Altitude Sickness and Other High Altitude Problems
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Conflict of Interest Disclosure

I have no conflicts and nothing to disclose

Warning sign on the top of Mt. Evans, Colorado. 14,265 feet
Topics

• Altitude Sickness
• Hypoxia
• Respiratory Alkalosis
• Trapped Gases
• Altitude Decompression Sickness

Objectives

• Identify the characteristics and symptoms of high altitude hypoxia.
• Discuss the physiologic principles of hypoxia and respiratory alkalosis.
• Recognize the signs and symptoms, diagnosis and treatment of altitude sickness.
• Identify the locations and symptoms of trapped gases.
• Discuss the symptoms, presentations and treatment of altitude decompression sickness.
Altitude Sickness

• AKA:
  • Acute mountain sickness
  • Altitude illness
  • Hypobaropathy
  • Monge’s disease
  • High altitude pulmonary edema (HAPE)
  • High altitude cerebral edema (HACE)
• Can occur above 7,000-8,000 feet.

Altitude Sickness

• What are the 2 primary pathophysiologic mechanisms of altitude sickness?
  • Hypoxia
  • Respiratory alkalosis

Definitions

• High Altitude
  • 5,000 to 11,499 feet (Parker, CO) 5,800 ft.
• Very High Altitude
  • 11,500 to 18,000 feet (Longs Peak) 14,000 ft.
• Extreme Altitude
  • 18,000 and above (Mount Everest) 29,000 ft.
Hypoxia

• At sea level (1 atm.) the FiO2 is 21%.
  • PaO2 = 100 mmHg

• At 18,000 ft. (1/2 atm.) the available oxygen is 50% as compared to sea level but the FiO2 is 21%. The same as a FiO2 of 10% at sea level.
  • PaO2 = 50 mmHg

<table>
<thead>
<tr>
<th>Altitude (ft)</th>
<th>Equivalent O2 Concentration at Sea Level – FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level</td>
<td>.209</td>
</tr>
<tr>
<td>4,000</td>
<td>.180</td>
</tr>
<tr>
<td>6,000</td>
<td>.167</td>
</tr>
<tr>
<td>8,000</td>
<td>.155</td>
</tr>
<tr>
<td>10,000</td>
<td>.143</td>
</tr>
<tr>
<td>12,000</td>
<td>.132</td>
</tr>
<tr>
<td>18,000</td>
<td>.102</td>
</tr>
</tbody>
</table>

OxyHemoglobin Dissociation Curve
Hypoxia
• Types of Hypoxia:
  • Hypoxic Hypoxia – any condition that interrupts the flow of oxygen into the lungs. Example: high altitude
  • Hypemic Hypoxia – any condition that interferes with the ability of the blood to carry oxygen. Example: anemia or carbon monoxide poisoning.

Hypoxia
• Type of Hypoxia (cont.):
  • Stagnant Hypoxia – any condition that interferes with the normal circulation of blood. Example: CHF, hypotension, abnormal g-forces
  • Histotoxic Hypoxia – any condition that interferes with the normal utilization of oxygen in the cell. Example: alcohol, narcotics, cyanide

Hypoxia
• Signs and Symptoms of Hypoxia:
  • Symptoms – air hunger, dyspnea, fatigue, headache, dizziness, tingling, visual impairment, euphoria
  • Signs – tachypnea, poor coordination, lethargy, executing poor judgment, LOC
### Hypoxia

<table>
<thead>
<tr>
<th>Altitude (ft)</th>
<th>Effective Performance Time (EPT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18,000</td>
<td>20-30 minutes</td>
</tr>
<tr>
<td>22,000</td>
<td>10 minutes</td>
</tr>
<tr>
<td>25,000</td>
<td>3-5 minutes</td>
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<tr>
<td>30,000</td>
<td>1-2 minutes</td>
</tr>
<tr>
<td>35,000</td>
<td>.5-1 minute</td>
</tr>
<tr>
<td>40,000</td>
<td>15-20 seconds</td>
</tr>
<tr>
<td>45,000</td>
<td>9-12 seconds</td>
</tr>
</tbody>
</table>

### Circulatory Changes due to Hypoxia

**Systemic Circulation**
- Increased sympathetic activity
  - Increase in BP
  - Increase in HR
  - Increase in venous tone

**Pulmonary Circulation**
- Pulmonary vasoconstriction
  - Increase in pulmonary vascular resistance
  - Pulmonary hypertension

### Circulatory Changes due to Hypoxia

**Cerebral Circulation**
- Cerebral blood flow (CBF) depends on the balance between, hypoxic vasodilation and hypocapnic vasoconstriction

  - CBF increases, despite the hypocapnia, when the PaO2 is less than 60 mmHg (altitude of 9,000 ft.)
Respiratory Alkalosis

• Respiratory alkalosis due to alveolar hyperventilation.
• Decrease in the PaCO2 (35-45 mmHg), hypocapnia, causes an alkalosis or increase in the pH (7.35 – 7.45). Above 7.45
• Decreasing PaCO2 and increasing HCO3, thus causing an increased pH.

Respiratory Alkalosis

• Renal compensation to respiratory alkalosis takes several days.
• Fluids and normal volume status is mandatory.
• Treat the underlying disorder.
• Acetazolamide (Diamox) – carbonic anhydrase inhibitor. Causes a metabolic acidosis.

Primary Signs & Symptoms of Altitude Sickness

• Nausea/Vomiting
• Fatigue
• Tachypnea
• Dizziness, lightheadness or weakness
• Insomnia
• Exertional dyspnea
• Nosebleed
• Headache
• Tachycardia
HAPE – High Altitude Pulmonary Edema

- Pulmonary Edema – Most common cause of death
  - Cough
  - Fever
  - SOB/dyspnea
  - Response to hypoxia in the lungs causes increased pulmonary arterial pressure due to hypoxic pulmonary vasoconstriction → results in injury to pulmonary capillaries → increased capillary permeability → pulmonary edema

HACE – High Altitude Cerebral Edema

- Cerebral Edema
  - Headache that does not respond to treatment
  - Unsteady gait/ataxia
  - Confusion/altered consciousness
  - LOC
  - Severe Nausea/Vomiting
  - Retinal hemorrhage
  - Severe hypoxia causes cerebral vasodilation → likely cause of the cerebral edema
Cerebral Edema

"Tight fit hypothesis" of high altitude cerebral edema. Lack of cerebrospinal fluid buffer is thought to result in a predisposition to earlier rise in intracranial pressure when there is edema formation or increased blood volume.

High Altitude Physiological Changes

Treatment of Altitude Sickness

- Descend to a lower altitude
- Oxygen
- Fluids
- Analgesics — NSAIDs or acetaminophen
- Avoid ETOH
- Acetazolamide (Diamox)
- Sildenafil (Viagra)
- Steroids
- Diuretics
- Mechanical ventilation
Prevention of Altitude Sickness

• Take your time traveling to higher altitudes.
  • Most healthy people can go from sea level to 8000 ft.
  • Spend a night at lower altitude before going above 8000 ft.
• Sleep at an altitude lower than the altitude you are at during the day.
  • Example: If you ski at 10,000 ft. sleep at 8,500 ft.
• Acetazolamide (Diamox) – 250 mg BID

Trapped Gases

• The body has several cavities that contain air.
• Changes in gas volume without equalization may result in pain and a visit to the physician.
• Examples:
  • Barotitis media
  • Barosinusitis
  • Gastrointestinal
  • Barodontalgia

Trapped Gases

• Barotitis Media
  • AKA “ear block”
  • Can occur on ascent or descent
  • Ascent – air expanding in the middle ear
  • Descent – air trapped in the middle ear due to eustachian tube dysfunction, cannot equalize pressure
  • Treatment - Valsalva maneuvers, topical and systemic decongestants
Trapped Gases

• Barosinusitis
  • Pressure in paranasal sinuses fails to equilibrate with change in air pressure and altitude
  • Maxillary sinus – pain under cheek bones or upper teeth
  • Frontal Sinus – pain under eyebrows or corner of eyes
  • Treatment – Valsalva, decongestants

• Gastrointestinal
  • Usually occurs during ascent in unpressurized aircraft
  • Expansion of gas in hollow organs causes pain
  • Barodontalgia
    • “Flyer’s toothache”
    • Rare, associated with recent filling of a cavity
    • Occurs during ascent

Altitude Decompression Sickness

• Definition:
  • Symptoms resulting from exposure to low barometric pressure causing inert gases (mainly nitrogen) normally dissolved in body fluids and tissues to come out of physical solution and form bubbles.
Altitude Decompression Sickness

• Altitude DCS first observed in the 1930’s associated with high altitude ballooning and unpressurized aircraft flights.

• Modern aircraft are pressurized and safer, but occupants are still subject to the stresses of high altitude flight.

Altitude Decompression Sickness

• Henry’s Law – when the pressure of a gas on a liquid is decreased, the amount of gas dissolved in that liquid will also decrease.

• Practical demonstration – Opening of a soft drink and the bubbles forming in the soda.

Altitude Decompression Sickness

• First documented case of DCS (Caisson Disease) was reported in 1841 among coal miners exposed to air-pressurized mine shafts to keep the water out.

• First case of DCS from diving while wearing a pressurized hard hat was reported in 1869.
Altitude Decompression Sickness

- Types of DCS: The Bends
  - Large joints: elbows, shoulders, hips, wrists, knees, ankles.
  - Localized deep pain from mild to excruciating.
  - Active and passive joint motion aggravate the pain.
  - Pain can occur at altitude, during descent or hours later.

- Types of DCS: Neurologic
  - Brain
    - Confusion or memory loss
    - Headache
    - Visual field changes (scotoma), tunnel vision, double vision (diplopia) or blurry vision.
    - Seizures, dizziness, vertigo, nausea, vomiting and loc.

Altitude Decompression Sickness

- Types of DCS: Neurologic (cont’d)
  - Spinal Cord
    - Abnormal sensations—burning, stinging and tingling in the lower chest and back.
    - Ascending lower extremity weakness and paralysis.
    - Abdominal or chest pain.
  - Peripheral Nerves
    - Urinary and rectal incontinence.
    - Abnormal sensations.
    - Muscle weakness or twitching.
Altitude Decompression Sickness

• Types of DCS: “The Chokes”
  • Lungs
    • Deep burning substernal chest pain.
    • Pain aggravated by breathing.
    • Dyspnea.
    • Non-productive cough.

Altitude Decompression Sickness

• Types of DCS: Skin Bends
  • Skin
    • Itching around ears, face, neck, arms and upper body.
    • Sensation of insects crawling over the skin (formication)
    • Mottled or marbled skin usually around upper chest and abdomen.
    • Swelling of the skin (subcutaneous emphysema)

Altitude Decompression Sickness

Medical Treatment:
• Mild Cases – “the bends” and skin bends may disappear during descent from high altitude.
• 100% hyperbaric oxygen.
• Neurological DCS, “the chokes and mottled skin lesions must be treated with hyperbaric oxygen
Altitude Decompression Sickness

• Facts about breathing 100% oxygen:
  • Breathing 100% oxygen before exposure to low barometric pressure (oxygen pre-breathing) decreases risk of developing DCS.
  • Oxygen pre-breathing promotes the elimination (washout) of nitrogen from body tissues.

Altitude Decompression Sickness

• Facts about breathing 100% oxygen (cont.):
  • Recommendation – Pre-breathing 100% for 30 minutes reduces risk for altitude DCS for short exposures (10-30 min.) to altitudes between 18,000 and 43,000 ft.

  • In flight 100% oxygen breathing can provide effective protection against altitude DCS, only after oxygen pre-breathing.

Altitude Decompression Sickness

• Predisposing factors:
  • Altitude:
    • No specific altitude can be considered on absolute threshold
    • Below 18,000 ft. – very little evidence
    • 18,000 – 25,000 ft. – low occurrence of DCS
    • 25,000 ft. and above – most cases of DCS
    • Repetitive exposure to high altitudes above 18,000 ft
    • Rate of ascent can causes increase risk of DCS
Altitude Decompression Sickness

- Predisposing factors (cont.):
  - Scuba diving before flying:
    - Scuba diving requires breathing air under high pressure
    - Increases the amount of nitrogen in body tissue
    - Deeper and longer the dive increases the amount of nitrogen saturation
    - Following a dive, if not enough time is allowed to eliminate excess nitrogen, DCS can occur at altitudes as low as 5,000 ft. or less

Questions?