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Flight Physiology

Advanced Care Paramedicine

Module: 12
Section: 04

Case 01

- You are at the local hospital when a 4 month old is brought to emergency with severe respiratory distress. The physician is concerned that this is epiglottitis and needs the patient to be transported to the children's hospital 3 hours away by ground.
- The question is raised if this would be better to be transported by air.
- Is this a better option and why?

Case 02

- A patient that was involved in a head on MVC is in serious condition. The 18 y/o M was ejected from the vehicle and has obvious head injuries, multiple rib fractures and a open fracture of the left femur. Dispatch has launched the helicopter to assist in the transport.
- Are there any concerns with flying this patient to a trauma center?

Content

- Describe the role of AMT
- Describe the stressors of flight
- Describe the four types of hypoxia
- Effects of flight on the body
- Effects of flight on equipment

Flight (Aeromedical)

- Specially outfitted aircraft that transports patients in a medical emergency or over distances or terrain impractical for a conventional ground ambulance.
- The advantages of air medical transport (AMT) may include:
  - Providing a higher level of care to the scene and during transport and during interfacility transport
  - Specialized teams (neonatal, OBS, trauma, etc)
  - Quicker transport times in some cases

Air Medical Transport

- Transport of patients that are critically or seriously ill and require interventions unavailable at the local hospital
- A benefit of receiving these interventions of specialized care must be weighted against the risk of transport

Modes of Transport

- Three main modes of transport for the sick and injured are:
  - Ground
  - Rotary Wing
  - Fixed Wing
- Each has their own advantages and disadvantages

Choice of Transport

- Items that could be taken into consideration for choosing the mode of transport include:

- Clinical scenario
  - Diagnosis
  - Stability
  - Anticipated complications
  - Urgency for definitive care
  - Current level of care
- Number of patients
- Availability
- Weather and Traffic
- Local geography
  - Distance
  - Terrain
  - Accessibility
- Safety
- Cost

Ground Ambulance

- Advantages
  - Easily available
  - Door to door
  - Easy to load / unload
  - Easy to divert
  - Relatively roomy
  - Familiarity
  - Relatively low cost
  - Well established infrastructure
  - Few weather constraints
- Disadvantages
  - Lengthy transit times over long distances or difficult terrain
  - Subject to traffic conditions
  - Rough ride
    - Firm suspension
    - High centre of gravity
  - Motion sickness

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Rotary Wing

Rotary Wing

- Advantages
  - Rapid transport times over moderate distances
  - Maneuverability
  - Versatility
  - Pretty much go anywhere
- Disadvantages
  - Loading problems
  - Limited space and patient access issues
  - Weather and fuel constraints
  - Non pressurised
  - Noise and vibration
  - High staff training requirements
  - Expensive

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Fixed Wing

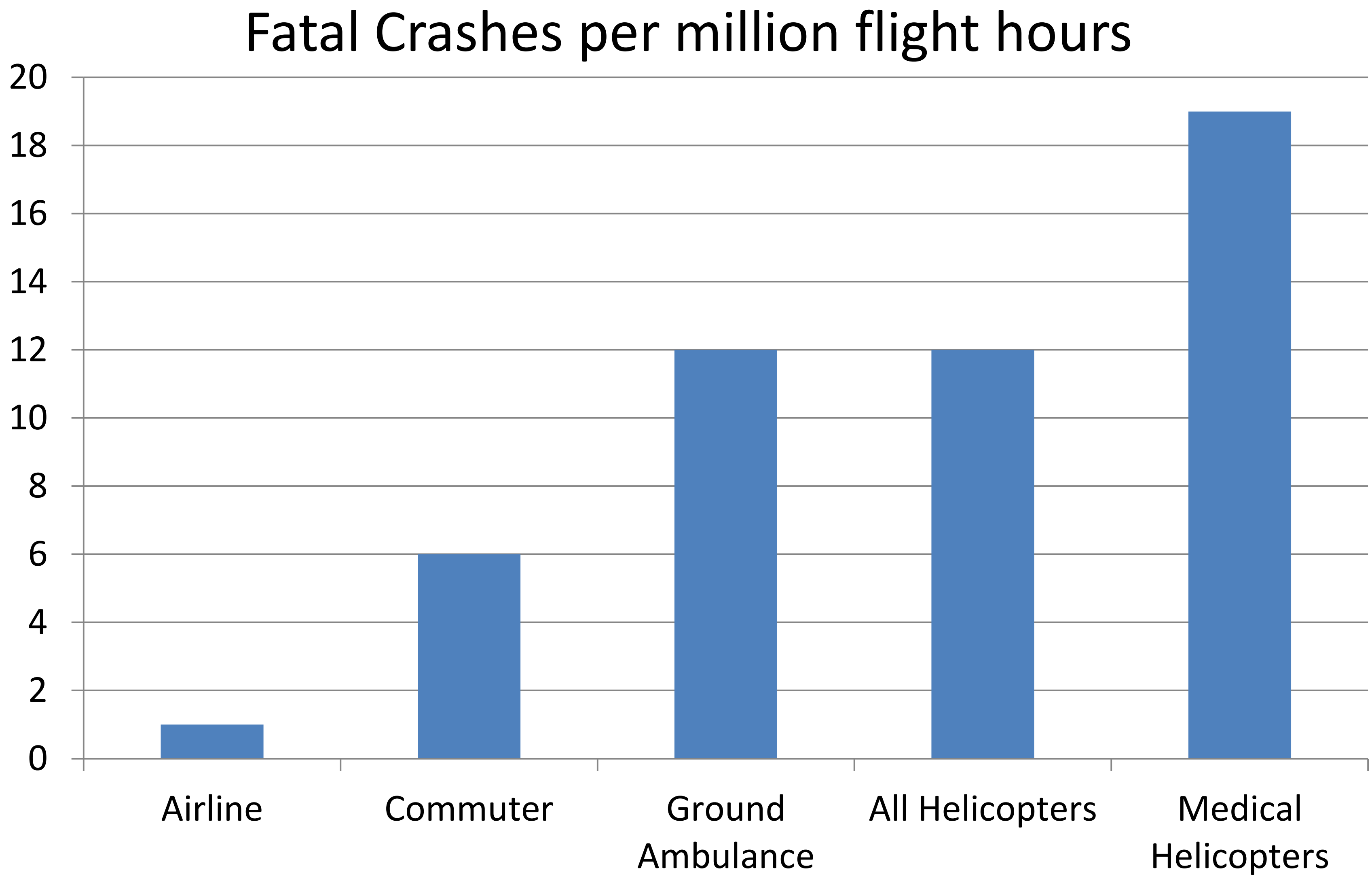
Fixed Wing

- Advantages
  - Rapid transport over long distances
  - Pressurisation (not always)
  - Higher operating ceiling
  - Ability to fly around bad weather
  - Relatively large cabin space (usually)
  - Quieter than RW
- Disadvantages
  - Need an airstrip to take off/land
  - Multiple patient transfers
  - Substantial take off/landing forces

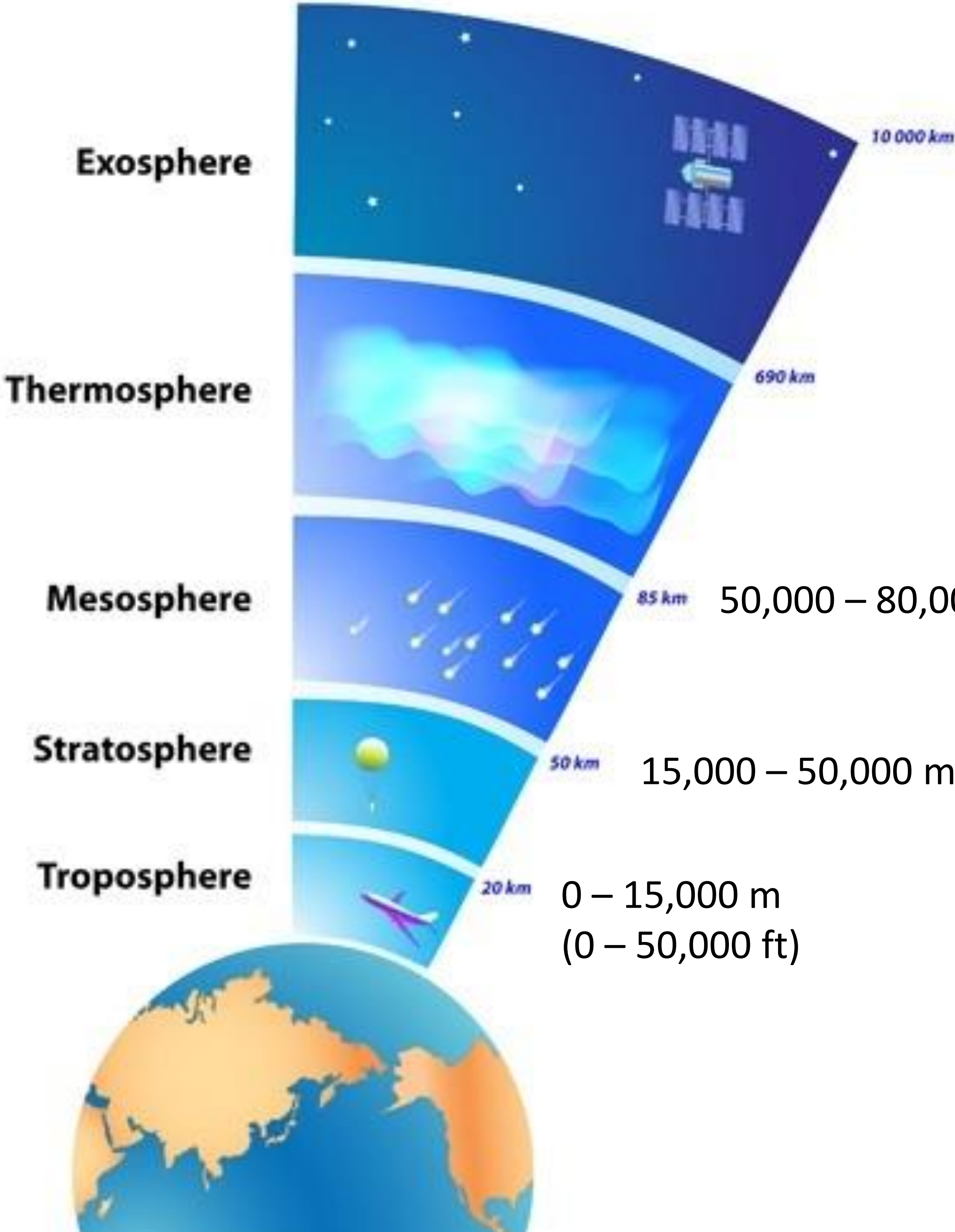
Un-pressurized aircraft

- Useful in transporting non emergent conditions
- Limited by altitude restrictions
- Lower altitude = increased turbulence
- Increased turbulence = greater incidence of complication (i.e spinal trauma, hemorrhage)
- Also complicates the administration of care

A Sobering Thought



Atmosphere



50,000 – 80,000 m

15,000 – 50,000 m

0 – 15,000 m
(0 – 50,000 ft)

Atmosphere

- Physiological Zone (< 10,000 ft)
  - Human body well adapted for
  - Oxygen levels adequate without supplemental
  - Rapid ascents or descents in this zone produce minor complications due to pressure changes
- Physiological Deficient Zone (10,000 – 50,000 ft)
  - Noticeable deficits occur
  - Reduction in oxygen availability leading to hypoxia
  - Problems may occur due to trapped gases
- Space-Equivalent Zone (> 50,000 ft)
  - Even with 100% O_2 there is no protection from hypoxia

Atmosphere

- Air temp drops 2°C per 1000 ft
- Atmospheric pressure decreases
- Water vapour decreases
- Turbulence increases

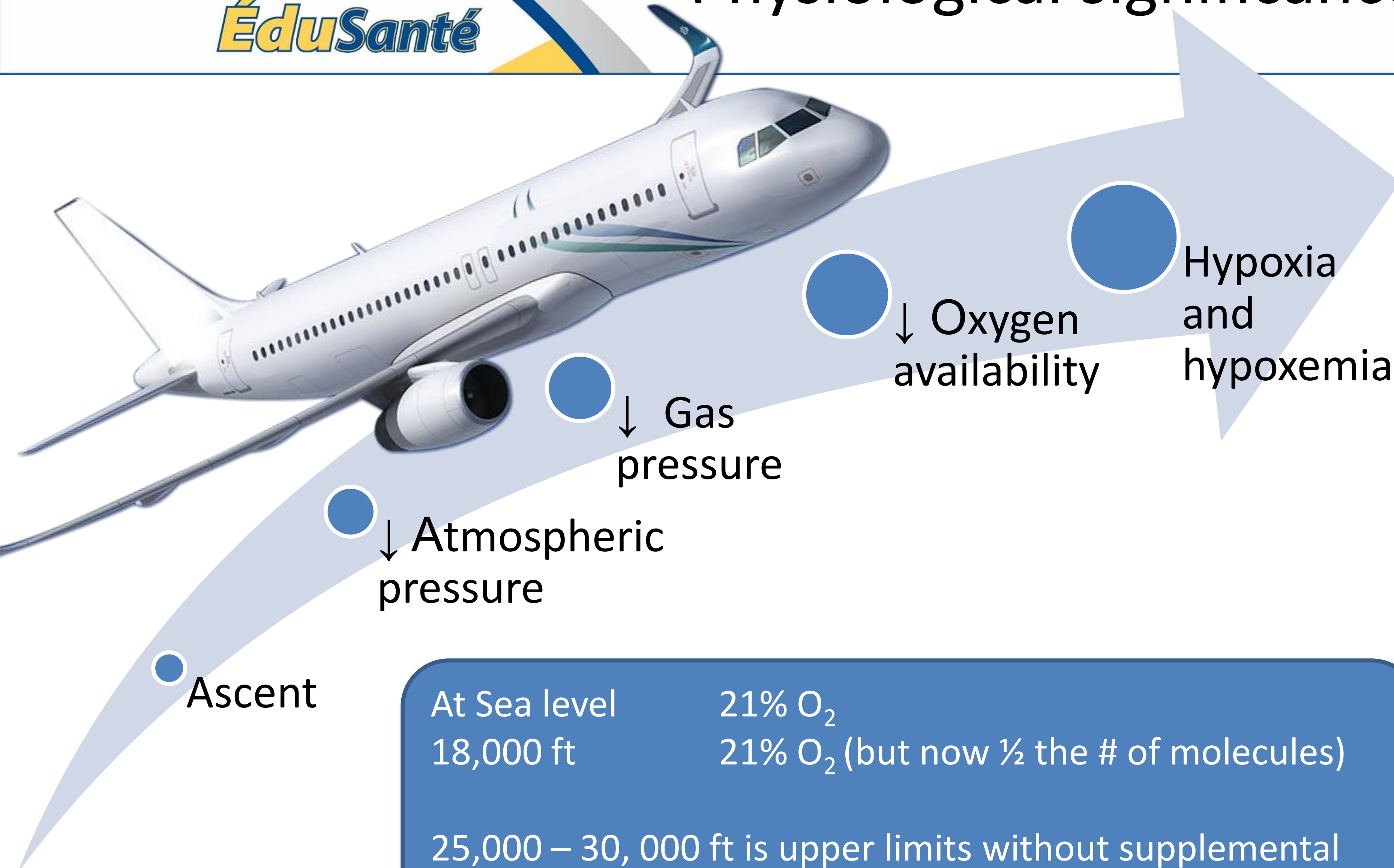
Altitude

Altitude (feet)	Pressure (mmHg)	pO_2 (mmHg)	Temp (°C)	Volume Change
Sea Level	760	159	15	N/A
1000	733	153	13	3.1%
2000	706	148	11	7.6%
4000	656	137	7.1	15.8%
7000	586	122	1.2	29.7%
10,000	523	110	-4.8	45%
20,000	349	73	-24.6	117%

Gas Laws

- Describe the relationship among variables of temperature, pressure, volume and mass of a gas.
- They govern the body's response to the aviation environment.
- The gas laws affecting physiology include:
  - Boyle's Law
  - Henry's Law
  - Dalton's Law
  - Charles' Law
  - Gay-Lussac's Law
  - Graham's Law
  - Fick's Law

Physiological significance



At Sea level	21% O_2
18,000 ft	21% O_2 (but now ½ the # of molecules)

25,000 – 30, 000 ft is upper limits without supplemental Oxygen

Flight Physiology

STRESSORS OF FLIGHT

Stressors of Flight

Related to Altitude

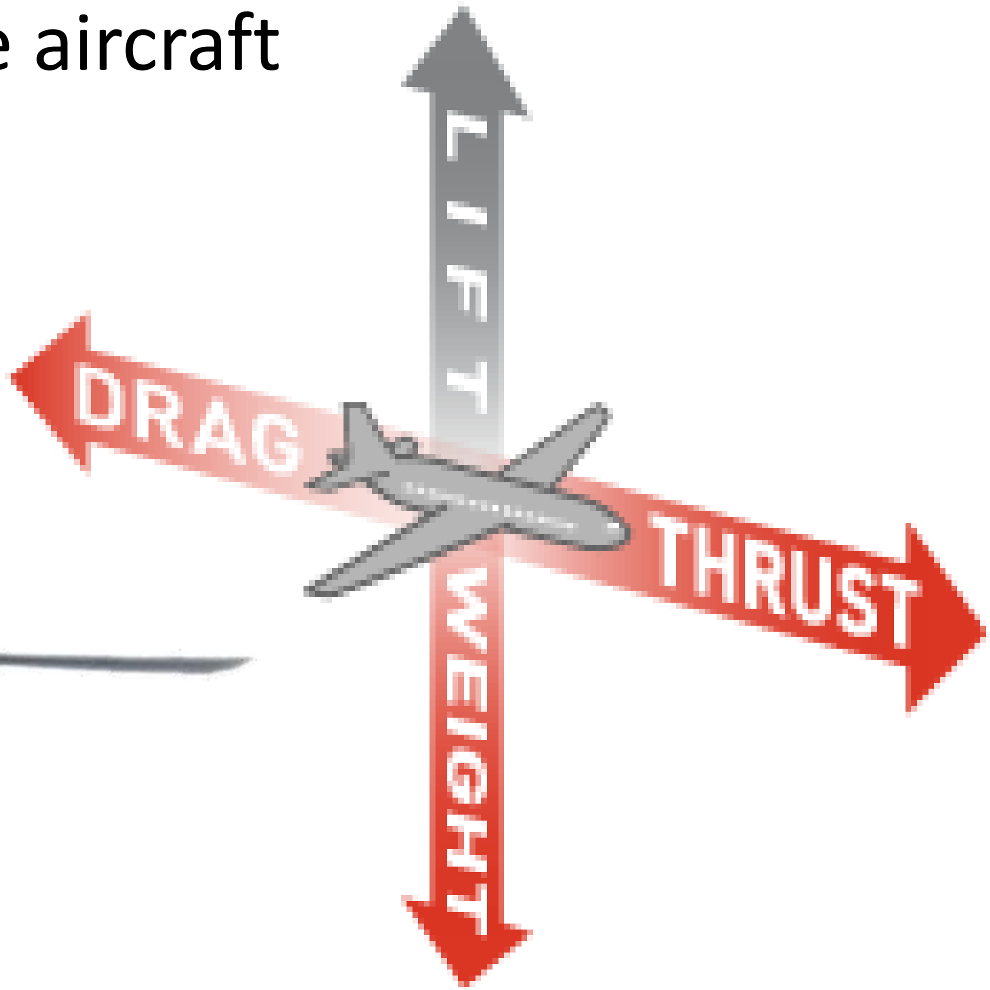
- Hypoxia
- Barometric pressure
- Thermal changes
- Fatigue
- Decreased humidity (dehydration)

Associated with flight

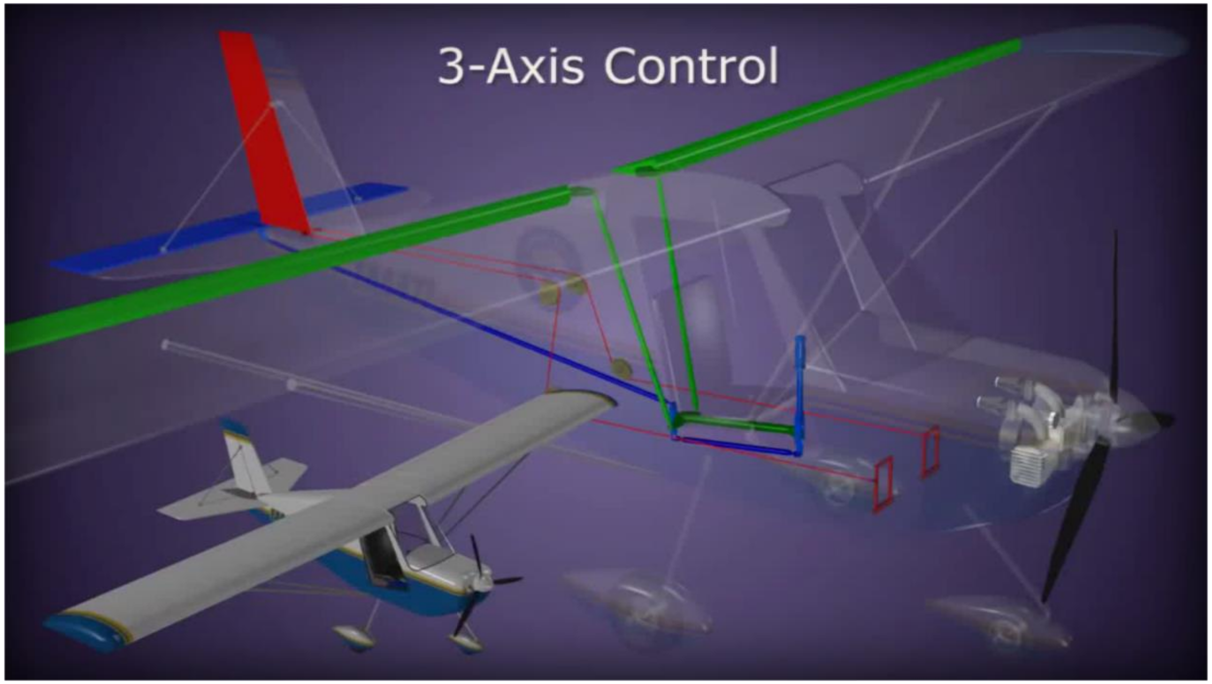
- Noise
- Vibration
- Gravitational forces
- Spatial Disorientation and Illusions of Flight
- Third spacing
- Flicker vertigo
- Anxiety

Flight Physics

- Forces affecting the aircraft
  - Lift
  - Weight (Gravity)
  - Thrust
  - Drag



Flight Physics



- 3 axis of flight
  - Vertical Axis ("Yaw")
  - Longitudinal Axis ("Roll")
  - Lateral Axis ("Pitch")

Decreased Partial Pressure

- Dalton's and Boyle's laws show that with altitude the availability of oxygen decreases even though it is still 21%.
- This lack of available oxygen will result in hypoxia.

Flight Physiology

HYPOXIA

Hypoxia

- Hypoxia
  - A state of oxygen deficiency in the body which is sufficient to cause an impairment of function.
  - Is caused by the reduction in partial pressure of oxygen, inadequate oxygen transport, or the inability of the tissues to use oxygen.
  - Being drunk is similar as being exposed to high altitude. In both cases, oxygen to your brain and muscles is reduced.

Hypoxia

- Four types of hypoxia are:
  - Hypoxic Hypoxia (Lungs)
  - Hypemic Hypoxia (Blood)
  - Stagnant Hypoxia (Blood Transport)
  - Histotoxic Hypoxia (Cell)

Hypoxia

- Hypoxic Hypoxia
  - A reduction in the amount of oxygen exchange in the lungs passing into the blood.
  - Some causes include:
    - Decreased partial pressure of oxygen available at altitude.
    - Conditions that block the exchange at the alveolar capillary level (e.g. pneumonia, pulmonary edema, asthma, drowning).
  - This is the hypoxia that is a hazard to the crew.

Hypoxia

- Hypemic (Anemic) Hypoxia
  - A reduction in the oxygen carrying capacity of the blood. It is caused by a reduction in the amount of hemoglobin in the blood or a reduced number of red blood cells.
  - Occurs through:
    - Blood donation, hemorrhage, or anemia.
    - Drugs, chemicals, or carbon monoxide.

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Hypoxia

- Stagnant Hypoxia
  - An oxygen deficiency due to poor circulation of the blood or poor blood flow.
  - Examples
    - High "G" forces
    - Prolonged sitting in one position or hanging in a harness
    - Cold temperatures
    - PPV

Hypoxia

- Histotoxic Hypoxia
  - The inability of the tissues to use oxygen
  - Examples
    - Carbon monoxide
    - Cyanide poisoning
    - Narcotics, chewing tobacco, and alcohol will prevent oxygen use by the tissues

Factors Influencing Hypoxia

- Altitude
- Rate of ascent
- Time at altitude
- Individual tolerance
- Fitness of individual
- Activity at altitude
- Temperature at altitude
- Medications, toxic substances, smoking

Stages of Hypoxia

- Indifferent Stage
- Compensatory Stage
- Disturbance Stage
- Critical Stage

Indifferent Stage

- People are not generally aware of the effects of hypoxia at this stage.
  - Primary symptoms are a loss of night vision and a loss of color vision. (These changes can occur at relatively modest altitudes as low as 4,000 ft)
  - SaO_2 are typically between 90 and 95%
  - Slight increase in HR and RR, decreased night vision at 5,000 ft.
  - Experienced between sea level – 10,000ft.
  - Minor physiological effects on the body.

Compensatory Stage

- In healthy people, this stage may occur at altitudes between 10,000 and 15,000 feet.
- The body is able to provide short-term physiologic compensation by increasing the HR, respiratory rate and depth of ventilation and cardiac output.
- SaO_2 are typically between 80 and 90%
- Dependent upon the health of the individual
- Symptoms may include drowsiness, poor judgment, impaired coordination and efficiency.

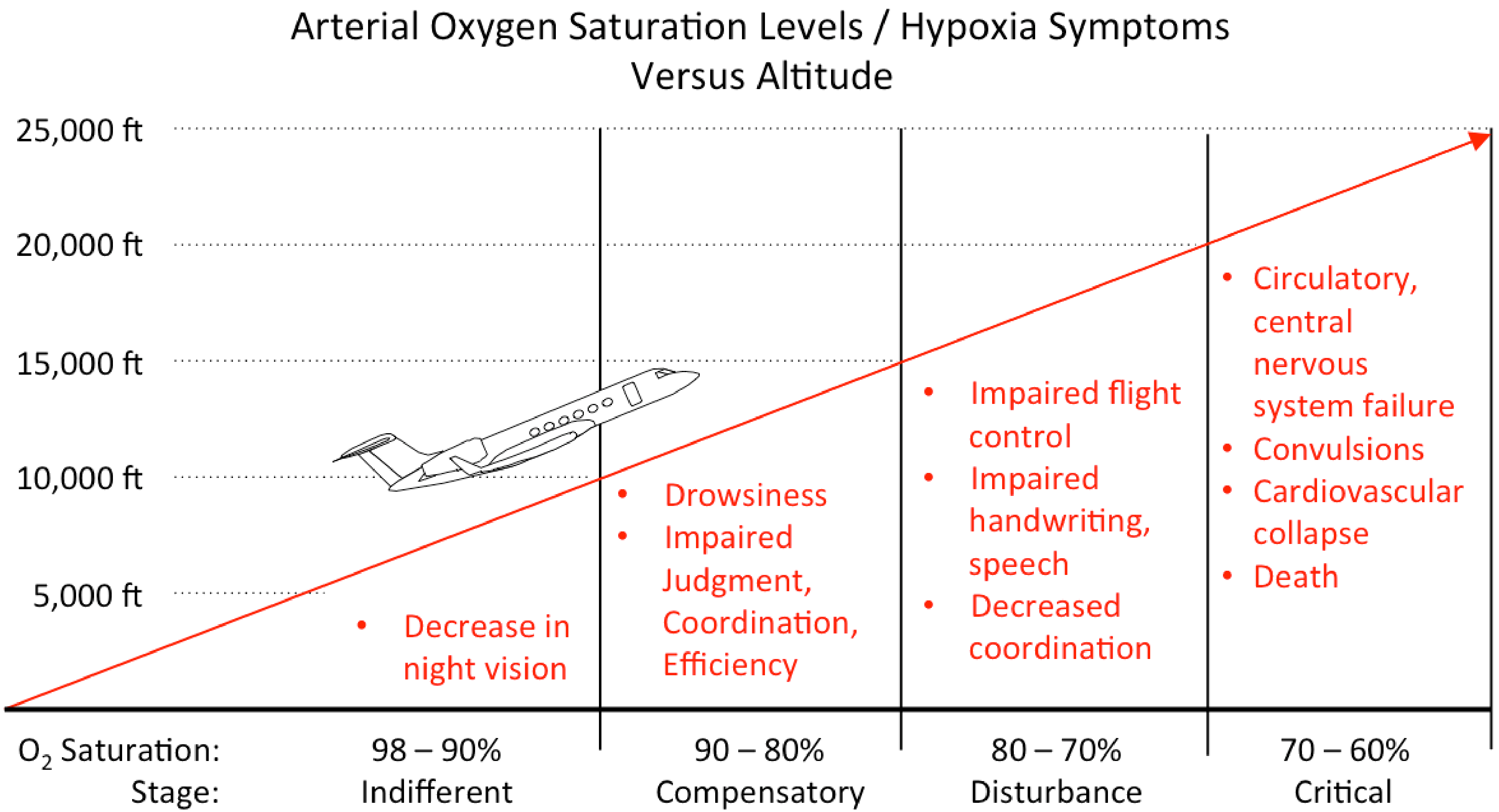
Disturbance Stage

- Unable to compensate further
- Affects the senses, cognition, personality and psychomotor functions slowed thinking and coordination, cyanosis, sleepiness, dizziness and tunnel vision.
- SaO_2 are typically between 80 and 90%
- Experienced between 15,000 – 20,000 ft.

Critical Stage

- Terminal stage leading up to death.
- People are almost completely incapacitated physically and mentally.
- SaO_2 are typically less than 70%
- Severe confusion, incapacitation, unconsciousness, seizures and death.
- Experienced between 20,000 – 30,000 ft

Hypoxia


Arterial Oxygen Saturation Levels / Hypoxia Symptoms
Versus Altitude
25,000 ft
20,000 ft
15,000 ft
10,000 ft
5,000 ft
• Decrease in night vision
• Drowsiness
• Impaired Judgment, Coordination, Efficiency
• Impaired flight control
• Impaired handwriting, speech
• Decreased coordination
• Circulatory, central nervous system failure
• Convulsions
• Cardiovascular collapse
• Death
O_2 Saturation:
Stage:
98 – 90%
Indifferent
90 – 80%
Compensatory
80 – 70%
Disturbance
70 – 60%
Critical

Symptoms of Hypoxia

- Confusion/altered mental status
- Fatigue
- Headache
- Changes in vision acuity
- Tunnel vision
- Blurred vision and/or inability to focus
- Difficulty focusing from near to far
- Loss of night vision
- Euphoria
- Tingling in the hands or feet
- Feelings of air hunger
- Tachypnea

Symptoms of Hypoxia

- Cyanosis of the skin
- Arrhythmias
- Short term memory loss
- Decreased muscular coordination
- Loss of hearing
- Diminished sense of pain
- Diminished sense of touch and feel
- Difficulty speaking; stammering
- Loss of self-criticism
- Overconfidence
- Overly aggressive behavior

Effective Performance Time (EPT)

- Refers to the amount of time a person is able to perform useful duties in an environment with decrease oxygen.

Time of Useful Consciousness (TUC)

- The time between loss of O_2 supply and dysfunction as it relates to altitude

Altitude	Time of Useful Consciousness
45,000 feet MSL	9 to 15 seconds
40,000 feet MSL	15 to 20 seconds
35,000 feet MSL	30 to 60 seconds
30,000 feet MSL	1 to 2 minutes
28,000 feet MSL	2½ to 3 minutes
25,000 feet MSL	3 to 5 minutes
22,000 feet MSL	5 to 10 minutes
20,000 feet MSL	30 minutes or more

Management

- Management of the hypoxic patient during transport remains the same in the air.
- Apply supplemental oxygen (humidity when possible) and titrate the SaO_2 to 95% or more, unless contraindicated.
- Correct problems that may exacerbate hypoxia.
- Make allowances for the patient's condition and ask the pilots to fly at lower altitudes (when possible)
- If in a pressurized cabin the pilots may be able to adjust the cabin pressure if requested
- Hyperventilation caused by psychological and environmental stress can also be a concern because of the similar symptoms with hypoxia.

Oxygen Administration

- For barometric changes
  - $FiO_{2\ (\text{at flight level})} = \dfrac{FiO_2 \text{ X Barometric pressure one}}{\text{Barometric pressure two}}$
- If you were going to be transporting a patient at an altitude of 7000 ft what would your FiO_2 need to be adjusted to in order to compensate for the change in pressures?

- Knowing our altitude will be 7000 ft and referencing our barometric pressure chart we know that the pressure would be approximately 632 mmHg.

- Therefore:
  - $FiO_{2\ (7000')} = \frac{0.50 \text{ X } 760 \text{ mmHg}}{586 \text{ mmHg}} = 0.65$

Oxygen Paradox

- Approximately 15 second period when the hypoxic patient's symptoms actually worsen following oxygen administration
- Researchers unsure of cause
- Possible link to role of O_2 - CO_2 balance regarding vasoconstriction / vasodilatation

Flight Physiology

EFFECTS OF FLIGHT ON THE BODY

Effects of Flight on the Body

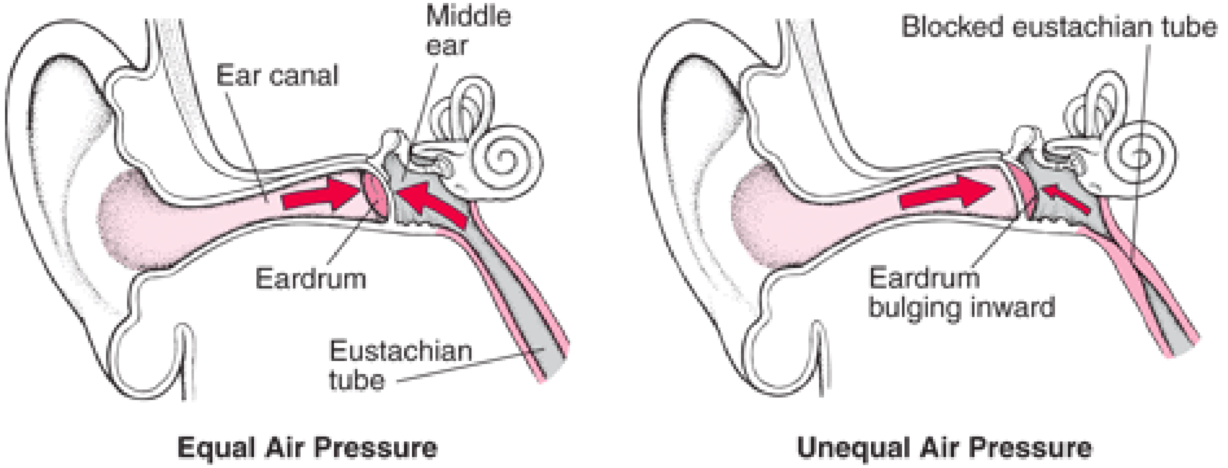
- Difficulties associated with gas expansion at altitude are a challenge for AMT
- Trapped gasses within body cavities expand when pressure decreases (Boyle's Law).

Effects of Flight on the Body

- Middle Ear & Sinus
- Teeth
- GI Tract
- GU Tract
- Lungs
- MSK Trauma
- Head Injury
- Eyes
- Pregnancy

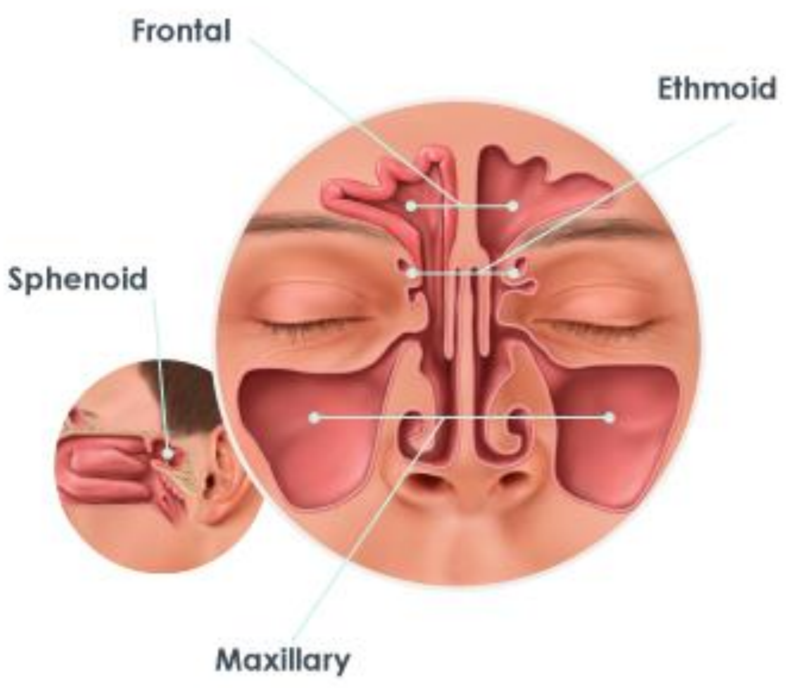
Ears and Sinus

- Barotitis results from pressure changes (most common problem)
  - Results in pain and decreased hearing
  - Tinnitus, nausea and vertigo may also be present
  - Pressure in the middle ear may become too low causing the eardrum to rupture.



Ears and Sinus

- Barosinusitis is inflammation of one or more of the paranasal sinuses as a result of expanding air being trapped
  - May cause facial and jaw pain
  - Nosebleeds and lacrimation.
- These can usually be relieved by equalizing the pressure

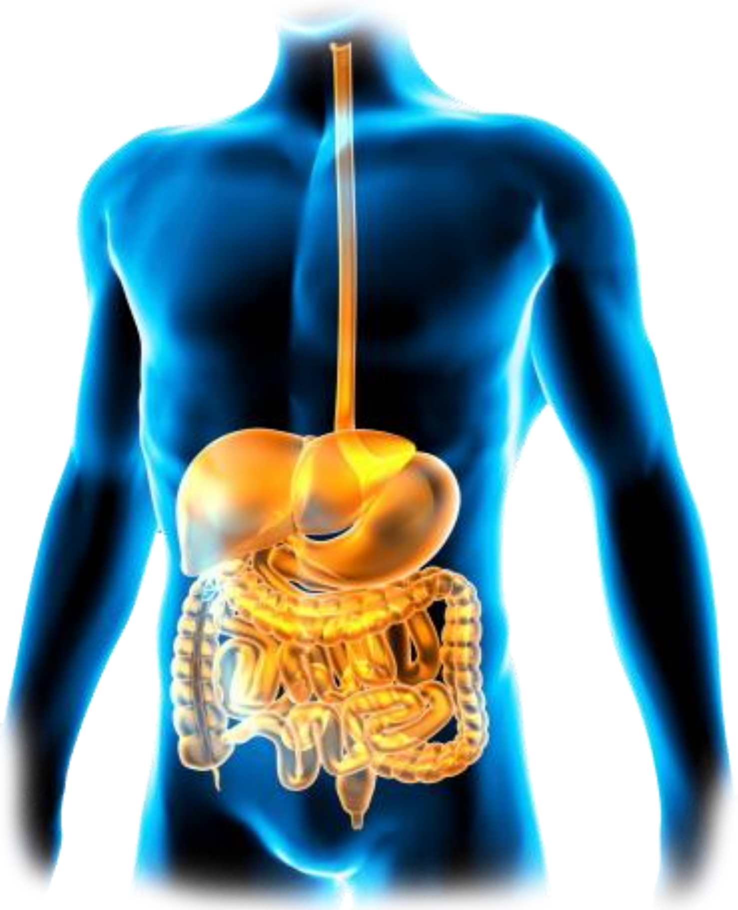


Teeth

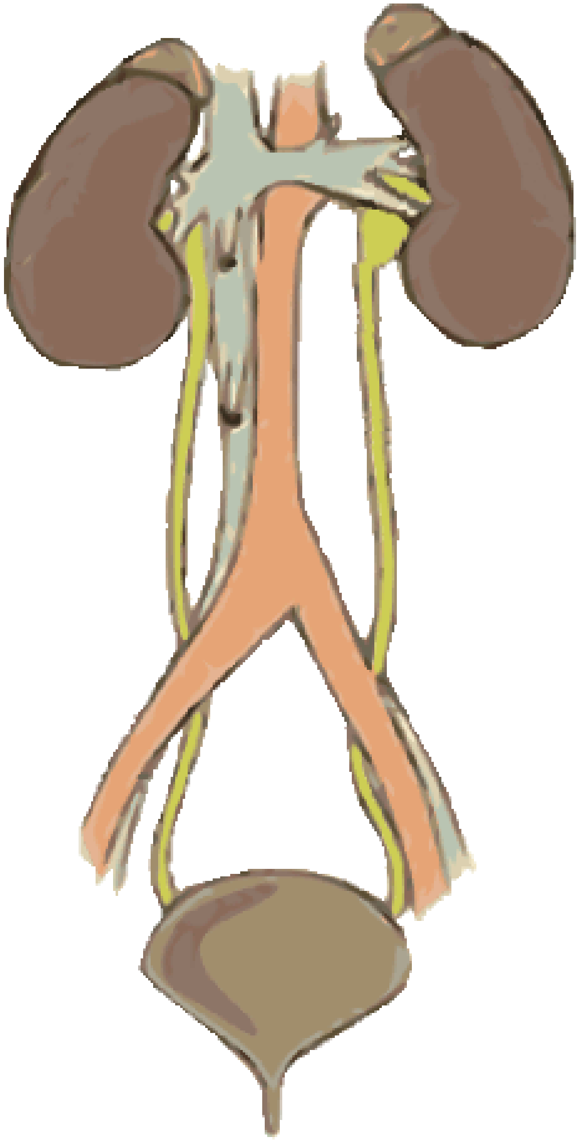
- Barodontalgia is a toothache caused by decaying and abscessed teeth, new crowns and fillings.
- Crowns and fillings can pop off during ascent.

GI Tract

- Patients with abdominal complications (ie. bowel obstruction) may have problems with bloating, nausea and pain.
- This can cause problems with breathing and ventilation at higher altitudes with compression of the diaphragm.



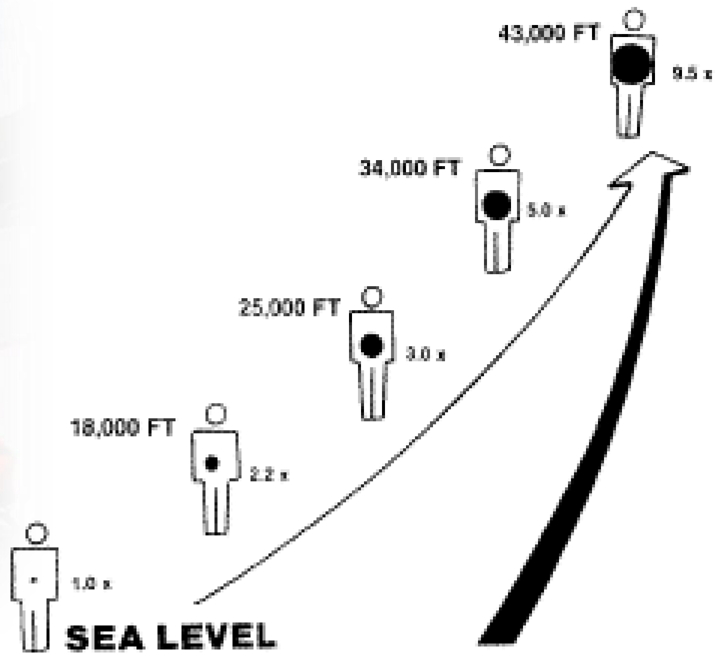
GU Tract



- Expanded gas in the bladder will create more pressure.

Lungs

- Areas of air trapping (emphysematous blebs or bullae) may develop a pneumothorax.



MSK

- Injury swells during air medical transport
- Can result in neurovascular compromise (especially when restrictive splinting devices and casts are used)

Head

- Certain skull fractures (ie. basal skull fracture) have potential for introducing air into the brain
- Tumors and cysts may have gas occupying spaces
- Decreasing ambient pressure increases intracranial pressure (ICP), reducing blood flow
- Further edema from the tissue hypoxia compounds the problem.
- Anxiety, hypoxia, hyperventilation and flicker vertigo may result in seizure activity

Eyes

- Following penetrating trauma or recent surgery, eyes often have gas trapped within them
- Even low altitude flight may cause sutures to rupture
- Gas can expand and exert pressure on blood vessels and the optic nerve
- Hypoxia can cause retinal damage (retinal vasodilation cause re-bleeding, increased intraocular pressure or aggravation of existing eye disease)

Pregnancy

- Hypoxemia in the mother contributes to fetal hypoxia.
  - Compromised uteroplacental perfusion may interfere with the fetus's compensatory mechanisms for maternal hypoxemia.
- Uterine stimulation from intestinal gas and bladder expansion
- Breast expansion can occur, causing oxytocin release and labour enhancement.
- Pre-eclamptic patients have increased pulmonary permeability
  - Possibly leading to hypoxia and pulmonary edema
- Flicker vertigo may initiate seizure activity.

Problems Related to Flight

- High Altitude Pulmonary Edema
- High Altitude Cerebral Edema
- Rapid Decompression
- Decompression Sickness
- Hypothermia

Flight Physiology

EFFECTS OF FLIGHT ON EQUIPMENT

Effects of Flight on Equipment

- What equipment do you think would be affected by high altitudes?

Effects of Flight on Equipment

Pressure Dependent Devices

- Airway devices
  - CPAP
  - Ventilators
- IV Lines
- Catheters

Air Spaces

- IV bags
- Catheter balloon and bags
- Chest tubes
- Intubation tubes
- NG/OG Tubes
- BP Cuffs
- Air splints
- Vacuum dressings

Flight Physiology

PREPARING A PATIENT FOR MEDICAL TRANSPORT

Preparing the Patient

- The AMT environment is challenging. To complete the transport safely your patient may need certain interventions prior to transport that would not performed if the patient remained in the hospital.

Preparing the Patient

From Scene

- IV’s in place
- Medications if needed
- Airway supported/secured
- Fractures splinted

From Hospital

- Foley Catheter
- Intubation/Vent
- NG/OG Tube
- IV Pumps (Pressure bags or infusion pumps)
- Medications

Flight Physiology

LANDING ZONE

Landing Zones

- Interfacility
- Scene Response (Rotary Wing)

Landing Zone

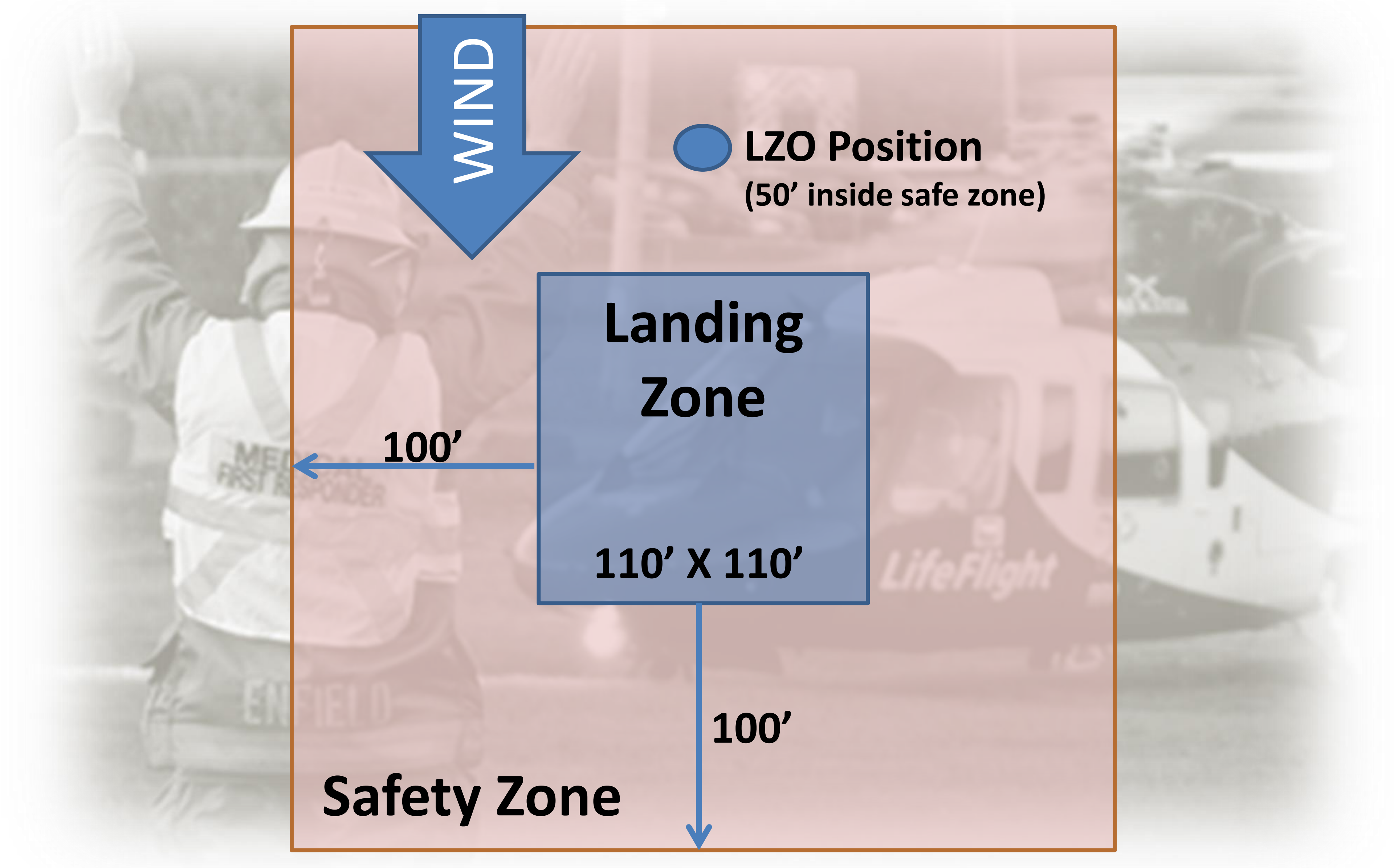
LZ Selection

- Downwind from scene
- 110 X 110 ft
- On firm and level ground
- Free of hazards

LZ Set Up

- Ensure traffic is stopped 500 metres back in all directions
- Do a foreign object debris (FOD) walk through
- Identify wires if any by parking emergency vehicles under them
- Establish communications
- Have LZ wet down if dusty or clear snow if needed.

Landing Zone



Landing Zone

Communications

- TMR Radio
- VHF Radio
- Cell Phone
- Hand Signals

Communications Needs

- LZ Lat/Long, map locations, etc
- Description of LZ surface
- Wind direction/strength
- Identify any hazards (approach, security, scene)

Approaching the Aircraft