward preventative dental care, descending to a lower altitude and pain control. Following dental procedures, a minimum of 24 hours is advised before air transport.

Barogastralgia

Refers to the effects that barometric pressure change will have on the gastrointestinal system. Under normal circumstances, the stomach and intestines contain approximately one quarter of gas. Gas expansion during ascent may cause discomfort, abdominal pain, belching, flatulence, nausea, vomiting, shortness of breath or hyperventilation. Significant distension of the abdominal contents may result in venous pooling that may lead to syncope. In addition, tachycardia, hypotension and syncope may result from a vasovagal response to severe pain.

Barogastralgia is rarely a serious problem. However, ingesting a large amount of carbonated beverage, chewing gum (and swallowing air), eating large meals and pre-existing GI problems may all increase the amount of gas in the intestines. Wearing clothes that are loose and non-restrictive, belching or passing flatus may help prevent or relieve symptoms. Patients with a bowel obstruction or recent abdominal surgery must have a patent and unclamped nasogastric tube placed prior to transport. After a major surgical procedure, air trapped could persist. It is advisable to delay high-altitude, fixed-wing transport for 24 hours to 48 hours for these patients.

Barometric Effects on the Respiratory System

The most critical impact that altitude will have on the respiratory system is hypoxia as previously discussed. In addition, special attention should be paid to the patient with a suspected or documented pneumothorax. Due to expansion of the trapped gas, a patient with an existing closed pneumothorax is prone to further collapse if exposed to high altitude transport. Generally, once a chest tube is placed, most patients can be transported safely by helicopter or fixed-wing aircraft. If a chest tube is placed, it is important to carefully monitor the patient for evidence of hypoxia or

malfunction / occlusion of the chest tube. In addition, artificially ventilated patients must be monitored for the possible development of a tension pneumothorax.

During helicopter transport from the scene of an accident, it may not always be possible or practical to place a chest tube prior to transport. With normal ascent of 1,000 feet to 2,000 feet, the barometric pressure change will be minimal, and the change in volume of the pneumothorax will be less than 10%. If this were the only factor that might change, the patient may not be affected adversely. It is essential, however, for the crew to closely monitor the patient for any clinical deterioration during transport.

Barobariatrauma

A potential complication of barometric changes in the presence of obesity. Adipose tissue has a high concentration of nitrogen. Changes in ambient barometric pressure may weaken the adipose cell membrane allowing nitrogen to be released into the blood stream. Additionally, fat emboli may develop from the release of large concentrations of lipids.

To minimise the risk of barobariatrauma, it is recommended that the obese patient be placed on 100% oxygen for approximately 15 minutes prior to air medical transport to help remove nitrogen from the patient and reducing the risk by as much as 50%.⁸

The symptoms of barobariatrauma will be similar to those that may be seen with decompression sickness or with fat emboli. The obese patient should be observed for severe dyspnoea, chest pain, tachycardia, pallor and petechiae in areas of the neck, upper thorax or axilla.

Considerations during Pregnancy

Foetal hypoxia may be a concern during air medical transport of pregnant patients or for pregnant flight crew members. However the results of available research suggests that there is no significant risk to the mother or to the foetus as a result of air medical transport.

It has been shown that the arterial partial pressure of oxygen in the foetus is significantly lower than that of the mother. A normal foetus at sea level has an arterial oxygenation (PaO₂) of 32 torr in the umbilical arterial circulation. The mother's PaO₂ will be approximately 100 torr⁹. At an altitude of 8,000 feet, the mother's PaO₂ will drop to 64 torr and a saturation of approximately 90%, while the foetal PaO₂ will drop only from 32 torr to 25.6 torr.¹⁰ Another study looking at this topic showed no evidence of foetal hypoxia with cabin altitudes of 1,100 feet to 7,000 feet for flights up to 80 minutes long.¹¹ In addition to the lower arterial partial pressure of oxygen in the foetus, it has been shown that the oxygen dissociation curve for foetal haemoglobin differs from that for mature haemoglobin. Consequently, foetal haemoglobin is more fully saturated at a lower PaO₂ than is the mother's¹⁰.

Barometric Effects on Medical Equipment

Air enclosed within a confined space in any piece of medical equipment will be subject to the changes in atmospheric pressure. This phenomenon may complicate medical care, creating challenging and unusual problems for the air medical crew.

Endotracheal tube cuffs will be affected by the change in altitude and should be evaluated to prevent balloon rupture or excessive pressure on the tracheal wall during ascent. During descent, an inadequate air seal may develop. The air in intravenous containers will expand on ascent resulting in an increased flow rate. On descent, the flow will slow as air volume is decreased. Military antishock trousers and pneumatic splints also may be affected by pressure changes. At altitude, compartment syndrome may develop and distal circulation may be compromised. On descent, inadequate support may occur from inadequate air pressure in the pneumatic splints.

Decompression Sickness

A loss of cabin pressurisation may result in a variety of decompression sicknesses, as gas dissolved in blood is released. The altitude threshold for this complication is approximately 18,000 feet. However, this is rarely a problem under 25,000 feet¹² unless there has been recent exposure to compressed gas (e.g. scuba diving). An exposure of 30 minutes to three hours at altitudes from 26,000 feet to 47,500 feet will result in a 1.5% incidence of decompression sickness, with the severity increasing with increased altitude and prolonged exposure.¹³

The *bends* refers to a musculoskeletal syndrome involving the joints and is caused by the release of nitrogen gas from the blood into the tissues surrounding the joint. A sharp, throbbing or dull ache is a common presentation. In addition, there may be associated numbness or tingling. The most common joints affected are the knees, shoulders and elbows. Symptomatic relief may be obtained by splinting the extremity or by applying pressure over the affected joint. Massaging or moving the affected extremity often exacerbates the pain. The bends occur up to 75% of all decompression injuries.

The *chokes* is caused by gas embolisation that obstructs the pulmonary vasculature. Classic symptoms include shortness of breath, cough and substernal chest pain, tightness or burning sensation. The shortness of breath is described as a feeling of suffocation and the individual becomes tachycardiac, tachypnoeic and hypoxic. An uncontrollable dry cough is common, which is exacerbated by deep inspiration. The chest pain is most frequently appreciated with deep inspiration, increased activity and smoking. There is no radiation of the pain to the neck, arms or abdomen.

Cutaneous forms of decompression sickness may cause a variety of skin rashes with or without tingling, numbness and itching. The release of gas bubbles also can cause subcutaneous emphysema, often involving the neck and other sites. If the neck is involved, the individual may complain of difficulty breathing or swallowing, and may notice a change in phonation.

Other vital organs, including the brain, may be affected by decompression sickness. This may result in headache, visual disturbances (blurred vision, blind spots), sensory disturbance, partial paralysis, confusion, face or jaw pain, seizures or loss of consciousness.

High-flow oxygen (100% FIO₂) and rapid descent represent the emergency treatment for all forms of decompression sickness. Treatment in a hyperbaric chamber will be necessary for severe symptoms that do not resolve.

Scuba divers should pay special attention to the possibility of decompression illness. An underwater dive to a depth of 30 feet with compressed air will cause the body to absorb twice the normal amount of nitrogen. As a result, flying above 8,000 feet will be equivalent to a non-diver flying at 40,000 feet in an unpressurised aircraft. Nitrogen gas bubbles may escape into the body resulting in a decompression sickness. The Federal Aviation Administration recommends that scuba divers delay flying as follows: at least 12 hours after diving to a depth greater than 30 feet, or at least 24 hours after an ascent requiring staging.¹⁴



Activity & Fatigue

By understanding the elements that cause and contribute to fatigue, air medical crew may be able to mitigate the impact of this stressor. Fatigue is a state or condition that follows a period of excessive mental or physical activity or inactivity. While fatigue is considered one of the stresses of flight, it also may be considered an end product of the contributing factors that make up the stresses of flight. Hypoxia, G-forces, barometric changes and dehydration contribute to fatigue. In addition, the emotional and physical stress of prolonged patient care in the air medical environment may add to crew fatigue.

N Noise

Noise and vibration may represent the most difficult and troublesome stresses encountered in the air medical environment. Noise may be considered any loud, unpleasant or unwanted sound and may be annoying, cause speech interference and promote hearing loss. Excessive noise, within any transport vehicle air or ground, may interfere with and complicate patient care. In helicopters and fixed wing aircraft, the main source of noise comes from the engines, rotors/propellers, air turbulence and on-board ventilation systems. In addition, noise from aviation radios and medical equipment (e.g. monitors, ventilators, alarms) all contribute to airborne “noise pollution.”

Physiological effects - As with many of the stresses of flight, there is individual variation in tolerance and effect of noise. The longer the exposure and the more intense the noise, the greater the potential damage. Prolonged and intense exposure to noise may result in a deterioration of work performance, headaches, fatigue, nausea, visual disturbances, vertigo, general discomfort and ear damage, either temporary or permanent.

Transport considerations - During transport, it may be impossible to accurately auscultate the lungs or blood pressure. Inadequate communication between the medical team and an awake patient may interfere with the detection of changes in symptoms or condition. As a result, the crew must rely on other means to monitor and assess patient condition. Close observation for alteration in the patient’s respiratory rate, chest expansion, level of consciousness, discomfort and abdominal distention, may indicate a possible change in the patient’s condition. Blood pressure can be monitored through invasive or non-invasive devices. Pulse oximetry & EtCO₂ monitoring provides valuable information about the patient’s oxygenation and respiratory status particularly when assessing intubated patients. Both the crew and patient should wear some form of noise attenuation device during aircraft operation. Options for hearing protection include earplugs, headsets and helmets.

Third Spacing

Long-distance or high-altitude air medical transport may precipitate third spacing, which represents the loss of fluids from the intravascular spaces into the extra-vascular tissues. This occurs in response to a decreasing ambient pressure surrounding the vessel walls and may cause leakage of fluid from the intravascular space into the surrounding tissues. Additionally, increased intravascular pressures or increased permeability of the vessel walls may also contribute to fluid loss.

The onset and complications of third spacing may be aggravated by pre-existing medical problems or other stresses of flight. Patients with pre-existing fluid leakage, including cardiac patients or those with nephrotic disease, may be at increased risk for third spacing. In addition, exposure to excessive G-forces, vibration and temperature extremes may also exacerbate third spacing of fluids. Signs and symptoms include oedema, increased heart rate, decreased blood pressure and dehydration.

Self-Imposed Stress

A patient or crew member's self-imposed stresses can influence greatly their physiological performance during air medical transport. Therefore, a clear understanding of these stresses is important for optimal patient care. Self-imposed stresses are often under direct control of the individual. The acronym "DEATH" may be useful to remember these stresses that include: Drugs, Exhaustion (fatigue), Alcohol, Tobacco, and Hypoglycaemia (diet/dehydration).

Medications (prescription and non-prescription) and the medical conditions for which they are taken may interfere with performance, perception, decision-making and motor skills. Crew members must be aware of the side effects, overdose reactions, allergic response and synergistic effects of medication they may be taking.

Exhaustion or fatigue must be avoided to prevent errors in judgement, poor attention span and a decrease in work capacity and performance. In general, the first type of fatigue to develop, *acute fatigue*, is accompanied by a feeling of being tired, desire for rest, inattention, distraction, errors in timing, need for greater stimuli, neglect of secondary tasks, loss of accuracy and control and unawareness of error accumulation. Acute fatigue is usually remediated by adequate sleep. Flight crews may be subject to rotating shifts or changes in time zone that can affect their sleeping patterns and further complicate a transport.

Chronic fatigue, potentially more serious than acute fatigue, represents a self-imposed stress rather than a stress of flight. Presenting signs and symptoms include: physical and mental tiredness, insomnia, depression, irritability, poor judgement, loss of appetite, weight loss, and slowed reaction time. In some cases, the underlying cause may be related to personal factors (e.g. family, money and so on).

Causative agents for both acute and chronic fatigue must be addressed accordingly so as not to compromise patient care or jeopardise personal or transport safety.

The effects of alcohol ingestion tend to be exacerbated "at altitude". One drink at 10,000 feet is equivalent to two to three drinks ingested at sea level. Similarly, the effects of tobacco are magnified during flight. The carbon monoxide by-product of smoking at sea level may result in mild hypoxia similar to that seen at an altitude of 8,000 feet. This may occur with as few as three cigarettes.

Diet represents the final self-imposed stress. An inadequate diet can result in nausea, headache, dizziness, errors in judgement and loss of consciousness. Precautions should be taken to avoid the development of hypoglycaemia or dehydration.

Recommended Altitude Restrictions for Medical Conditions

Note – This is an older guide and is subjective – clinical judgement is required and consideration of the patient's specific pathology and how this may be affected by increasing cabin pressure.

10,000 Feet	Any Symptomatic cardio-respiratory disease
8000 Feet	Marked Ventilatory restriction: Pregnancy Pleural Effusion Pleural Fibrosis More than mildly symptomatic cardio-respiratory disease
6000 Feet	Myocardial Infarction 8-24 weeks ago Space occupying lung lesion Angina Pectoris
4000 Feet	Anaemia Acute traumatic Brain Injury CVA Decreased level of consciousness Recent Eye Surgery Severe Pulmonary emphysema
2000 Feet	Gas in body cavities unable to be drained Severe Cardiac disease with cyanosis or recent decompensation MI up to 8 weeks ago Retinal Injury Clinical Cyanosis Cor-pulmonale Respiratory Acidosis Bullous Emphysema Ventricular Arrhythmias Congestive Heart Failure Traumatic Brain Injury and raised ICP Post Craniotomy CSF leak Severe Facial Injuries GI disturbances: Strangulated Hernia Acute Appendicitis Recent GI Surgery Peptic Ulcer Disease Diverticulitis Intestinal obstruction
Sea Level	Untreated Pneumothorax Pneumocephaly Decompression Illness Air Emboli Perforating Eye Injuries Venous or arterial grafting less than 21 days ago Chest Tubes removed less than 72 hours previously High altitude pulmonary oedema (HAPE) High altitude cerebral oedema (HACE)

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King Air Fixed Wing Operating Cabin Altitudes

Actual Airplane Altitude (ft)	Achievable Cabin Altitude (ft)	Flight Direction (North or South)	Turbulence	Equivalent FiO ₂ at sea level (if not supplemented)
Under 10000	Sea Level 	N	More likely 	21%
10000		S		
11000		N		
12000		S		
13000		N		
14000		Transition Layer		
15000		N	Less likely	21%
16000		S		20.6%
17000		N		20.3%
18000		S		19.6%
19000		N		19.3%
20000		S		19.1%
21000		N		18.7%
22000		S		18.3%
23000		N		17.8%
24000		S		17.4%
25000		N		17.2%

Section Four

Transfer Process

Patient Referral

Referral processes for acute and non-acute patient transfers differ between the various flight services in NZ. For any service there should be a process for referral, assessment and decision-making around the most appropriate mode of transport and medical team composition. This may include tools for identifying the category of patient and prioritisation.

The following charts outline the processes used by the Wellington Aeromedical Retrieval Service (WARS) & NICU. A PDF version can be found online [here](#).

Adult, Paediatric & Neonatal Retrieval & Repatriation Services		
Urgency and Response Ratings for Inter Hospital Transfers (IHT)		
Select one from each of PRIORITY & CATEGORY tables for each IHT event		CATEGORY²
PRIORITY¹		
1	Emergency Transfer <i>Immediate response.</i> Fastest mode of transport to achieve shortest mission time required. No avoidable delay acceptable	
2	Urgent Transfer <i>Rapid response.</i> Most appropriate mode of transport for urgent retrieval	
3	Non-urgent Transfer Acceptable to wait for most appropriate aircraft and team if within 3 hours	
4	Scheduled Transfer Acceptable to wait for most appropriate aircraft and team. Should endeavour to complete within daylight hours	
		Adult/Paediatric
A	Patients requiring invasive ventilation or other means of advanced life support such as pacing, vasoactive medication or intra-aortic balloon pump. Require both ICU flight nurse & doctor with full continuous monitoring during transfer	Critical infant, invasive ventilation and/or multiple infusions. Examples include nitric oxide or congenital heart defect with prostins, extreme prematurity, seizures or apnoeas, potential bowel obstruction, compromised airway in community/ birth centre. Requires NICU Flight nurse & NNP/NNS/doctor team
B	Patients who have undergone an acute incident requiring high dependency/coronary care or specialist treatment, not ventilated or on advanced life support, but at risk of further deterioration. Examples include myocardial infarction, subarachnoid haemorrhage, spinal injury or multi-trauma. Require an ICU flight nurse +/- doctor	Serious/stable infant requiring invasive ventilation or CPAP, tracheostomy, central lines, non duct-dependent cardiac lesions, HIE requiring therapeutic cooling, or risk of deterioration to Cat A. Requires NICU Flight nurse & NNP/NNS/doctor team
C	Patients post-treatment or investigation & not requiring intensive clinical care during flight. May be accompanied by a flight nurse or a paramedic/EMT	Stable infant, low level Optiflow, low flow or nil respiratory support, PIV line, retrieval for minor surgery or post cardiac surgery, hypoglycaemic, still requiring hospitalisation & monitoring. Requires NICU Flight nurse
D	Repatriation patients, accompanied by a flight nurse or ambulance officer only because they are transported with another patient. Usually to be discharged home or whom could have otherwise been transferred by commercial flight	Inpatient but ready for discharge, repatriation to base hospital for follow up care, no monitoring usually, post minor surgery, Requires NICU Flight nurse

1: **Priority rating 1-4** guides the response time and aircraft selection for all IHT missions

2: **Category rating A-D** guides the level of clinical support required and appropriate crew selection

A patient may be Category B but require a Priority 1 response, or Category A but require a Priority 4 response

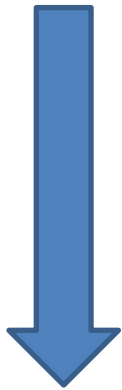
Decisions around tasking must always be made in conjunction with clinical personnel and aeromedical crew.

Priority categories use the standardised wording common to both NZ ambulance services to ensure an optimal response.

Wellington Hospital Acute retrieval flow chart (Office hours 0800-1630 Mon-Sun)

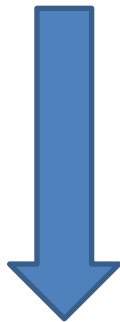
Flight Coordinator

- Receives request for transfer from referring DNM or ICU SMO
- Completes Call Sheet with basic patient information, weight, location and destination
- Confirms bed availability at receiving hospital with DNM
- Contacts **Flight Nurse** to pass on initial information
If FN not immediately available, more details must be obtained in order to discuss with ICU SMO (complete pre-flight assessment)
- Contacts Life Flight to check aircraft availability. Considers urgency, team composition, altitude restrictions, weather, weight/size limits
- Discusses with ICU SMO and establishes need for Flight Doctor or referral to Air Desk
- Assists Flight Nurse to prepare for transfer and immediate departure



Flight Nurse

- ☐ Receives Call Sheet from Flight Coordinator
- ☐ Contacts **referring hospital** - completes patient assessment, ascertains plan at destination & urgency
- ☐ Discusses with **ICU SMO** - establishes urgency & need for flight doctor
- ☐ Confirms pick up time with **Life Flight** and scans through booking form
- ☐ Contacts **Flight doctor** and advises of pick up time
- ☐ Calls **Operator 777** with heli pick up time on hospital helipad
- ☐ Gathers appropriate equipment and prepares for departure
- ☐ Advises **referring and receiving wards** of ETA



Life Flight

- Obtains patient information via booking form
- Reviews urgency rating and available aircraft
- Confirms ability to complete transfer and timing with Flight Coordinator or flight nurse
- Arranges all flight requirements – aircraft, crew, pilots, equipment
- Books road ambulances & picks up team from hospital
-

At referring hospital

- Flight Nurse advises ICU/ward ACNM of patient status and requirements prior to return + ETA
- Flight Dr calls ICU SMO to discuss patient status and flight plan
- Patient for IR/OT – team deals with key person e.g. accepting SMO/ OT coordinator with ETA
- Life Flight crew advise road ambulance of ETAs (and operator if helipad to be used)

Post flight

- Handover of patient to medical and nursing staff, documentation completed, unused medication disposed
- Advise flight coordinator of return
- Restocks drugs, bags, folder; charges flight phone and tablet
- Enters details on Flight database

Wellington Hospital After-Hours Retrieval Flow Chart

Requests for transfer are typically made by the referring hospital DNM. These requests may be received via the Flight Hotline or directly from the ICU ACNM/ ICU consultant.

Any referrals direct from a speciality Dr must be confirmed with referring DNM to ensure there is not dual team activation (e.g. Neurosurg reg., paed for PICU, Christchurch spinals).

ICU ACNM

- Answers Flight Hotline or receives referral from ICU SMO
- Completes Call Sheet with basic patient information
- Contacts **Flight Nurse**



Flight Nurse

- Contacts **Life Flight** from home to alert them of transfer, can give basic information and indication of urgency if known
- Return to hospital within 20 mins and collect Call Sheet from ICU. If time critical or >20min from hospital – complete assessment at home.

Contacts:

- **Referring DNM** – confirm plan for transfer, ensure no dual team activation
- **Referring hospital ward** - complete patient assessment, ascertain plan at destination, provide tentative ETA
 - **Accepting consultant** – if need more info around plan at destination to help prioritise acute referrals and aircraft selection
- **ICU SMO** - establish urgency, need for flight doctor +/- referral to Air Desk
- **Accepting DNM** - advise of transfer and confirm bed
- **Life Flight** - confirm flight & pick up time (office/ roof); scan booking form
- **Flight doctor** – advise of pick up time, confirm their ETA
- **Operator 777** – notify if Heli landing on roof, time and reason
- **Referring and destination wards** – advise ETA and any prep required

Other tasks:

- Collect flight bag, drug bag, controlled drugs, flight phone, tablet, folder
- Consider other equipment: Vacu-mattress, syringe drivers, BEAR air, paed equipment
- Leave flight details on ICU whiteboard & flight office whiteboard with WRH ETA
- Meet Heli on roof; don life jacket and helmet



Life Flight

- Obtains patient information via booking form
- Reviews urgency rating and available aircraft
- Confirms ability to complete transfer and timing with Flight Nurse
- Arranges flight requirements – aircraft, crew, pilots, equipment
- Books road ambulances for fixed wing transfers
- Picks up flight team from flight office (or roof if heli retrieval)

NZ Flight Services

	Ideal for...	Phone - Day	Phone - A/Hrs
ICU flight teams (ICU Dr & flight nurse)			
Northland (Whangarei)	Upper North Island	DNM 09 430 4100	ICU 09 430 4100
Auckland NZAAS	North Island, International	NZAAS 24/7	0800 111 400
Auckland Hospital ECMO or SSH PICU	Nationwide	CVICU 09 367 0000	PICU 09 307 8900
Waikato Hospital ICU	Central North Island	Transport DNM 24/7 021 242 3422 ICU SMO to SMO referral for ICU transfers 07 839 8899	
Hawkes Bay	Lower North Island	Flt coord 027 498 4413	DNM 06 878 1342 ICU SMO for ICU transfers 06 878 8109
Wellington	Lower North Island, Upper South Island	Flt coord 027 297 2549	24/7 hotline 0508 935 535
Christchurch	South Island, West Coast	Flt coord 24/7	027 290 0970
Dunedin	Lower South Island	Flt coord	027 210 5973
Air Desk - Paramedic (CCP) transfer via heli	Option for suitable time critical patients (e.g. STEMI, clot retrievals, AAA, dissections with cardiac tamponade) - discuss with the ICU SMO; they activate the AIR DESK on 0800 AIR DESK (0800 247 3375)		
WFA EAS - Frontline ICP	#6800 or 0800 244 111		

Nurse only flight teams			
Waikato Life Flight	North Island	04 399 1056	04 399 1056
Tauranga	Central North Island	Transport coord 07 579 8000	DNM 021 2284792
Tairāwhiti (Gisborne)	Central North Island	Flight coord 021 412 038	DNM 06 869 0500
Taranaki	North Island	Transport coord 0508 482 7262	DNM 027 294 3108
Whanganui 24/7	North Island, Upper South Island	Flight coordinator 021 341 354	DNM 027 222 0926
Nelson	South Island	Flight coord 022 658 4308	DNM 027 204 7411

Section Five

Patient Assessment & Management

Pre-flight management

Factors that need to be considered:

- Communication
- Urgency of transfer – what is the clinical need of the patient; why does the patient need to be transferred
- Plan at destination e.g. OT/angio versus ICU or ward for assessment
- Mode of transport – determined by patient acuity, urgency, aircraft/pilot availability, weather, altitude restrictions
- Flight team composition - Any special population groups that require alternative or additional medical and/or nursing specialist expertise e.g. difficult airways, paediatrics
- Equipment
- Medications
- Assessment and preparation of patient
- Can the patient be safely transferred to the accepting area with the current level of care maintained or exceeded during the transport period?
- Do the benefits of transport outweigh the risks of the flight to the patient
- Is the accepting area the most appropriate place for the patient post transfer; based on the clinical status of the patient (pre and peri flight) and skill and expertise of the accepting ward. Consider their Early Warning Score (EWS)

The key aspects of managing these patients effectively relies on expert skills such as communication, clinical assessment, collaboration with the multi-disciplinary team, clinical decision making and contingency planning.

Good communication is essential to ensuring the safe and efficient transfer of the patient. Communicating effectively with accepting and referring areas, ambulance crews, helicopter and fixed wing pilots and crew members is vital to ensure a smooth transfer with the patient arriving at the accepting area at the appropriate time.

The overall objective is to ensure that you have appropriately trained personnel transporting a patient safely while maintaining or exceeding the current level of care.

SAFETY cannot be underestimated and if at any time you feel unsure or unsafe, ask.

Phone assessment

Patient assessment begins as soon as the telephone handover occurs and clinical details are taken. A telephone handover may reveal important information regarding the patient's current state, but often skilled questioning is needed to elicit specific and more detailed information, especially where contingency planning is concerned. For example, will the neurosurgical patient require intubation? How likely is it that the cardiac patient will have dysrhythmias and require defibrillation during transfer?

ISBAR Communication Tool

Introduction

- Identify self and designation

Situation

- Patient location and destination
- Treatment plan on arrival at destination
- Accepting doctor

Background

- Diagnosis / mechanism of injury and treatment
- Resuscitation status – is the transfer appropriate?
- Medical and mental illness history, allergies, last meal/drink
- Risk of violence or aggression from patient and/or support person

Assessment

- Thorough patient assessment e.g. bloods, lines, medications
- Patients weight, width and mobility
- Infectious disease and isolation status. Consider need for PPE and specialist microbiology advice. Post transfer cleaning will impact on follow on transfers
- Request for accompanying support people

Recommendation

- Suggest additional interventions and treatments required prior to retrieval e.g. lines, intubation, radiology and vasoactive agents

Patient History (SAMPLES mnemonic)

This should be as thorough and detailed as possible and include the following details:

- **Signs/symptoms;** history of presenting condition
- **Allergies**
- **Medications** (normal meds and any additions whilst in hospital)
- **Past** medical and surgical history
- **Last** meal/drink
- **Events** leading up to hospital/event presentation
- **Social** and family history (including smoking and alcohol history)

Depending on the patient's condition and results of phone assessment recommendations may need to be made such as:

- Preparing specific medications
- Additional drug infusions to help stabilise the patient
- Intubation pre-arrival of the transport team if able

If asked to transfer a patient with an acute behavioural disturbance, assess the patient's capacity to consent, seeking specialist medical and legal advice. Transferring these patients may require considerable planning to manage risk. Additional personnel may be required e.g. police, mental health worker or a duly authorised officer (health professional with special responsibilities under the Mental Health Act). Patients with a high risk of violence or aggression may require sedation, intubation and ventilation.

Patient Assessment & Management

Once in the referring area, the flight nurse is able to assess the patient and carry out a full head-to-toe assessment. Immediate interventions may be required to further stabilise the patient otherwise a plan can be made for transport.

Factors to consider:

- Blood test results including ABG
- Vital signs
- Current treatments and drug infusions

The following tables describe patient assessment and considerations for management.

Planning is key to a safe transfer

Airway

Assessment	Management
Is the airway compromised? Is GCS < 12	Intubate if GCS<10 or suspicion of airway compromise; consider for agitated patients
Intubated	- ETT position confirmed on CXR - Ensure ETT secure, check size, depth, cuff pressure
If C-spine immobilisation	Use of vacuum mattress and log rolling for all spinal injuries; suction available at all times in case of vomiting; NG in situ and on free drainage

Breathing

Assessment	Management
Respiratory assessment	- Including auscultation, work of breathing, colour, SaO₂ - Suction prior to transport if indicated
If ventilated: Check mode of ventilation, PEEP, FiO ₂ Patient-ventilator synchrony?	- Ensure close monitoring of respiratory and cardiac parameters once placed onto transport ventilator, continuous monitoring of end tidal CO₂ (check correlation with ABG) - May need to change modes if not ventilating appropriately (e.g. use a pressure control mode for high airway pressures) - Provide additional sedation, analgesia and paralysis as needed
Pneumothorax/haemothorax	- Ensure chest drain is inserted prior to transport and a check CXR performed - Attach Heimlich valves/pneumostat and drainage bags to all chest drains. May be necessary to perform another chest x ray to ensure correct drainage and re-inflation of lung

Circulation

Assessment	Management
Adequate hydration? - Any active bleeding? - Urine Output - Capillary refill - Warm to touch? - Skin dry, moist or clammy?	• Ensure IDC draining and patent • Continue fluids and monitor hydration status • Consider continuous temperature monitoring for brain injured patients, spinal patients, burns and paediatrics • Take blood products if bleeding a concern • Consider continuous temperature monitoring for patients with head injuries, spinal injuries, burns and paediatrics
Body temperature	• Keep warm with blankets +/- emergency blanket, warming pad
IV access	• Patent, secure and accessible IV line, IO if required • ICU/Critical patients - at least two large bore peripheral IV lines or ideally central line insitu
Medications & Infusions - Vasopressors - Anti-hypertensives - Fluid resus	• Swap infusions to transport syringe drivers/pumps • Discontinue any non-essential fluids, infusions or NG feeds • Have vasopressors ready if particularly unstable patient Have a primed line prepared if anticipating fluid or blood product administration & pressure bag

Disability / Neurological

Assessment	Management
Assess pupils, GCS and pain	• Close monitoring of LOC, GCS and pupillary reaction • Continue ICP monitoring and continuous monitoring of cerebral perfusion pressure if ICP bolt in situ • Plan for neurological deterioration. Consider carrying additional medications such as concentrated salt (23% saline) or mannitol – kids 3% saline
Sedation & Paralysis	• Anticipate pain and discomfort and have appropriate analgesics to hand • Ensure sufficient sedation and paralysis for entire transfer – adjust rates as needed
BSL	• Protect patient's ears with ear defenders and/or ear plugs whilst in the aircraft
Nausea?	• Administer anti-emetics

Are they at risk of violence/aggression to self or other e.g. agitated, combative, pulling at lines.	• Provide reassurance and good communication with patient. Consider anxiolytics for particularly anxious patients
Can the safety of the patient and crew be maintained at all times?	• Consider intubation if no other way to safely transport patient • Explain all procedures and what to expect during the flight

Exposure - Pieces of Plastic & Integumentary

Assessment	Management
• Nasogastric or orogastric tube • IDC • Stoma with ostomy bag • Surgical drains • Intercostal/chest under water seal drains • Plaster of Paris	• Ensure nasogastric/orogastric tube placed for gastric decompression if intubated; aspirate & place on free drainage • Empty all IDC, NG, stoma and drain bags prior to transport • Attach Heimlich valve drain • Bi-valve POP if < 48 hours
Skin integrity – any wounds, pressure areas, burns	• Ensure appropriate dressings insitu and intact • Appropriate positioning and protective measures

Monitoring and equipment

- Sufficient O₂ supply available for duration of transfer
- Emergency airway equipment available
- Defibrillator pads in situ for at-risk patients
- Transducers at correct heights. Pressure bags exchanged for team equipment
- Monitoring and ventilation equipment attached as required

Whanau

- Is there a support person wanting to accompany the patient? Consider their mobility, weight, space limitations, transport mode
- Support person must be fully independent and be able to cope in confined, noisy flight environment

In-Flight Patient Care

Ensure:

- Adequately securing of patient and stretcher to prevent undue movement
- Safe loading and unloading from aircraft – high risk time for injury or lines becoming snagged/dislodged
- Safe, secure stowage of all loose equipment
- Safety from extremes of pressure and temperature changes
- Adequate oxygenation and ventilation, circulatory efficiency
- Accurate fluid and drug administration

After loading, but prior to take-off, the following checks should be completed:

- Recheck ETT placement and secured
- Oxygen supply opened and accessible
- Ventilator parameters re-assessed
- Monitors secure and provide good visual access
- IV access patent. Arterial lines secured and accessible
- IV bags secured and infusion rates checked
- Equipment and medications needed in flight are within reach
- Suction readily available
- Receiving facility has been notified of ETA and patient status
- Ground arrangements confirmed

Anticipate potential complications and be prepared to intervene as necessary.

- During transfer, monitor patient condition including vital signs, temperature, comfort and pain. Document flight and cabin altitude
- Communicate frequently to alleviate patient anxiety
- Monitor ventilator and cuff pressure fluctuations carefully
- Document vital signs, drug & fluid administration & any treatment given
- Minimise removal of seat belt

Clinical emergencies

For high risk patients consider your plan in advance in case of any deterioration in flight. Consider-

- Medications drawn up and accessible
- Role allocation – who will do CPR etc.
- Who to contact in an emergency e.g. ICU SMO and how to contact them
- Inform the pilots if there is a clinical emergency and if you require priority flights, diverting or front line ambulance to meet the aircraft
- For road ambulance, request lights and sirens capability
- Consider if the destination is still appropriate for the patient

Death during transport

This is a rare event so be aware of your service's policy for if this situation does arise. There will be logistical and legal considerations around destination and police may be required. If a support person is present, they will also need support and clear explanations; it will be difficult to meet spiritual or cultural needs in this situation.

If the death is unexpected then the coroner and police will need to be notified and determine the destination of the patient – typically the hospital mortuary via road ambulance or funeral director. Verification and record of death forms will need to be completed by the flight doctor or the patient's hospital team.

This can be a stressful event for staff – seek support as needed whether debriefing or talking with a friend or colleague or senior staff member. Employee assistance programmes are also available and can be accessed confidentially.

Post flight Care

Provide a thorough handover to receiving area along with accompanying paperwork, investigation results, referral letters etc. The patient is the responsibility of the flight nurse until handed over to the staff in the receiving area. The handover process followed in the WRH ICU includes:

- **SAFETY CHECK** – Any immediate issues that need to be addressed?
- Transfer of patient to ICU bed, monitoring, ventilator and drug infusions.
- **SAFETY CHECK** – Any issues with ventilation or monitoring? Is the patient cardiovascularly stable?
- All activity STOPS for verbal handover of information – this may be by the flight nurse or flight doctor
 - **Identification** of transfer team, patient and accepting team
 - **Diagnosis/** presenting problems
 - **Background** including identification of airway devices/lines/infusions
 - **Significant events** before ICU admission
 - **Specific instructions** from treating/accepting doctors/handover team
 - **Family** informed of transfer/admission? By who? Where are they? Any patient property/valuables?

Complete post flight vital signs, GCS and pupil check. Handover/discard and sign for any controlled drugs and complete flight documentation including any feedback forms.

Section Six

Considerations for Specific Patient Groups

Cardiac and vascular disease

Acute Coronary Syndromes

- Assessment of chest pain, 12 lead ECG, Hx, PMHx
- Management – thrombolysis, aspirin, oxygen, anti-platelet, fibrinolytic agents, beta blockers, GTN etc. Normal medications.
- Prepare transport medications e.g GTN spray, morphine, anti-emetics, adrenaline
- Defibrillation pads if high risk of developing dysrhythmias - have a plan if you think you may need to do CPR
- Consider maximum cabin altitude, may need O₂ if flying at higher altitude

Aortic Dissection

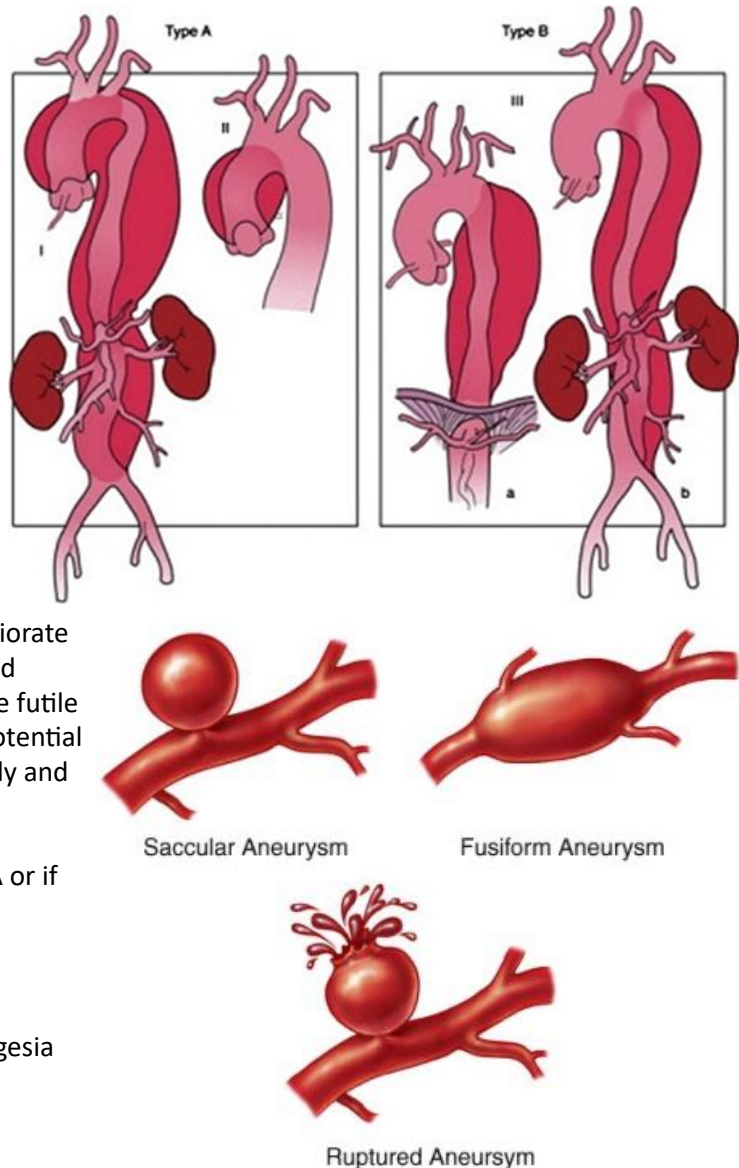
Type A dissections require surgical repair and may be life-threatening. Type B dissections may be medically managed with hypertension control and/or stenting.

Abdominal aortic aneurysms (AAA)

Once over 6cm the risk of rupture increases dramatically. Hypertension control is essential to minimise the risk of rupture. A patient with a ruptured AAA will present in a state of collapse and shock and require urgent surgery; this population has a mortality rate of up to 90%.

Good communication is essential between the flight team, receiving teams and OT/IR. A seemingly stable patient may rapidly deteriorate in flight with haemodynamic compromise and severe agitation. Resuscitation efforts may be futile in the face of a ruptured aneurysm and so potential outcomes should be discussed with the family and patient prior to transport.

- Time critical transfer if a ruptured AAA or if dissection is associated with cardiac tamponade
- Priority flights, long roll outs
- Assess pain and ensure sufficient analgesia
- Anti-emetics to prevent straining and vomiting
- 2 large bore cannulae insitu
- 2-4 units of blood boxed up and ready to go with the patient
- Arterial monitoring is the gold standard if does not delay transfer, aim to keep SBP < 100 mmHg or target as discussed with the ICU SMO/CT surgeon. Be prepared to use significant amounts of anti-hypertensive medications/infusions
- Discuss with ICU SMO the plan in event of acute deterioration – fluid resuscitation may be instituted but CPR will likely be futile particularly if airborne with substantial flight time remaining



Trauma and burns

Survival in major trauma is associated with early recognition and intervention. There are national trauma and spinal destination pathways in NZ for pre-hospital ambulance providers; however patients may still present to secondary hospitals and require timely transfer to a tertiary trauma centre. Significant burns will require transport to specialist burns centres.

Major trauma

- Thorough assessment of injury – time, mechanism of injury, passenger/driver front or back seat, GCS at scene, extrication time, Restrained or unrestrained
- Injuries sustained, spine cleared or immobilised, lacerations sutured or bandaged. Any diagnostics and treatment given
- Haemodynamic status – bleeding, continue fluid resus
- Essential medications given – antibiotics, ADT, TXA
- Barometric pressure – any air in the skull, sinuses or eyes will require a sea level cabin altitude; request long roll out

Chest and pelvic injury

- Assessment of chest injuries - if rib fractures or flail chest are present, consider if intubation and ventilation will be required for transport
- Patients with pneumothorax will require a chest drain with a Heimlich valve attached
- If a chest drain has recently been removed, a CXR should be performed prior to transport
- Ventilated patients must be monitored for development of a tension pneumothorax
- If pelvic injury is present, secure the pelvis with a pelvic binder to reduce bleeding risk

Limb injury

- Assess neurovascular status - colour, warmth, movement, sensation, pulses and capillary refill
- Plaster cast – time of application (plaster of paris splints need to be bi-valved if less than 48 hours in situ to allow for air bubble expansion in the cast and swelling of the limb)
- Any evidence of rhabdomyolysis or compartment syndrome needs to be considered prior to transport.
- Ensure recent bloods available including myoglobin, urea and creatinine if muscle damage
- Splint, elevate, analgesia
- Traction cannot be applied during transport due to a lack of space and G-forces - weights become a flying hazard

Maxillofacial Injuries

Maintaining a patient airway is of the utmost importance. If there is risk the airway may become compromised during transport then intubation or tracheostomy insertion will be required prior to transport.

If the patient has had max facs surgery and had their jaw wired, ensure there is a plan for how to release this in an emergency.

Ocular Injuries

- Ascertain MOI, penetrating or blunt injury, extent of injury, loss of vision, any other complications and other injuries to face
- Normal eye history, any past surgery or current medications/eye drops
- Pad both the eyes to maintain cleanliness and to restrict movements of eyes
- Orientate and provide reassurance
- Avoid analgesic medications that cause pupillary constriction
- Anti-emetics and naso/orogastric tube to avoid vomiting and straining hypertension
- Long flights may cause dryness and irritation of the eyes. Consider saline soaked pads over the eyes and changing regularly during the flight
- Administer oxygen – retina requires a high level of oxygen to maintain normal function
- Check with ICU SMO or ophthalmologist if unsure about the need for a sea level cabin pressure e.g. post retinal reattachment surgery, any air within the eye

Burns

The destination centre should be burns centre capable of managing the severity of the burns.

Referral criteria for the National Burn Centre (any of the following)

- Burns greater than 30% total body surface area
- Full thickness burns to the face, hands, feet, genitalia or perineum
- Burn Injury with significant inhalation injury
- High voltage electrical burns
- Significant chemical burns

Referral criteria for a Regional Burn Centre (any of the following)

- Burn > 10% TBSA in an adult. Burn >5% TBSA in a child
- Full thickness burn >5% TBSA in either adult or child
- Burns of special areas: face, hands, feet, perineum
- Electrical Burn
- Chemical Burn
- Burn associated with an inhalation injury
- Circumferential burns of limbs/ chest
- Burn at the extremes of age (e.g. <2yrs or > 70yrs)
- Associated trauma
- Any unexplained injury
- Burn injury in patients with pre-existing medical disorders that could complicate management, prolong recovery or increase mortality
- Any burn which has failed to heal with conservative management after 10 days

- Identify the time burns occurred, mechanism of injury, any loss of consciousness
- %BSA burnt, classification of burns, any other injuries sustained
- Airway assessment (think early intubation) – consider burns to face and neck, singed facial hair
- If compartment syndrome is developing in limbs, escharotomies may be required pre-transport, including to chest if thoracic burns restrict chest expansion and ventilation

- Fluid resuscitation for adults with >20% BSA burns or Paediatrics with >10% BSA burns using the modified Parkland formula:
3mls/kg/%BSA burnt. First half given in 8 hours from time of burn, 2nd half given over subsequent 16 hours.
- Monitor haemodynamic status and urine output (IDC required). Continue fluid resuscitation aiming for urine output 0.5mL/kg/hr for adults and 1mL/kg/hr for paediatrics <30kgs. If dark urine then increase urine output aim to 1-2mls/kg/hr
- Administer analgesia and sedation
- Monitor core body temperature and maintain warmth, use of heating in aircraft and road ambulances
- Appropriate dressings – glad wrap versus fully dressed, use of burns sheets to manage exudate
- 100% O₂ if carbon monoxide level elevated

Direct Referral Pathway to National Burn Centre

- Complete referral form –
<http://www.nationalburnservice.co.nz/pdf/referralform.pdf>
- Scan & email (oncallburnsnurse@middlemore.co.nz) referral and photographs
- Ring On Call Burn Coordinator (09 250 3800) to confirm receipt of referral
- On Call Burn Coordinator will call back and coordinate communication between referring team and the NBC.

Amputation Requiring Replantation

The amputated body part should accompany the patient. It should be retrieved and, with no interference, the exposed or torn muscle should be wrapped in gauze dressing moistened with saline and placed in a double plastic bag and sealed. Then place in a container of iced water to keep the amputated part from freezing. Revascularisation should be within four hours.

For transport of the incomplete amputated part, place in a normal position, dress lightly and splint. Take care not to complete the amputation. Ensure any bleeding is controlled and analgesia is administered.

Neurological and spinal cord injury

Traumatic brain injury (TBI) and subarachnoid haemorrhage (SAH) patients often require urgent transport with a specialised ICU transport team to a tertiary neurosurgical centre. SAH patients are at high risk of deterioration at any time.

TBI and SAH

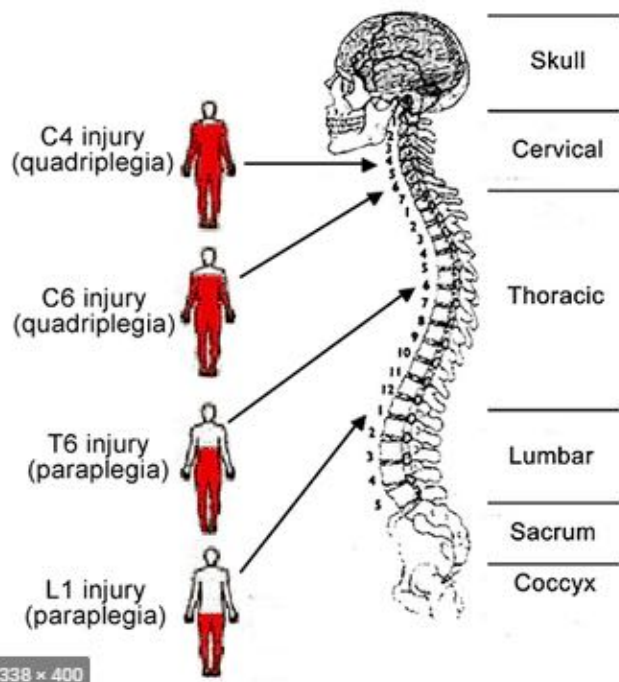
- Identify cause and mechanism of injury, concurrent injuries
- Assess neurological status – GCS, pupil size & reaction, seizures, photophobia, limb movement and strength bilaterally, any other focal changes.
- Assess haemodynamic status including ECG changes related specifically to SAH. Administer anti-hypertensives to avoid hypertension – discuss BP targets with ICU SMO or the neurosurgical team. If hypotensive then vasopressors and IV fluids may be required to maintain an adequate MAP and CPP.

- Prepare medications as required for transport including analgesia, anti-emetics, anti-hypertensives, vasopressors, concentrated salt 23%
- Review CT results – extent of bleed/ injury, any midline shift or signs of herniation? Will the patient require transport directly to OT?
- Blood results including serum sodium and electrolytes, ABG if ventilated
- Consider and minimise impact of noise, vibration, turbulence, g-forces – Long roll outs, priority flights, sea level cabin

Interventions for cerebro-protection:

- Adequate sedation and analgesia +/- paralysis
- Maintain SaO₂ >92% and if ventilated EtCO₂ 35-40mmHg
- Maintain cerebral perfusion pressure >60mmHg or MAP >80mmHg with IV fluids and vasopressors
- Hyperosmolar therapy for signs of raised ICP – Mannitol, concentrated saline 23% or 3% saline
- Avoid hyperthermia
- Position head up with neck in central alignment
- Eye and ear protection as required
- NG/OG tube
- Anti-emetics - vomiting can increase ICP by 100mmHg
- EVD management as per local policy. Clamp for take-off and landing

Level of Injury and Extent of Paralysis



Clot retrievals

Patients accepted for stroke clot retrieval require time critical transfers. Most centres have clot retrieval pathways that inform transport and management modalities.

- Assess neurological status, GCS, trends, aphasia, airway issues
- Continue thrombolytic infusion until complete
- Prepare medications for transport including anti-emetics and anti-hypertensives
- Ascertain systolic BP targets as per local SCR pathway, neurologist or ICU SMO
- Priority flights, emergency road ambulance transfer (lights & sirens capability)
- Establish key contact for ETAs to IR – often neurologist or in Auckland the stroke nurse

Spinal Cord Injuries

- Assess MOI, time, any loss of consciousness at the scene, other injuries

- Keep spine in line and immobilised, towels and hard collar, head tape, vacuum mattress – spinal precautions at all times, log roll
- Full ABC assessment + neurological state
- Assess level of sensation, dermatome level and any limb movement
- Assess respiratory function, consider early NIV
- Assess skin - log roll to ensure back and sacrum free of any tubes, leads and caps, etc. before sliding onto stretcher
- Ensure haemodynamics stable prior to transfer. Maintain MAP over 85mmHg to prevent secondary injury if incomplete cervical spinal cord injury; may require IV fluids and/or vasopressors
- NGT on free drainage and anti-emetics. Prone to paralytic ileus. Maintain NBM. Ensure suction easy to access and available at all times
- Note initial amount in bladder on insertion of IDC as important for rehabilitation. IDC patent, free of kinks

Vacuum mattress – decrease in barometric pressure causes the air to expand, depressurising the mattress on ascent and tightening on descent. Readjustment may be required using a suction unit. Long transfers in the “bean bag” can be uncomfortable for the patient so ensure adequate analgesia is provided. Monitor temperature also as the bean bag can get hot compounded by vibrations of the aircraft.

Abdominal conditions

- Comprehensive history and abdominal examination prior to transfer
- Mode of transport important to consider early – perforation of small bowel, ileus and acute appendicitis all produce gas, sea level cabin will help to reduce the risk of rupture where gas expansion may occur
- Administer anti-emetics and analgesia
- Recent bloods including Hb, Coags, Urea and electrolytes, and LFT's. If an arterial line is insitu an ABG and lactate level may be useful
- Assess for bleeding, consider taking blood and products and volume replacement
- Orogastric/nasogastric output. Ensure bag is emptied prior to transfer and tube is not kinked

Decompression Illness

- Assess cardiac, respiratory and neurological status – risk of MI, stroke and death
- Ascertain time and mechanism – Details of dive, previous experience, previous diving accidents, number of dives, max depth, number of ascents, time of onset of symptoms and nature of symptoms
- Treatment given and response to treatment
- Rapid and continuous intravenous fluid replacement (take extra)
- Consider ways of giving 100 % FiO₂, tight fitting non-rebreather, CPAP, etc.
- Consider mode of transport, if fixed wing maintain cabin pressure at sea level; rotor wing aircraft should fly as low as possible less than 1000 feet
- Patient must remain lying flat at all times to prevent air embolism in brain and stroke, no standing transfers

- Catheterise for transfer to monitor fluid balance status, aiming to keep urine output >1ml/kg/hour
- Ensure good communication between receiving area and the hyperbaric chamber staff. Notify if anything changes with the patient's status

Paediatrics

Paediatric patients have the best outcomes when transported by specialised paediatric teams. Where possible a parent or caregiver should travel with the child to reduce anxiety and provide advocacy for the child. Children <4kg or within the first 28 days of life are generally transferred by NICU transport teams. Critically ill paediatric patients should be referred to the Starship PICU team for transport or advice.

- Paediatric assessment including weight, height, LOC, immunisations, social history
- Calculate resuscitation drugs based on child's weight – use of Queensland Children's Hospital weight based charts
- Starship protocols available for management of various conditions
- Correct equipment available for age and size of child e.g. airways, IV/IO insertion
- Feeding requirements (bottle or breast), frequency of nappy changes, wet or dry nappies
- Assess respiratory status - rate, drooling, coughing, sternal retractions, in-drawing etc
- Assess haemodynamic status - colour, perfusion, heart rate, capillary refill, PEWS
- General state e.g. crying, somnolent, difficult to console, interaction with family
- Maternal and pregnancy history, delivery problems, neonatal history
- Ensure the appropriate MDTs are notified and communicated with (including social work, Oranga Tamariki, etc). This will need to be communicated to the accepting area on handover of the patient
- Ascertain which securement device will be needed – NeoMate (3.2kg – 6.7kg), BabyPod (up to 8kg), and Pedi-Mate (up to 18kg)
- Maintain warmth – ambient temperature in vehicle, blankets, clothing, beanies

Acute behavioural disturbance

Patients with acute behavioural disturbances can be challenging to manage in the transport environment. The safety of the clinical team, aviation crew/pilot, support people and the patient themselves is paramount. A comprehensive history and risk assessment should be undertaken prior to planning for transfer. Patients at high risk for aggression or violence may require awake sedation or intubation and ventilation.

- Conduct a thorough risk assessment
 - Any history of violence or aggression to self or others? Assess previous 24 hours, over admission and past history. Code blacks? How have these been managed?
 - Signs of drug or alcohol withdrawal
 - Known substance abuse
 - Recent environmental stressors (e.g. relationships, financial, death of a loved one)
 - TBI or other organic brain issue in the last 6 months affecting behaviour
 - Fear of flying

- Assess for current signs of agitations/aggression – e.g. pacing, unable to maintain eye contact, impulsive, unable to follow instructions, loud outbursts, anxious
- Plan made for management of agitation in flight - If high risk for violence/aggression - sedate well +/- intubate and ventilate
- Ensure sufficient medications to manage acute agitation – large quantities may be needed for young people post TBI, or those with hx of ETOH/recreational drug use. Medications may include IV and IM ketamine, droperidol, midazolam (including emergency IM rescue medications)
- Trial oral sedative/ anti-psychotics in advance if possible e.g. olanzapine, quetiapine
- Access to emergency equipment – airway adjuncts, BVM, oxygen, suction
- Legal considerations around mental capacity to consent to transfer and/or intubation, sectioning under the Mental Health Act
- Consider land based transport methods
- Ensure adequate IV access, use of IV extension sets
- Adequate staff to manage patient and any risks
- Are there any accompanying personnel – police, DAO, mental health workers, family

Section Seven

Obstetrics

Possible reasons for emergency transfer:

- Premature labour and threatened premature labour are the most common reasons for transfer
- Baby in need of NICU once born or occasionally women/pregnant persons are transferred out from Wellington, as there are no beds in the Wellington NNU
- Pre-eclampsia
- Mother/pregnant person in need of secondary or tertiary level care
- Placental abruption or placenta praevia - Careful thought needs to be given before transporting the mother/pregnant person with vaginal bleeding. With placental abruption the baby may perish quickly and of course a caesarean section cannot be performed in the air. The transferring and receiving obstetric teams must decide whether it is safer to deliver at the secondary hospital with subsequent neonatal retrieval, or to proceed with in-utero transfer.

Premature labour

Uterine contractions accompanied by cervical change before 37 weeks gestation. 11% of all pregnancies end in preterm labour. The baby may be viable from around 23-24 weeks.

Premature labour can be difficult to diagnose. Some women/pregnant persons have very little cervical change, and contractions that do not appear to be very strong, but go on to birth quickly. Others have an “irritable” uterus with some cervical effacement but do not establish in premature labour. Most units now have access to predictive testing, such as fetal fibronectin and/or transvaginal ultrasound to assess cervical length. These tests aim to triage those at most risk of premature birth and avoid unnecessary transfer. Premature birth is a major cause of perinatal morbidity and mortality.



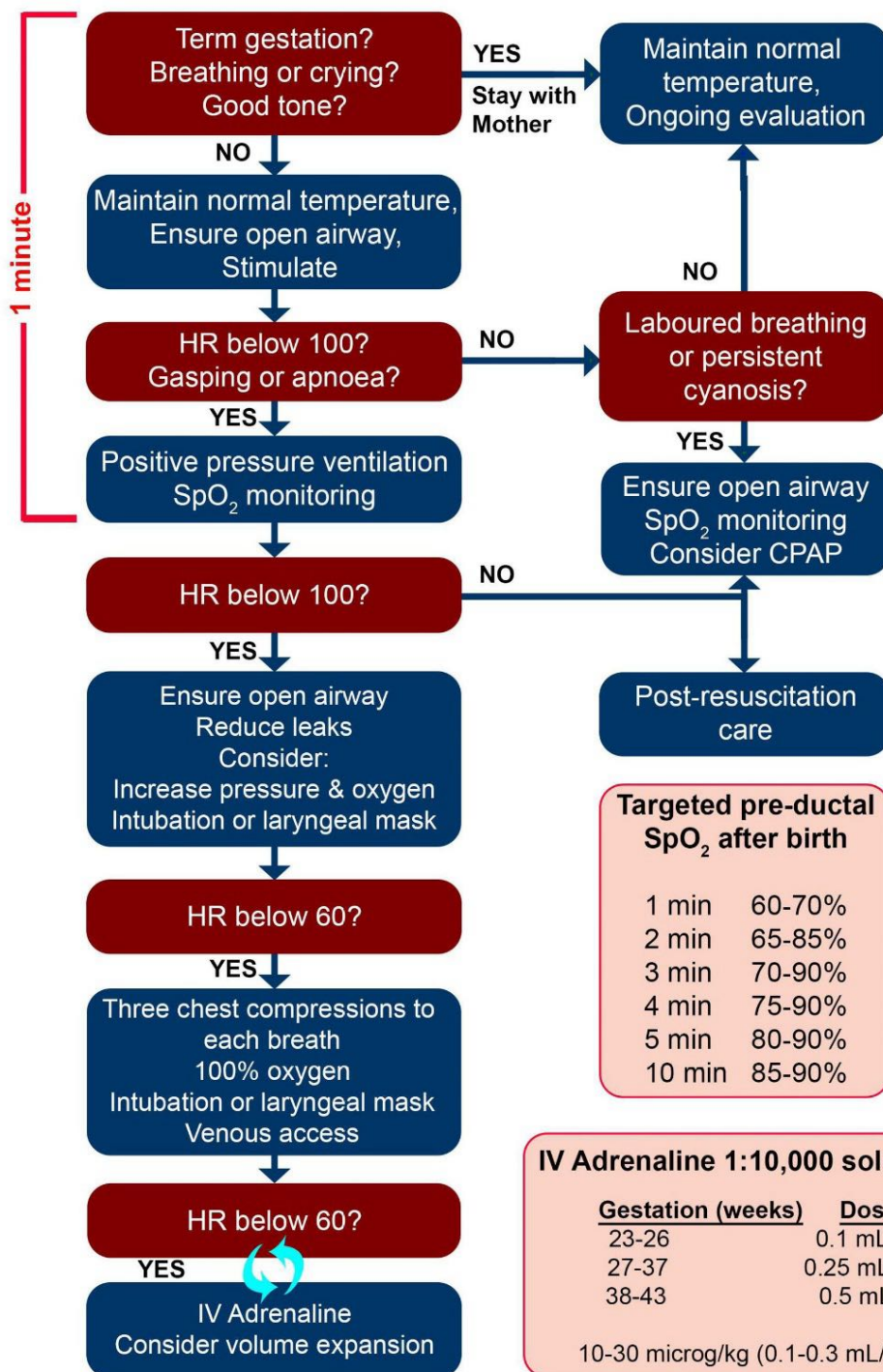
This picture shows the cervix at the end of the vagina. It looks like a tunnel when the woman/pregnant person is not in labour. As the cervix gets shorter the cervix effaces (thins out). The cervix may be partially or fully effaced. The cervix is assessed by either speculum or digital examination. As labour progresses the cervix will also dilate.

Causes of premature labour are not entirely understood but there are recognised risk factors:

- Previous premature birth
- Low socioeconomic status
- Infection e.g. bacterial vaginosis, bacteriuria
- Increased uterine size e.g. twins
- Trauma
- Pregnancy complications e.g. abruption, cervical incompetence

Newborn Life Support

At all stages ask: do you need help?



January 2016



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Risks of premature labour

- Labour progress can be unpredictable and woman/pregnant person may give birth quickly
- Malpresentation more likely, especially breech
- Risk of cord presentation more likely with malpresentation and a small baby

A premature breech presentation is said to be more dangerous than that of a full term infant as the largest part of the baby is the head. With a full term infant the diameter of the buttocks is similar to that of a well flexed head. With a premature baby, the diameter of the buttocks is smaller than a well flexed head. This means that there is a greater risk of the premature baby's body slipping through the cervix with the head still trapped inside the uterus. If the cervix is not fully dilated the head is more likely to become trapped. If a decision is made to transfer, do it early and get on with it.

Things to look for:

- If the woman says she thinks the baby is coming then it probably is!
- If the membranes rupture, the baby will often come shortly after
- If the membranes rupture, think about the possibility of cord prolapse
- Bowel motion or urge to pass same often means the woman/pregnant person is close to birthing
- Watch for the woman/pregnant person pushing involuntarily. Look under the blanket, part the woman's legs, and see if you can see the head. Watch the perineal area if she starts pushing as the baby can come quickly.

Management of premature labour

- Nifedipine – tocolytic, aim to delay birth until steroids are given.
- Steroids – betamethasone 2 doses 12-24 hours apart to mature baby's lungs. The first dose should be given prior to transfer. Every hour that passes once the steroid injection has been given to the mother improves the baby's chance of survival.
- IV antibiotics for infection or prolonged rupture of membranes
- Transport to a hospital with an appropriate level of neonatal care – different NICUs and SCBUs around NZ take babies from varying gestations. Tertiary NICUs will generally take from 23+ weeks gestation
- If birth is thought likely and gestation is between 24 and 30 completed weeks, magnesium sulphate is recommended for foetal neuroprotection.

Birth of premature infant (see NBLS algorithm)

- Not difficult if cephalic (head first) presentation
- Keep warm – apply plastic wrap immediately if less than 30 weeks. Over 30 weeks dry with warm towels then wrap in dry warm towels. Place beanie on head. Inflight consider how you will warm towels e.g. sit on them, place inside uniform
- Ventilate with ambu-bag if not breathing – apply sat probe to right wrist (pre-ductal sats). Start with room air, if needs CPR then apply 10L/min Oxygen.
- Check HR – usually good if bagging effective



If ventilation is adequate, then the heart rate should be good

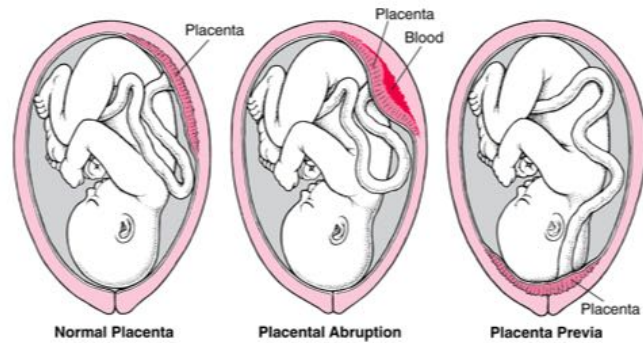
Example - An independent midwife in Wanaka ventilated a baby of 24 weeks gestation for four hours until help arrived from Dunedin. The help was slow due to adverse weather conditions. The baby survived. This demonstrates that keeping even a premature baby warm and ventilating with a bag and mask will often keep that baby alive.

Vaginal Bleeding

- Placenta praevia
- Placental abruption
- Ruptured uterus
- Ruptured membranes
- Cervical erosion
- Vaginal trauma
- "Show"

Transport considerations

- Large bore IVs
- Blood products
- Stable vital signs
- NBM



Pre-eclampsia

A multi-organ disease process characterised by hypertension, proteinuria and sometimes oedema. It can be mild, moderate or severe.

Signs of severe pre-eclampsia

- Headache, visual disturbances, hyper-reflexia/cerebral irritability (jittery, altered level of consciousness/confusion)
- Epigastric or RUQ abdominal pain
- Increasing BP
- Increasing proteinuria
- Increased creatinine
- Oliguria
- Pulmonary oedema
- Seizures
- Thrombocytopaenia
- Elevated liver enzymes
- IUGR (Intra-Uterine Growth Restriction)

Women/pregnant persons with severe pre-eclampsia need to be transferred to larger centres for intensive care, especially if premature or there is significant foetal growth restriction.

The onset of severe pre-eclampsia may be sudden with multiple organ systems involved:

- Nervous system – Headache, and visual disturbances, hyper-reflexia, can be signs of impending convulsion.
- Severe vasospasm and increased peripheral resistance stress the cardiovascular system, and pulmonary oedema may occur.
- Haematological derangements include decreased vascular volume, increased blood viscosity and haemoconcentration. Coagulopathies including HELLP and DIC may occur.
- Renal manifestations include a decreased glomerular filtration rate, which may progress to oliguria and acute renal failure.
- Liver damage causes raised ALT. Sub capsular haemorrhage may cause right upper quadrant pain to occur.

Treatment

- Timely birth of baby
- MgSO₄ if risk of seizures
- Anti-hypertensive medications to keep BP <160/110
- Strict fluid balance

Women/pregnant persons with severe pre-eclampsia, at risk of seizure, should be transferred with magnesium sulphate infusing. If the woman does seize, protect from injury, maintain airway, and ensure magnesium sulphate is infusing. Seizures are usually self-limiting; if clear seizure activity persists beyond 90s seek obstetric advice. Look for signs of abruption. The uterus should be soft to palpate between contractions. The baby should be delivered at the earliest opportunity.

Transport considerations

- Ascertain severity of pre-eclampsia (mild, severe).
- Bloods pre transfer, especially creatinine, proteins, Coags, LFTs.
- Full systems assessment, may be evidence of respiratory distress, hypertension, fluid overload, pulmonary oedema and oliguria. Note fluid balance also & assessment of fetus and FHR.
- Hospital history, any seizures, visual disturbances, headache, clonus etc.
- Magnesium therapy thus far & medications for hypertension, dosage and frequency.
- Establish targets for blood pressure – discuss with obstetric and ICU team.

Further considerations for obstetric transports

- Take an experienced midwife, ideally with flight transfer training
- Do you also need an ICU doctor - depending on the mother's condition e.g. severe pre-eclampsia with risk of seizures and airway compromise, high risk of haemorrhage.
- Beds available and accepting Doctors in both the birthing suite and NICU. Charge midwife aware of transfer to plan.
- Maternal Early Warning Score
- Using a stretcher with space at the leg end in case of delivery
- Consider the logistics of how you would resus a baby in flight
- If labour is progressing should NICU retrieval team go as well or instead if likely long transfer process or birth imminent

Caution if >6cm dilated with regular contractions

- Thorough examination of the woman/pregnant person including vaginal exam as appropriate, before transfer if not contraindicated (i.e. ante-partum hemorrhage & placental abruption). Note PV losses and contractions, how long and how far apart.
- Details of past pregnancies and problems, especially previous rapid births and premature labours.
- Ascertain BP targets from obstetrician/obs registrar if systolic or diastolic is elevated and requiring anti-hypertensive (oral or IV)
- Midwives are the experts in maternal care while the flight nurse has expertise in aviation medicine – there must be good communication particularly if either person believes the woman/birthing person should not be transferred including with referring and accepting Doctors

- Nifedipine (tocolytic) and bethamethasone (steroids) pre transfer – dose and time and regime followed for premature labour. Antibiotics if SROM.
- If history of ante partum hemorrhages think about taking extra fluids, blood and colloid and close monitoring of haemodynamic status.
- Fetal heart rate monitoring, prior to departure – midwife attending should ascertain if a CTG is needed/appropriate
- Essential to monitor oxygen saturations closely and continue with oxygen therapy through the transfer to avoid fetal hypoxia.
- Be aware that turbulence, G-Forces during take-off and landing may increase uterine contractions and spontaneous rupture of membranes if cervix is already dilated.

Some obstetric terms

- A nulliparous woman (nullip) has not given birth previously
- A primagravida is in her first pregnancy
- A primiparous woman has given birth once. The term 'primip' is often used interchangeably with primagravida, although technically incorrect, as a woman does not become primiparous until she has delivered her baby.
- A multigravida has been pregnant more than once.
- A multiparous woman (multip) has given birth more than once.
- A grand multipara is a woman who has already delivered five or more infants who have achieved a gestational age of 24 weeks or more, and such women are considered to be at higher risk than the average in subsequent pregnancies.

Gravida = Number of pregnancies a woman has had

Para = Number of births (alive or stillborn) past 24 weeks gestation a woman has had

e.g. G3P2 means a woman has had 3 pregnancies and 2 deliveries past 24 weeks.

G2P0 means a woman has had 2 pregnancies and neither foetus survived to 24 weeks.

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