How High Am I? A discussion on Altitude Medicine

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Disclosures

- Nothing to disclose
Objectives

- Brief History
- Discuss altitude affects on physiology
- Environmental Exposures at Altitude
- Acute Mountain Sickness (AMS)
- High Altitude Pulmonary Edema (HAPE)
- High Altitude Cerebral Edema (HACE)
- Prevention/Treatment
- Golden Rules
- Summary
History

- **30 BC** – Reference to the Great Mountain and Little Headache Mountain in the Ch’ien Han Shu (classical Chinese history)
  - “...men’s bodies become feverish, they lose colour, and are attached with headache and vomiting...”
Introduction

• High Altitude – 1500-3500m (5000-11500ft)
• Very High Altitude – 3500 – 5500m (11500 – 18000ft)
• Extreme Altitude – above 5500m
Pathophysiology

- Hypoxia is main contributor to high-altitude illness.
- Barometric pressure & partial pressure of oxygen decr. w/ elevation and as one moves northward.
- At sea level, Barometric pressure is 760 mmHg.
- Temperature drops 6.5°C for every 1000m.
Acclimatization

• Acute hypoxic stress is poorly tolerated but given time to adapt the body can handle certain degrees of hypoxia very well
• How? Changes in ventilation, blood, fluid balance, and cardiovascular parameters.
Acclimatization Adaptations

- Acute adaptations can occur quickly!!
- Example:
  - 5 out of 10 people from 1947 to 1993 who stowed away w/o survival gear in the wheel wells of airliners that flew at 11,900 m (39,000 ft) on transcontinental flights survived!!
Blood Acclimatization

• Increase in EPO within 2 hours - benefit in exercise tolerance only with long term stays. Not important for alt. Sickness
• Increase 2,3-DPG (shifts oxyhemoglobin diss curve R). However resp alkalosis shifts curve L so likely no net effect
• If at altitude for a while, ↑ red cells (some advise aspirin while at altitude)
Hypoxic Response

- **Respiratory**
  - ↑rate

- **Cardiovascular**
  - ↑rate and stroke volume
  - Pulmonary vasoconstriction and cerebral vasodilatation (increases PA pressure)

- **Hematology**
  - ↑red blood cell mass and plasma viscosity
  - O2 Hb dissociation curve shift to left to increase affinity for O2 (so less delivered to tissues)
Exercise and Altitude

• VO\textsubscript{2} max drops 10\% for each 1000m in elevation.
  ▫ No acclimatization for this

• Fick equation: \textit{VO}2 = Q \times (A-V \textit{O2} difference)
Environmental Stresses at Altitude

- Temperature
- Dehydration
- UV exposure
Temperature exposure

- **Frost nip**
  - Blanching
  - Rev. Ice Crystals
  - Tx = gradual warming

- **Frost bite**
  - More Serious!
  - 4 Stages
  - Numbness-Blisters-Necrosis-Amputation
  - Tx = Whirlpool warm
Temperature exposure cont

- Hypothermia -
- Progression from:
  - cool skin and shivering;
  - to confusion,
  - loss of fine motor control,
  - dysarthria and sleepiness
  - to coma (core temp <32oC),
  - arrhythmias (J-wave, v-fib, asystole),
  - DEATH.
Dehydration

- Insensible loss
- Increased work
- At high altitude, only way to get water is to melt ice
- Heat Exhaustion
UV Exposure

- Penetration increases by 4% per 300m gain in elevation.
- Risks:
  - UV Keratensis (snow-blindness)
  - Sun-burn
  - Skin Cancer (long-term exposure)
- UV light can reflect off snow/ice and produce temperatures of 40.0°C/104.0°F.
  - Heat Exhaustion (esp. in tent)
High Altitude Travel: Contraindications

- Uncompensated Congestive Heart Failure
- Pulmonary Hypertension
- Sickle Cell Anemia
- Severe Chronic Obstructive Pulmonary Disease
High Altitude Travel: Precautions

- Compensated Congestive Heart Failure
- Troublesome arrhythmias
- Sickle cell trait
- Moderate COPD
- Seizure disorder (not controlled on meds)
- Stable angina or CAD
- Sleep apnea
- High-risk pregnancy
High Altitude Illness

- Caused by ascending too rapidly
  - Acute Mountain Sickness (AMS)
  - High Altitude Pulmonary Edema (HAPE)
  - High Altitude Cerebral Edema (HACE)
AMS

- Symptoms may present as early as 6-24 hours following ascent
- Common in those flying directly to altitudes above 3800m
- In untreated individuals symptoms are usually worse on Day 2 and Day 3 at altitude
  - Symptoms usually disappear at Day 5
    - May reappear if higher altitude is attempted
Symptoms of AMS

• Headaches
• Fatigue/weakness
• Gastrointestinal upset (N/V/Anorexia)
• Difficulty sleeping
• Dizziness/Lightheadedness
AMS

- International Hypoxia Symposium (Lake Louise, Alberta, Canada, 1993):
  - Generally: AMS is HA plus one other symptom in light of recent gain in altitude
  - Can classify into Mild, Moderate-Severe, HACE
# AMS Classifications

<table>
<thead>
<tr>
<th>Category</th>
<th>Mild AMS</th>
<th>Moderate-severe AMS</th>
<th>High altitude cerebral edema (HACE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms</td>
<td>Headache plus one or more other symptoms (nausea/vomiting; fatigue, lassitude, dizziness; difficulty sleeping)</td>
<td>Headache plus one or more other symptoms (nausea/vomiting; fatigue, lassitude, dizziness; difficulty sleeping)</td>
<td>Worsening of symptoms seen in moderate-severe AMS</td>
</tr>
<tr>
<td>Signs</td>
<td>All symptoms of mild intensity</td>
<td>All symptoms of moderate-severe intensity</td>
<td>Ataxia, severe lassitude, altered mental status, encephalopathy</td>
</tr>
<tr>
<td>Lake Louise AMS Score</td>
<td>2–4</td>
<td>5–15</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

This table provides an overview of the symptoms and signs associated with different categories of AMS (Altitude Sickness). The Lake Louise AMS Score is also included, which ranges from 2 to 15, with higher scores indicating more severe symptoms. The high altitude cerebral edema (HACE) is noted as a more severe condition with worsening symptoms seen in moderate-severe AMS.
AMS: Lake Louise Score

1) Headache 0-3pts
2) GI Sxs 0-3pts
3) Fatigue/weakness 0-3pts
4) Dizzy/LH 0-3pts
5) Difficulty Sleeping 0-3pts

TOTAL 15pts

Additional Scoring (Clinical Assessment)
6) Change in mental Status 0-4pts
7) Ataxia 0-4pts
8) Peripheral Edema 0-2pts
9) Functional Scoring 0-3pts
Lake Louise Scoring: Headache

0 – None at all
1 – Mild headache
2 – Moderate headache
3 – Severe headache, incapacitating
Lake Louise Scoring: GI symptoms

0 – Good appetite
1 – Poor appetite or nausea
2 – Moderate nausea or vomiting
3 – Severe, incapacitating nausea and vomiting
Lake Louise Scoring: Fatigue and/or weakness

0 – Not tired or weak
1 – Mild fatigue/weakness
2 – Moderate fatigue/weakness
3 – Severe fatigue/weakness
Lake Louise Scoring: Dizziness/Light-headedness

0 – None
1 – Mild
2 – Moderate
3 – Severe, incapacitating
Lake Louise Scoring: Difficulty sleeping

0 – Slept as well as usual
1 – Did not sleep as well as usual
2 – Wake many times, poor nights sleep
3 – Could not sleep at all
Lake Louise Scoring: Change in mental status

0 – No change
1 – Lethargy/lassitude
2 – Disorientated/confused
3 – Stupor/semiconscious
4 - Coma
Lake Louise Scoring: Ataxia (heel/toe walking)

0 – None
1 – Balancing maneuvers
2 – Steps off the line
3 – Falls down
4 – Unable to stand
Lake Louise Scoring: Peripheral edema

0 – None
1 – One location
2 – Two or more locations
Lake Louise Scoring: Functional score

- Overall, if you had any of these symptoms, how did they affect your activities?
  - 0 – Not at all
  - 1 – Mild reduction
  - 2 – Moderate reduction
  - 3 – Severe reduction (i.e. bedrest)
AMS: Treatment

Treatment:
- Stopping ascent & allowing acclimatization.
- Start Acetazolamide (Diamox) - diuretic, 125-250 mg PO BID.
- Alternatively, descend 460m/1500 ft or more until symptoms resolve.
- ASA useful in treating HA.
- Non-barbiturate sedative can improve sleep.
AMS: Post treatment recommendations

- Ascent can resume once symptoms have resolved
- No evidence to support counseling patient to avoid altitude after episode of AMS
- Recurrence rate not increased with repeated ascents
Dyspnea at altitude

- Common with exertion at elevation
- Dyspnea at rest indicates severe AMS or HAPE
- Symptoms that may mimic dyspnea related to elevation:
  - Viral illness
  - CO poisoning (cooking stoves used in tents)
  - Exhaustion
  - Dehydration
High Altitude Pulmonary Edema (HAPE)

- HAPE: A form of non-cardiogenic pulmonary edema and is associated with marked pulmonary HTN
- 15% of travelers to altitudes > 2,500, 8,200 ft will develop HAPE depending on:
  - age (<20y.o.)
  - sex (M>F)
  - rate of ascent
High Altitude Pulmonary Edema (HAPE)

- Diagnostic Criteria: 1991 Hypoxia symposium
- In setting of recent gain in altitude, at least two of the following symptoms must be present:
  - Dyspnea at rest
  - Cough
  - Weakness
  - Decreased exercise performance
  - Chest tightness or congestion
High Altitude Pulmonary Edema (HAPE)

- Diagnostic Criteria (continued)
- At least two of the following signs must be present:
  - Rales or wheezing in at least one lung field (RML)
  - Central Cyanosis
  - Tachycardia
  - Tachypnea
High Altitude Pulmonary Edema (HAPE)

- Occurs 1 to 3 days after ascent is begun
- It is a medical emergency!!
- The most common cause of death at high altitude
High Altitude Pulmonary Edema (HAPE)

- **Treatment:**
  - Immediate descent of 1000 meters until symptoms resolve is the **Definitive Treatment!!**
  - If HAPE severe enough that pt. cannot descend
    - Rest & Keep warm
    - Give Oxygen at 4-6 LPM
    - Nifedipine SR 10mg PO, then 30mg q12 hrs
    - Acetazolamide 500mg
    - Dexamethasone 20mg IV
High Altitude Pulmonary Edema (HAPE)

- **Treatment:**
  - Portable single person hyperbaric bags
    - Gamow
    - Chamberlite
  - Mult-person hyperbaric bags
High Altitude Pulmonary Edema (HAPE)

- If diagnosed early, pt. usually recovers.
- Mortality rate is 44%.
- Recurrence rate of HAPE in pts. w/ previous episode on subsequent climbs is 66%.
- Repeat ascent should not be attempted soon after episode. Can take up to 2 weeks to fully recover.
High Altitude Cerebral Edema (HACE)

- HACE constitutes the progression of HAPE or AMS to include involvement of the brain, causing encephalopathy.
- Cause is probably vasogenic cerebral edema, resulting from increased intracranial pressure.
High Altitude Cerebral Edema (HACE)

- **Symptoms:**
  - Severe lassitude
  - Altered consciousness
  - Ataxia
    - (+) Tandem Gait Test, Finger-to-nose not affected
    - Focal neurologic signs are rare
- Symptoms worse at night
High Altitude Cerebral Edema (HACE)

- AMS may progress to HACE w/ unconsciousness w/ in 12 hrs
- Usually takes 1 to 3 days to develop HACE
- MRI shows
  - Edema/generalized swelling
High Altitude Cerebral Edema (HACE)

- **Treatment:**
  - Immediate descent of at least 1000 meters, if symptoms do not improve, descent should continue.
  - If descent is impossible:
    - Oxygen at 2-4 LPM
    - Dexamethasone (Decadron) 4mg PO/IM q 6
    - Portable hyperbaric therapy (as with HAPE)
High Altitude Cerebral Edema (HACE)

- Post HACE:
  - Sequelae can last weeks but eventually, pts usually recover completely.
  - Mortality rate in untreated patient is 13%, up to 60% if they are comatose!
Altitude Illness Prophylaxis

- Although various treatment options exist for AMS, prevention is the best approach
- Should be tailored to individual
- Non-pharmacologic vs. Pharmacologic
Altitude Illness Risk Stratification

- **Low**
  - Individuals with no prior history of altitude illness and ascending to ≤2800 m
  - Individuals taking ≥2 days to arrive at 2500–3000 m with subsequent increases in sleeping elevation <500 m/d and an extra day for acclimatization every 1000 m

- **Moderate**
  - Individuals with prior history of AMS and ascending to 2500–2800 m in 1 day
  - No history of AMS and ascending to >2800 m in 1 day
  - All individuals ascending >500 m/d (increase in sleeping elevation) at altitudes above 3000 m but with an extra day for acclimatization every 1000 m

- **High**
  - Individuals with a history of AMS and ascending to >2800 m in 1 day
  - All individuals with a prior history of HACE
  - All individuals ascending to >3500 m in 1 day
  - All individuals ascending >500 m/d (increase in sleeping elevation) above >3000 m without extra days for acclimatization
  - Very rapid ascents (eg, <7-day ascents of Mt Kilimanjaro)
Non-pharmacologic prevention

- **Rate of ascent**
  - Slowing it down helps – especially with regards to sleeping
  - Once above 3000m – should not increase sleeping elevation by more than 500m day

- **Fluid intake**
  - Should remember to drink – with the caveat that if they drink too much without adequate salt intake could lead to hyponatremia

- **Pre-acclimatization**
  - Exposure to hypoxia in a hypobaric or normobaric environment

- **Staged ascent**
  - Staged ascent (spending 6-7 days at moderate altitude)
### Pharmacologic Prevention/Treatment

<table>
<thead>
<tr>
<th>Medication</th>
<th>Indication</th>
<th>Route</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetazolamide</td>
<td>AMS, HACE Prevention</td>
<td>Oral</td>
<td>125 mg bid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peds:</td>
<td>2.5mg/kg q 12 hrs</td>
</tr>
<tr>
<td></td>
<td>AMS Treatment</td>
<td>Oral</td>
<td>250mg bid</td>
</tr>
<tr>
<td>Dexamethasone</td>
<td>AMS, HACE Prevention</td>
<td>Oral</td>
<td>2mg q6h or 4mg q12h</td>
</tr>
<tr>
<td></td>
<td>AMS, HACE Treatment</td>
<td>Oral, IV, IM</td>
<td>AMS: 4mg q6h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HACE: 8mg once then 4mg q6h</td>
</tr>
<tr>
<td>Nifedipine</td>
<td>HAPE Prevention</td>
<td>Oral</td>
<td>30mg ER q12h</td>
</tr>
<tr>
<td></td>
<td>HAPE Treatment</td>
<td>Oral</td>
<td>30mg ER q12 h</td>
</tr>
<tr>
<td>Tadalafil</td>
<td>HAPE Prevention</td>
<td>Oral</td>
<td>10mg bid</td>
</tr>
<tr>
<td>Sildenafil</td>
<td>HAPE Prevention</td>
<td>Oral</td>
<td>50mg q8h</td>
</tr>
<tr>
<td>Salmeterol</td>
<td>HAPE Prevention</td>
<td>Inhalation</td>
<td>125μg bid</td>
</tr>
</tbody>
</table>
Golden Rules

• Rule 1:
  ▫ If you feel unwell at altitude it is altitude illness until proven otherwise

• Rule 2:
  ▫ Never ascend with symptoms of AMS

• Rule 3:
  ▫ If you are getting worse (have HAPE or HACE) go down immediately
Summary

• Brief History
• Discuss altitude affects on physiology
• Environmental Exposures at Altitude
• Acute Mountain Sickness (AMS)
• High Altitude Pulmonary Edema (HAPE)
• High Altitude Cerebral Edema (HACE)
• Prevention/Treatment
• Golden Rules
References

- http://www.wemjournal.org/article/S1080-6032(14)00257-9/fulltext#s0035