The Traveling Diver and Alpinist

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FACP
Prepared by CAPT David Regis
Disclosures

• Views are my own opinion, and not those of the US Navy or DoD
• I have no financial relationships with any of the products / companies discussed
Background

• Estimated to be 1.5 to 3.5 million certified divers in the U.S. (100-200K new/year)
• >100 million people visit ≥ 2,500m (∼8,000 ft) annually
• Many travel the world to prime destinations
• Each carries risks of both travel and environment.
  – Pressure (Direct and Indirect Effects)
  – Temperature
Trip of a Lifetime Mentality

• Usually large investment in time, money and training
• Pressure to make the dives/summit
• Overestimations of abilities
• Incorrect assumptions WRT fitness etc.
• Competition within group
• Leader/dive master reluctant to split group.
  – Fear of being left behind
• Climbing/Trekking commercial outfits:
  – Published itinerary’s are average schedules
  – Not meant to prevent AMS
    • Inflexible schedule = left behind
    • Flexible schedule = acclimatize within a day and can continue
  – Underestimating the first case of AMS by the trip leader
We are all saturation divers at 1 atm
Boyle’s Law

\[ pV = k \]

\[ p_1 V_1 = p_2 V_2 \]

OR

\[ \frac{V_1}{V_2} = \frac{p_2}{p_1} \]
BOYLE'S LAW:

THE VOLUME OF A GAS IS INVERSELY PROPORTIONAL TO ITS PRESSURE, WITH TEMPERATURE REMAINING CONSTANT.

43,000 —— 6 TIMES
34,000 ———— 4 TIMES
25,000 ———— 2.5 TIMES
16,000 ———— 2 TIMES

DRY GAS EXPANSION
## Depth, partial pressure and lung volumes

<table>
<thead>
<tr>
<th>Lung volume</th>
<th>Pressure (atmospheres)</th>
<th>pO₂</th>
<th>pN₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>1</td>
<td>0.21</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>(101 kPa)</td>
<td>(21.2 kPa)</td>
<td>(79.8 kPa)</td>
</tr>
<tr>
<td>10 metres</td>
<td>2</td>
<td>0.42</td>
<td>1.58</td>
</tr>
<tr>
<td></td>
<td>(202 kPa)</td>
<td>(42.4 kPa)</td>
<td>(159.6 kPa)</td>
</tr>
<tr>
<td>20 metres</td>
<td>3</td>
<td>0.63</td>
<td>2.37</td>
</tr>
<tr>
<td></td>
<td>(303 kPa)</td>
<td>(63.6 kPa)</td>
<td>(239.4 kPa)</td>
</tr>
<tr>
<td>30 metres</td>
<td>4</td>
<td>0.84</td>
<td>3.16</td>
</tr>
<tr>
<td></td>
<td>(404 kPa)</td>
<td>(84.8 kPa)</td>
<td>(319.2 kPa)</td>
</tr>
</tbody>
</table>
DIVING
Introduction

• 3-9/100,000 diving deaths per year
  – Drowning most common cause (60%)
• Pre-disposing risk factors/mitigators
  – Fitness
  – Age
  – Concurrent illness (acute or chronic)
  – Sex?
  – Training
• All risks directly related to effects of pressure
Risk Factors/Mitigators

• Fitness
  – Being physically fit reduces risk of Decompression Sickness (DCS)
    • May be more directly related to BMI
• Age
  – Some related to above plus acquisition of chronic illnesses
  – Dive certification usually not allowed until 12 yrs
Risk Factors/Mitigators

• Concurrent illness/Conditions
  – Short/long term meds may preclude from diving
  – Dehydration; Alcohol; obesity; cold
  – PFO controversial: 20% of population; 40% DCS cases

• Women
  – No clear relationship with DCS: Risk 0-3x vs Men
  – Menses DOES NOT increase risk of shark attack
  – Pregnancy contraindicated
## RELATIVE CONTRAINDICATIONS

<table>
<thead>
<tr>
<th>Condition</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthma</td>
<td>Absolute contraindication for commercial and military; regulations vary country to country; controversial topic – control of illness, medications, maturity of diver&lt;sup&gt;9-19&lt;/sup&gt;</td>
</tr>
<tr>
<td>Diabetes mellitus&lt;sup&gt;19-25&lt;/sup&gt;</td>
<td>Depends on control and whether episodes of hypoglycemia occur</td>
</tr>
<tr>
<td>Cardiovascular problems</td>
<td>Those with mitral valve prolapse should have evaluation to make sure no concurrent problems&lt;sup&gt;25&lt;/sup&gt;</td>
</tr>
<tr>
<td>Migraine headaches</td>
<td>Symptoms can be confused with those of DCS</td>
</tr>
<tr>
<td>Limited visual acuity</td>
<td>Contact lenses are safe;&lt;sup&gt;33&lt;/sup&gt; post radial keratotomy patients should probably wait 2-5 months (mask squeeze prior to complete healing can be harmful);&lt;sup&gt;34&lt;/sup&gt; no problem for those with previously repaired retinal detachments or controlled glaucoma&lt;sup&gt;27, 35&lt;/sup&gt;</td>
</tr>
<tr>
<td>Post-operative patients</td>
<td>Usually safe to dive when asymptomatic; ostomies fine; those with airtight Kock pouches should not dive; those with breast implants may have higher risk of bubble formation, though appears tissue damage minimal&lt;sup&gt;32&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hernias</td>
<td>Inguinal or abdominal hernias must be repaired prior to diving</td>
</tr>
<tr>
<td>Disabilities</td>
<td>Depends on nature of disability; many who undergo proper training after screening do extremely well&lt;sup&gt;37&lt;/sup&gt;</td>
</tr>
<tr>
<td>Infectious diseases</td>
<td>Active upper and lower respiratory infections are a temporary contraindication</td>
</tr>
<tr>
<td>Pregnancy</td>
<td>Controversial; most do not recommend.&lt;sup&gt;5&lt;/sup&gt; May be higher incidence of DCS II;&lt;sup&gt;4, 6, 7&lt;/sup&gt; no data to suggest greater risk of spontaneous abortion;&lt;sup&gt;8&lt;/sup&gt; though fetal death in utero has been associated with diving&lt;sup&gt;7&lt;/sup&gt;</td>
</tr>
<tr>
<td>Orthopedic injuries</td>
<td>Contraindicated until healed</td>
</tr>
<tr>
<td>Migraine headaches</td>
<td>Diving contraindicated during active headaches</td>
</tr>
</tbody>
</table>

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## Table 39.1 Contraindications to diving

<table>
<thead>
<tr>
<th>Absolute Contraindications</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical condition</td>
<td></td>
</tr>
<tr>
<td>Seizure disorders</td>
<td>Exclusions include childhood febrile seizures, or those due to medication(^{27}). EEG may be done if indicated, particularly following head trauma(^{27}).</td>
</tr>
<tr>
<td>Cardiovascular problems</td>
<td>Heart disease accounts for up to 25% scuba deaths(^{26}), myocardial infarction within previous year, symptomatic coronary artery disease, arrhythmia, congestive heart failure, atrial septal defect, history of cerebrovascular accident, uncontrolled hypertension(^{26, 30}).</td>
</tr>
<tr>
<td>Psychological</td>
<td>Depression, schizophrenia, anxiety/panic disorder(^{2, 36}), history of psychosis or suicide attempts(^{27}), children with hyperactivity disorder require evaluation(^3).</td>
</tr>
<tr>
<td>Sickle cell disease</td>
<td>Homozygous sicklers; risk to heterozygotes as well(^{3, 31}).</td>
</tr>
<tr>
<td>Unexplained syncpe</td>
<td></td>
</tr>
<tr>
<td>Vertigo</td>
<td></td>
</tr>
<tr>
<td>Inability to equalize</td>
<td>Temporary contraindication if due to temporary condition.</td>
</tr>
<tr>
<td>middle ear pressures</td>
<td></td>
</tr>
<tr>
<td>Chronic lung disease</td>
<td>Bullous, emphasematous lung disease, history of spontaneous pneumothorax.</td>
</tr>
<tr>
<td>Previous POPS</td>
<td></td>
</tr>
<tr>
<td>Tympamic membrane</td>
<td>Unless healed or surgically repaired.</td>
</tr>
<tr>
<td>perforation</td>
<td></td>
</tr>
<tr>
<td>Medication or Medication Class</td>
<td>Comments</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Sedatives/Analgesics</td>
<td>Narcotics contraindicated; Nonsteroidal anti-inflammatory drugs safe; Acetaminophen safe</td>
</tr>
<tr>
<td>Cardiovascular agents</td>
<td>Beta-blockers relatively contraindicated; ACE inhibitors, vasodilators use with caution; Cardiac glycosides (digoxin) safe</td>
</tr>
<tr>
<td>Birth control pills</td>
<td>Little data; appear safe</td>
</tr>
<tr>
<td>Insulin</td>
<td>Insulin requirements may change; Lower levels of glucose/glucagon measured while diving in some diabetics</td>
</tr>
<tr>
<td>Antipsychotics</td>
<td>Contraindicated</td>
</tr>
<tr>
<td>Anticonvulsants</td>
<td>Contraindicated</td>
</tr>
<tr>
<td>Antimicrobial agents</td>
<td>Appear safe, unless underlying acute illness for which there is a contraindication</td>
</tr>
<tr>
<td>Antimalarials</td>
<td>Mefloquine may induce adverse events confused with decompression sickness. Test doses may be taken prior to diving to make sure tolerated. Atovaquone-proguanil or doxycycline may be better choices depending upon the circumstances</td>
</tr>
<tr>
<td>Antihistamines/decongestants</td>
<td>Depends on medication and underlying cause for its administration; pseudoephedrine may decrease risk and severity of otic barotraumas</td>
</tr>
<tr>
<td>Anti-motion sickness agents</td>
<td>Some may cause sedation; scopolamine has been used safely</td>
</tr>
</tbody>
</table>
Training (or lack there of)
DIVING PROBLEMS
Barotrauma (Dysbarism)

- Otic
- Sinus
- Dental
- GI
- Mask
- Pulmonary (POIS = POPS)
Otic Barotrauma

- **Squeeze**
  - On descent

- **Reverse Squeeze**
  - On Ascent

- **Other related issues**
  - **Alternobaric Vertigo**
    - Usually on ascent
    - Brief, self limited
  - **Caloric Vertigo**
    - Colder water
    - Brief, self limited
Sinus/Tooth (Barodontalgia) Squeeze

- Anatomy
- Allergies/Infections
- Medications

- Bad dentition
- Filling defect
- May need DDS/DMD
GI Distention/Mask Squeeze

- Ill fitting mask (too tight)
- Not clearing properly
- Will resolve on own

-Swallowing Air on Descent
  - Vigorous/Freq Clearing
-Burping/distention Ascent
Pulmonary Over-Inflation/Pressure Syndrome (POIS/POPS)

• Due to pulmonary barotrauma
  – Breath-holding or too rapid ascent
  – Expanding gas bubbles into blood stream
  – Risk greatest near the surface

• 4 important entities:
  – Arterial Gas Embolism
    • 2\textsuperscript{nd} most common cause of death in divers
    • Usually occurs within 10 minutes of surfacing
  – Pneumomediastinum
  – Pneumothorax
  – Subcutaneous emphysema

• Tx: Oxygen, Recompression

• NEEDS F/U TO R/O Underlying cause
Gas Problems
Nitrogen Narcosis

- Rapture of the Deep
- Generally $\geq 100$ fsw
- Martini’s Law
- Loosened inhibitions
- Agitation
- Tunnel Vision
- Tinnitus/Rushing Sound
- Poor Judgement
- Simple Tasks Become Difficult
- LOC
- Resolves with ascent or He
Hypoxia/Hyperoxia

• Issue with Nitrox Diving and Rebreathers
  • Hypoxia
    – Similar to Narcosis
  • Hyperoxia
    – VENTID-C
      • Visual
      • Ear
      • Nausea/Vomitting
      • Twitching/tingling
      • Irritability
      • Dizziness
      • Convulsions
Carbon Dioxide/Monoxide Poisoning

• Usually from bad air source
  – Compressor intakes near exhausts
• CO₂ also from over-breathing equipment
  – Hyperventilation
  – CO₂ Scrubber Failure (Rebreathers)

• Increased RR
• Irritability
• Sweating/N/V
• Drowsiness
• HA
• Difficulty Concentrating
• Seizures (CO₂)
• LOC
Decompression Sickness

• Otherwise known as DCS, Decompression Illness, ‘The Bends’.
• Result of nitrogen leaving tissues too quickly causing venous bubble formation.
• Categorized into Type I and Type II but argument for more of a spectrum of ‘Illness’
• No dive is without DCS risk but generally \( \leq 1-2\% \) range for recreational if follow training/tables.
  – “Plan your dive; Dive your plan.”
Decompression Sickness

DESATURATION OF TISSUES

Lung Capillary Bed

Venous Return

Arterial Supply

Right Heart Pump

Left Heart Pump

A

B

C

A

B

C

A
Decompression Sickness

• DCS Type I
  – Not life-threatening
  – Affects bones/joints manifesting as pain
  – Skin/lymphatics manifesting as Cutis Marmorata
    • Skin marbling
    • Itching
    • Treated like Type II
Decompression Sickness

- DCS Type II
  - Life/Limb Threatening Emergency
  - Neurologic
    - Peripheral and CNS symptoms
    - Cardiopulmonary (“Chokes”)
      - Overwhelming Lung/CV congestion
      - Usually from deep dive ‘blow-up’
    - Vestibular (“Staggers”)
      - Most common with Heliox Diving
## Decompression Sickness

### Onset of DCS symptoms

<table>
<thead>
<tr>
<th>Time to onset</th>
<th>Percentage of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>within 1 hour</td>
<td>42%</td>
</tr>
<tr>
<td>within 3 hours</td>
<td>60%</td>
</tr>
<tr>
<td>within 8 hours</td>
<td>83%</td>
</tr>
<tr>
<td>within 24 hours</td>
<td>98%</td>
</tr>
<tr>
<td>within 48 hours</td>
<td>100%</td>
</tr>
</tbody>
</table>

- Denial common among divers
- May occur / worsen while flying

### Symptoms by frequency

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>local joint pain</td>
<td>89%</td>
</tr>
<tr>
<td>arm symptoms</td>
<td>70%</td>
</tr>
<tr>
<td>leg symptoms</td>
<td>30%</td>
</tr>
<tr>
<td>dizziness</td>
<td>5.3%</td>
</tr>
<tr>
<td>paralysis</td>
<td>2.3%</td>
</tr>
<tr>
<td>shortness of breath</td>
<td>1.6%</td>
</tr>
<tr>
<td>extreme fatigue</td>
<td>1.3%</td>
</tr>
<tr>
<td>collapse/unconscious ness</td>
<td>0.5%</td>
</tr>
</tbody>
</table>
DCS Treatment

- High flow $O_2$
- Rest
- Hydrate
- Treat Symptoms
- Pain control
- Steroids not recom.
- For serious DCS pt likely unstable
- RECOMPRESSION TX
Flying After Diving

• Most commercial flights pressurized to 8000 feet – USN Dive Manual has recommendations
• Each certifying organization has their own as well
• In general as follows:
  – No decompression diving: 12 hours
  – Decompression Diving: 24 hours or longer
  – Multiple days of multiple dives: 24 hours

http://www.supsalv.org/00c3_publications.asp?destPage=00c3&pageId=3.9
Returning To Diving After . . .

• Otic BT: When healed and can clear.
• Eye surgery (Lasek): 1 month w/ Opth approv
• Pulmonary BT (known cause): 1 month + w/u
  – 6 months for traumatic PTX with neg w/u
• +PPD/LTBI post Tx and neg w/u
• Abd Surgery: After 3 months and neg w/u
• Successful DCS Tx post 1 Tx
  – Type I: 2d-1 week - Type II: 30+ days
• NOTE: These are for guidelines only. Consult a DMO on case by case basis.

Case

• Your patient, an avid diver, is planning on a dive trip to Belize but has a cold and was recently diagnosed with an ear infection, is taking Septra and Pseudoephedrine. He also has a very short itinerary, and he wants to know if he can dive each day, including the day of his flight home.

• Can he dive? When?
• What are possible effects of diving?
• Recommendations for flight?
Diving Key Points

• The hazards of diving and the sophistication of advising travelers are underappreciated by the travel medicine community
• Many with underlying chronic illnesses or with disabilities may dive
• Barotrauma results from the uncontrolled expansion of gas within body compartments
• Decompression sickness results from too rapid a return to atmospheric pressure
• Consider doing a detailed neuro exam on any traveling diver
• Encourage refresher courses for infrequent divers.
• There are many organizations and resources for diving travelers and travel medicine physicians
Table 39.4  Recreational and professional scuba diving organizations and resources

<table>
<thead>
<tr>
<th>Organization</th>
<th>Address</th>
<th>Phone</th>
<th>Fax</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Canadian Underwater Certification Inc. (ACUC)</td>
<td>1264 Osprey Dr, Ancaster, Ontario L9G 3L2 Canada</td>
<td>905 546 5500</td>
<td>905 648 5440</td>
<td><a href="http://www.acuc.org">www.acuc.org</a></td>
</tr>
<tr>
<td>British Sub-Aqua Club (BSAC)</td>
<td>18 Upper Woburn Place, London WC1 0QW, UK or; Telford’s Quay, Ellesmere Port, South Wirral, Cheshire L65 4FY, UK</td>
<td>44 0151 350 6200</td>
<td>44 0151 350 6215</td>
<td><a href="http://www.bsac.org">www.bsac.org</a></td>
</tr>
<tr>
<td>International Association of Nitrox &amp; Technical Divers (IANTD)</td>
<td>9228 NE 2nd, Suite D, Miami Shores FL 33138 USA</td>
<td>305 751 4873</td>
<td>305 751 3559</td>
<td><a href="http://www.iandt.com/">www.iandt.com/</a></td>
</tr>
<tr>
<td>Korean Underwater Association</td>
<td>Rm. 146, #2 Gymnasium, Oryun-dong, Songpa-ku, Seoul 138-151, Korea</td>
<td>011 622 420293</td>
<td></td>
<td><a href="http://www.kua.or.kr">www.kua.or.kr</a></td>
</tr>
<tr>
<td>International Diving Educators Association (IDEA)</td>
<td>P.O. Box 8427, Jacksonville, FL 32239 USA</td>
<td>904 744 5554</td>
<td>904 743 5425</td>
<td><a href="http://www.idea-scubadiving.com/">www.idea-scubadiving.com/</a></td>
</tr>
<tr>
<td>MDEA - Multinational Diving Educators Assoc.</td>
<td>Box 3162, 202 22 Malmö, Sweden</td>
<td>+46 40 290240</td>
<td>+46 40 290240</td>
<td><a href="http://www.mdea.se/">www.mdea.se/</a></td>
</tr>
<tr>
<td>National Association of Underwater Instructors (NAUI)</td>
<td>P.O. Box 14650 Montclair, CA 91763 USA</td>
<td>909 621 3801</td>
<td>909 621 6465</td>
<td><a href="http://www.naui.org">www.naui.org</a></td>
</tr>
<tr>
<td>Professional Association of Diving Instructors (PADI)</td>
<td>1251 East Dyer Road, #100 Santa Ana, CA 92705</td>
<td>714 540 7234</td>
<td>714 540 2009</td>
<td><a href="http://www.padi.com">www.padi.com</a></td>
</tr>
<tr>
<td>Scuba Schools International (SSI)</td>
<td>2619 Canton Ct., Fort Collins, CO 80525 USA</td>
<td>970 482 0883</td>
<td>970 482 6157</td>
<td><a href="http://www.ssiusa.com/">www.ssiusa.com/</a></td>
</tr>
<tr>
<td>Sub-Aqua Association (SAA)</td>
<td>19 Harrier Drive, Canford Marina, Wimborne, Dorset BH21 1XG UK</td>
<td>0151 287 1026</td>
<td></td>
<td><a href="http://www.saa.org.uk">www.saa.org.uk</a></td>
</tr>
<tr>
<td>South Pacific Undersea Medical Society (SPUMS)</td>
<td>630 St Kilda Road, Melbourne, Victoria 3004, Australia</td>
<td></td>
<td></td>
<td><a href="http://www.spums.org.au/index.html">www.spums.org.au/index.html</a></td>
</tr>
</tbody>
</table>

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Problems with Altitude
Problems with Altitude
High Altitude Definitions

• Over 1500m (4900 ft)
• Moderate altitude is 2000-3500m (6600 to 11,500 ft)
  – Mild tissue hypoxia from low arterial PO2 and altitude sickness is common
• Very high altitude is 3500-5500m (18,000 ft)
  – Arterial oxygen saturation is not maintained
  – HAPE and HACE most common in this range
• Extreme altitude is over 5500m (18,000 ft)
  – Successful long-term acclimatization is “impossible”
Boyle . . . Again!

**Boyle’s Law:**
The volume of a gas is inversely proportional to its pressure, with temperature remaining constant.

Dry Gas Expansion
Temperature and other issues

• Decreases up to 12°F (6.5°C) per 3300ft (1000m).
  – Effects of hypothermia can be additive
    • HAPE
    • Frostbite

• UV exposure increases 4%/1000ft (300m)
  – Sunburn
  – UV keratoconjunctivitis
  – Cataracts

• Dry air predisposes to dehydration/dry airways
## Demographics

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Persons</th>
<th>Activities</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>High altitude</td>
<td>Everyone</td>
<td>Skiing/Air Travel, Touring, Trekking, Mountaineering</td>
<td>Millions</td>
</tr>
<tr>
<td>1500 - 3500 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5,000 - 11,500)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very High altitude</td>
<td>Healthy adults</td>
<td>Skiing, Trekking, Mountaineering</td>
<td>Many thousands</td>
</tr>
<tr>
<td>3500-5500 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(11,500 - 18,000)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme altitude</td>
<td>Extreme athletes</td>
<td>Mountaineering</td>
<td>Few thousands</td>
</tr>
<tr>
<td>5500 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 18,000 feet</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Acclimatization is Key!

• If you could immediately “dissaparate” to the summit of Everest (P_{i}O_{2} 43) you would be unconscious within 2 minutes.

• Normal Physiologic Changes:
  – Hyperventilation (Resp Alkalosis)
  – SOB w/exercise (↓VO_{2} max 10%/1000m > 1500m)
  – Increased urination (Bicarb excretion)
  – Increased Cerebral Blood Flow (HA?)
  – Increased Hgb
  – Changed breathing pattern at night (Cheyne-Stokes)
  – Awakening frequently at night/Headache (up to 80%)
Acclimatization

• Initially @ 9,000 to 10,000 ft for most
  – This line can move up the mountain
    • @ 400m/day (1300ft/d)*
  – If you get too far above the line it only gets worse, no acclimatization possible

• Avoid heavy excersion
• Don’t ascend when symptomatic

* Am J Respir Crit Care Med 2012; 185:192–198
HIGH ALTITUDE SYNDROMES
High Altitude Syndromes

• Cerebral and pulmonary syndromes that develop in non-acclimatized persons
• Cerebral
  – Acute mountain sickness (AMS)
  – High altitude cerebral edema (HACE)
• Pulmonary
  – High altitude pulmonary edema (HAPE)
• Pathophysiology of hypoxia in otherwise healthy persons
### Frequency of AMS, crackles, and HAPE in adults on ascent to moderately high altitudes (3600 – 4600 m)

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Altitude</th>
<th>Number</th>
<th>AMS</th>
<th>Lung crackles</th>
<th>Clinically relevant HAPE *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hackett and Rennie⁴</td>
<td>Pheriche, Nepal</td>
<td>4243 m</td>
<td>278</td>
<td>53%</td>
<td>“Common”</td>
<td>2.5%</td>
</tr>
<tr>
<td>Houston⁵†</td>
<td>Mt Rainier, USA</td>
<td>4400 m</td>
<td>141</td>
<td></td>
<td>15%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Hackett and Rennie¹²</td>
<td>Pheriche, Nepal</td>
<td>4243 m</td>
<td>200</td>
<td>43%</td>
<td>23%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Maggiorini et al⁶</td>
<td>Swiss Alps</td>
<td>3650 m</td>
<td>82</td>
<td>34%</td>
<td>27%</td>
<td>2.4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4559 m</td>
<td>209</td>
<td>53%</td>
<td>26%</td>
<td>3.8%</td>
</tr>
<tr>
<td>Basnyat et al¹³</td>
<td>Gosainkund, Nepal</td>
<td>4300 m</td>
<td>228</td>
<td>68%</td>
<td></td>
<td>4.8%</td>
</tr>
<tr>
<td>Cremona et al¹⁷</td>
<td>Monte Rosa, Italy</td>
<td>4559 m</td>
<td>262§</td>
<td></td>
<td>15%‡§</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

*Definition varies from study to study
†Unpublished data as cited by the author and by Hultgren and Marticorena¹⁴
‡Includes both crackles and radiographic evidence of oedema
§Excludes the one identified case of clinically relevant HAPE, for whom data were incomplete.

Lancet 359, Issue 9303, 26 January 2002 Pages 276-277
High Altitude Syndromes

• Rate of ascent (>1300 ft/day)
• Altitude
  – Altitude reached and slept at
  – Incidence of AMS at 2000-3500m is 10-40%
  – 25-50% above 4000m
• Variable susceptibility
• Past history of AMS is best predictor
  – Muted response & desaturation to hypoxia
• Slight decrease in risk after age 50
• Physical fitness NOT protective
  – But obesity/smoking may be a risk factor
• HTN, CAD and DM do not increase risk

5/7/14
Acute Mountain Sickness AMS & High-Altitude Cerebral Edema (HACE)

• Spectrum of disease
• Pathophysiology poorly understood
  – Effects and response to hypoxia
    • Cerebral vasodilation
    • Impaired cerebral autoregulation
    • Elevated capillary pressures
    • Cytokine induced changes in BBB permeability
      – Capillary leaks
      – Edema
• Edema is what will cause herniation and death
AMS/HACE

• Occurs within 48 hrs of ascent to > 8000 ft
  – After rapid ascent (1 day or less)
  – Usually within hours of arrival but up to 3 days out
• Similar to ‘hangover’ or afebrile viral illness
  – HA that is throbbing /bilateral
  – Anorexia, N/V
  – Weakness, lightheadedness
  – Often report reduced UOP (vs expected increase)
  – Most resolve 1-2 days depending on situation
• Can worsen to ataxia, MS changes = HACE
  – < 10% go on to HACE (40% mortality with limited medical care.)
## AMS Worksheet

<table>
<thead>
<tr>
<th>TIME</th>
<th>Altitude</th>
<th>SYMPTOMS</th>
<th>Headache</th>
<th>GI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 – None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 – Mild</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 – Mod</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 – Severe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

0- None | 1- Nausea | 2 - Mod N/V | 3 - Severe |

+ 1 other symptom = AMS
AMS/HACE Treatment

- No further ascent until asymptomatic
- Descend to lower altitude if no improvement with therapy
  - 500-1000m (1600-3200ft) usually sufficient
- Descend at first sign of HACE
- $O_2$ if available

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AMS/HACE Treatment

• Acetazolamide
  – Speeds acclimatization
  – Hastens resolution in 12-24hrs
• Dexamethasone
  – Rapidly reverses symptoms 2-4 hrs
  – Does not affect acclimatization
  – Rebound
    • Continue 1-2 days post descent or when MS clears
• No evidence for Coca leaf tea or garlic
AMS/HACE Treatment

- Gamow Bag, CERTEC,
- Manually inflated
- Pressurize to 105-220 mmHg above ambient
  - @ 1/3 descent
- Similar efficacy to O2
- 1 hour to effect

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AMS/HACE Prevention

• Preacclimatization
• Acclimatization!!!
  – Effects for AMS will last for > 1wk; 1-2d for HAPE
• Acetazolamide
  – Will not mask AMS
  – Appears 125 mg BID as effective as 250mg or 500mg QD

• Journal of Travel Medicine 2012; Volume 19 (Issue 5): 298–307
Unscreaded Slide 62

Acetazolamide

• Sulfa allergy a concern
• Serious allergic reactions are rare
• Although at increased risk, individuals with Sulfa allergy are less likely to react to Diamox than PCN allergic patients
• Travelers with any allergic history should test their tolerance prior to departure

• References:
High Altitude Pulmonary Edema (HAPE)

- Incidence 0.01%-15%
- Genetic predisposition
  - Pulmonary artery hypertension
    - Exaggerated hypoxic pulmonary vasoconstriction
- Male
- Pre-existing medical conditions
  - Pulmonary HTN
  - Restricted pulmonary vascular bed
- Non-cardiogenic hydrostatic pulmonary edema
HAPE

- Occurs 2-4 days after ascent
- Worse at night
- Decreased exercise performance
- Dry cough
- Insidious onset that can quickly become fatal
  - Productive frothy cough
  - Severe Dyspnea
  - ↑HR and RR
  - Drowsiness and other CNS symptoms
HAPE
**HAPE Severity Classification**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Symptoms</th>
<th>Signs</th>
<th>Chest X ray</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mild</td>
<td>HR (rest) &lt; 90 - 100</td>
<td>Minor exudate involving &lt; 25% of one lung field</td>
</tr>
<tr>
<td></td>
<td>Dyspnea on exertion</td>
<td>RR (rest) &lt; 20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dry cough</td>
<td>Dusky nail-beds or exertional desaturation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fatigue while moving uphill</td>
<td>+/- localized crackles</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>HR 90-100</td>
<td>Some infiltrate involving 50% of one lung or smaller area of both lungs</td>
</tr>
<tr>
<td></td>
<td>Dyspnea, weakness, fatigue on level walking</td>
<td>RR 16-30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Raspy cough</td>
<td>Cyanotic nail-beds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Headache, anorexia</td>
<td>Crackles present</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+/- ataxia</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Severe</td>
<td>HR &gt; 110</td>
<td>Bilateral infiltrates &gt; 50% of each lung</td>
</tr>
<tr>
<td></td>
<td>Dyspnea at rest</td>
<td>RR &gt; 30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extreme weakness</td>
<td>Facial and nail-bed cyanosis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orthopnea</td>
<td>Bilateral crackles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Productive cough</td>
<td>Blood tinged sputum</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stupor or coma</td>
<td></td>
</tr>
</tbody>
</table>
HAPE Treatment

• Descend if possible
• Oxygen
• Nifedipine if descent is NOT possible
• Hyperbaric treatment
  – 1 hour increments; 3-6 hours usually
• May need 3 days – 2 weeks for full recovery
  – Excellent prognosis with rapid recovery
  – May cautiously re-ascend after
HAPE Prevention

• Indicated if a history of repeated episodes
• Slower ascent
• Nifedipine
  – Use prophylactically or at the first signs
• Salmeterol
  – 50% reduction in susceptible persons
Other HAPE Prophylaxis

Table 1—Pharmacologic Treatment Option for Altitude Illnesses, Not Including Recommendations of Ascent Rates, Descent Rescue

<table>
<thead>
<tr>
<th>Illness</th>
<th>Medication</th>
<th>Prevention</th>
<th>Treatment</th>
<th>Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMS</td>
<td>Acetazolamide (oral)</td>
<td>125–250 mg b.i.d.</td>
<td>250 mg b.i.d.</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Dexamethasone (oral, IM, IV)</td>
<td>2 mg q6h or 4 mg b.i.d.</td>
<td>Same</td>
<td>Yes</td>
</tr>
<tr>
<td>HACE</td>
<td>Dexamethasone (oral, IM, IV)</td>
<td>Same as for AMS</td>
<td>8–10 mg intranasal dose then 4 mg q6h</td>
<td>Yes</td>
</tr>
<tr>
<td>HAP</td>
<td>Nifedipine (oral)</td>
<td>20–30 mg extended release b.i.d.</td>
<td>10 mg sublingual intranasal dose, then 20–30 mg extended release b.i.d.</td>
<td>Yes</td>
</tr>
<tr>
<td>Taralafti (oral)</td>
<td>10 mg b.i.d.</td>
<td>Not tested for treatment</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Phlendalfi (oral)</td>
<td>50 mg t.i.d.</td>
<td>Not tested for treatment</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Sameterol (inhaled)</td>
<td>125 μg b.i.d.</td>
<td>Not tested for treatment</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

Schoene - CHEST 2008; 134:402–416
OTHER ALTITUDE RELATED CONDITIONS
Other Altitude-Related Conditions

• ‘High Altitude Syncope’ – first 24 hours
  – No work-up needed unless recurs
• Focal Neurologic Deficits
  – Unmasked conditions that need evaluation
• High-Altitude Retinal Hemorrhage (HARH)
  – Altitude dependent 4%(4243m) to 50%(5360m)
  – Descend if symptomatic; Usually resolve completely within a few weeks.
Other Altitude-Related Conditions

• Peripheral Edema
  – Females more at risk; Evaluate for AMS
  – Can use diuretics but caution with dehydration

• High-altitude cough
  – Altitude dependent; Cold/Arid
  – Paroxysmal; Forceful; Purulent; Afebrile
  – Normal exercise tolerance and exam
  – Can have associated sore throat
  – Symptomatic treatment

• UV Keratitis aka “Snow Blindness”
  – Sunglasses!; Ointment; Analgesics: 24-48h to clear
Summary of Management

HAH  AMS mild  AMS severe  HACE  HAPE

Stop ascent, Rest Acetazolamide NSAIDs

Stop ascent, Oxygen (4-6 L/min) or Hyperbaric Chamber or CPAP

Dexamethasone  Nifedipine or Sildenafil

Descent!!

Figure 2 Overview on approved strategies of field treatment of high-altitude illnesses.

* Am J Respir Crit Care Med 2012; 185:192–198
Table 1  Medications for prevention and therapy of high-altitude illnesses.  

<table>
<thead>
<tr>
<th>High-altitude illness</th>
<th>Medication</th>
<th>Prevention administration, dose</th>
<th>Therapy administration, dose</th>
<th>Side effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep disturbances</td>
<td>Acetazolamide</td>
<td>Oral: 125 mg once per night</td>
<td></td>
<td>Diuresis, malaise, paresthesias, nausea, and taste disturbances</td>
</tr>
<tr>
<td></td>
<td>Temazepam</td>
<td>7.5–10 mg once per night</td>
<td>7.5–10 mg once per night</td>
<td>Drowsiness and dizziness</td>
</tr>
<tr>
<td>HAH</td>
<td>Acetaminophen</td>
<td>Oral: 1 g every 6 hours</td>
<td>Oral: 400 mg every 8 hours</td>
<td>Gastrointestinal bleeding</td>
</tr>
<tr>
<td></td>
<td>Ibuprofen</td>
<td>Oral: 400 mg every 8 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AMS</td>
<td>Acetazolamide</td>
<td>Oral: 125 mg every 12 hours</td>
<td>Oral: 250 mg every 12 hours</td>
<td>Diuresis, malaise, paresthesias, nausea, and taste disturbances</td>
</tr>
<tr>
<td></td>
<td>Dexamethasone</td>
<td>Oral: 2 mg every 6 hours or 4 mg every 12 hours</td>
<td>Oral, im, iv: 4 mg every 6 hours</td>
<td>Hyperglycemia and psychiatric alterations</td>
</tr>
<tr>
<td></td>
<td>Theophylline</td>
<td>Oral: 250 mg SR version every 12 hours</td>
<td></td>
<td>Nausea, headache, and interaction with azithromycin</td>
</tr>
<tr>
<td></td>
<td>Acetaminophen</td>
<td>Oral: 1 g every 6 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ibuprofen</td>
<td>Oral: 400 mg every 8 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HACE</td>
<td>Dexamethasone</td>
<td>Oral: 2 mg every 6 hours or 4 mg every 12 hours</td>
<td>Oral, im, iv: 4 mg every 6 hours</td>
<td>Gastrointestinal bleeding</td>
</tr>
<tr>
<td></td>
<td>Dexamethasone</td>
<td>Pediatrics: should not be used for prophylaxis</td>
<td>Pediatrics: 0.15 mg/kg every 6 hours</td>
<td>Hyperglycemia and psychiatric alterations</td>
</tr>
<tr>
<td>HAPE</td>
<td>Nifedipine slow release</td>
<td>Oral: 30 mg SR version every 12 hours or 20 mg SR version every 8 hours</td>
<td>Oral: 30 mg SR version every 12 hours or 20 mg SR version every 8 hours</td>
<td>Dizziness, headache, and hypotension</td>
</tr>
<tr>
<td></td>
<td>Dexamethasone</td>
<td>Oral: 2 mg every 6 hours or 4 mg every 12 hours</td>
<td></td>
<td>Hyperglycemia and psychiatric alterations</td>
</tr>
<tr>
<td></td>
<td>Tadalafil</td>
<td>Oral: 10 mg every 12 hours</td>
<td></td>
<td>Dizziness, headache, and hypotension</td>
</tr>
<tr>
<td></td>
<td>Sildenafil</td>
<td>Oral: 50 mg every 8 hours</td>
<td></td>
<td>Dizziness, headache, and hypotension</td>
</tr>
<tr>
<td></td>
<td>Salmeterol</td>
<td>Inhaled: 125 μg every 12 hours</td>
<td></td>
<td>Tremor, tachycardia, and hypokalemia</td>
</tr>
</tbody>
</table>

Medication for prevention of AMS, HACE, and HAPE should be started approximately 12 hours before ascent.

HAH = high-altitude headache; AMS = acute mountain sickness; HACE = high-altitude cerebral edema; HAPE = high-altitude pulmonary edema; SR = sustained release; iv = intravenous; im = intramuscular.

* Am J Respir Crit Care Med 2012; 185:192–198
“CLIMBER’S LITTLE HELPER”

“Several near deaths on the world’s highest peaks have shed light on a dangerous trend in mountaineering: rampant use of performance-enhancing drugs, particularly the powerful steroid dexamethasone.”

OUTSIDE MAGAZINE, APRIL 2013

COUNSEL YOUR PATIENTS ABOUT ILLICIT/UNREGULATED USE!!
<table>
<thead>
<tr>
<th>Minimal risk</th>
<th>Some documented risk – consider medical monitoring, availability of oxygen</th>
<th>Substantial risk – ascent not advised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children and elderly</td>
<td>Carotid surgery or irradiation</td>
<td>COPD, severe</td>
</tr>
<tr>
<td>Physically fit and unfit</td>
<td>Sleep-disordered breathing and apnea</td>
<td>Coronary artery disease, with poorly controlled angina</td>
</tr>
<tr>
<td>Obesity</td>
<td>COPD, moderate</td>
<td>CHF, uncompensated</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease (COPD), mild</td>
<td>Cystic fibrosis</td>
<td>Congenital heart disease</td>
</tr>
<tr>
<td>Asthma</td>
<td>Hypertension, poorly controlled</td>
<td>ASD, PDA, Down’s syndrome</td>
</tr>
<tr>
<td>Hypertension, controlled</td>
<td>Coronary artery disease, with stable angina</td>
<td>Pulmonary hypertension</td>
</tr>
<tr>
<td>Coronary artery bypass grafting, angioplasty, or stenting (without angina)</td>
<td>Arrhythmias, high-grade</td>
<td>Pulmonary vascular abnormalities</td>
</tr>
<tr>
<td>Anemia, stable</td>
<td>Congestive heart failure (CHF), compensated</td>
<td></td>
</tr>
<tr>
<td>Migraine</td>
<td>Sickle cell trait</td>
<td>Sickle cell anemia</td>
</tr>
<tr>
<td>Seizure disorder, on medication</td>
<td>Cerebrovascular disorders</td>
<td>(with history of crises)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>Seizure disorder, not on medication</td>
<td>Pregnancy, high-risk</td>
</tr>
<tr>
<td>LASIK, PRK</td>
<td>Radial keratotomy</td>
<td></td>
</tr>
<tr>
<td>Oral contraceptives</td>
<td>Diabetic retinopathy</td>
<td></td>
</tr>
<tr>
<td>Pregnancy, low-risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychiatric disorders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neoplastic diseases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflammatory conditions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Table 38.4  Practical advice for travelers to altitude

Go slowly
   Avoid overexertion
   Avoid abrupt ascent to sleeping elevations over 3000 m
   Spend one to two nights at an intermediate elevation (2500–3000 m) before further ascent
   Above 3000 m, sleeping elevations should not increase by more than 300–400 m per night
   When topography or village locations dictate more rapid ascent, or after every 1000 m gained, spend
   a second night at the same elevation
Day hikes to higher elevations, with return to lower sleeping elevations help to improve acclimatization
Avoid alcohol consumption in the first 2 days at a new, higher elevation
Memorize the Golden Rules of Altitude

The Golden Rules of Altitude
   If you feel unwell at altitude, it is altitude illness until proven otherwise
   If you have symptoms of AMS, go no higher
   If your symptoms are worsening (or with HACE or HAPE), you must go down immediately

Note: Thanks to Dr David Shlim who originally popularized The Golden Rules of Altitude

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Altitude Medicine Key Points

• Most individuals can safely travel to altitude if advised properly and are careful to acclimatize
• Acute mountain sickness is common and affects up to 40% of individuals even at moderate altitudes (2000-3500 M) at popular ski resorts
• Management of AMS includes:
  – Stop ascent; Descend if no improvement or for HAPE
• There are a variety of medications available, including acetazolamide, dexamethasone, and nifedipine
Case

• This 39 y/o French male patient was carried down from Dzongla (4800 m) with complaints of a cough and extreme fatigue with exercise. He was noted to have gurgling respirations during the night. He denied dyspnea at rest, and had had no orthopnea. He had a fever of 40 C the morning of presentation, along with a moderate headache which partially responded to aspirin and/or descent. He seemed confused on arising in Dzongla, according to a trekking partner. He attempted to walk down to Pheriche but was able to walk only 1/2 km before needing to be carried due to fatigue and gross ataxia.

• PMH: no prior AMS, HACE or HAPE. Resides at sea-level, and is a marathon runner
Case

- Trekked in from Jiri (a very gradual 7-9 day ascent)
- Namche x 1 night (3440 m)
- Dole x 1 night (4080 m)
- Gokyo x 1 night (4750 m)
- ascended Gokyo Ri (5500 m) on a day hike
- Dragnag x 1 night (4690 m)
- crossed Cho La pass (5420 m)
- Dzongla last night (4840 m)

- Exam: Thin, shivering man.
  - HR 110, BP 120/80, RR 30, SaO2 58% (“normal” is 82-86% at 4250 m)
  - Cardiac: tachycardic, otherwise normal
  - Lungs: Right Middle Lobe crackles and some right-sided intercostal retractions noted.
  - Neuro: stepped off line on tandem-gait testing.
  - Classic physically fit man
  - Rapid ascent
  - HAPE → HACE
  - Classic denial “I cannot have altitude sickness, I am a marathon runner!”
<table>
<thead>
<tr>
<th>Table 38.1</th>
<th>Online information resources on altitude illness</th>
</tr>
</thead>
</table>
| **International Society for Mountain Medicine:** [www.ismmed.org](http://www.ismmed.org)  
  Detailed practical information on altitude illness available for both physicians and non-physicians.  
  Includes diagnostic criteria for AMS, HACE, and HAPE, as well as AMS scoring tools for adults and children. An ‘ask the experts’ section is available for difficult cases. |
| **The High Altitude Medicine Guide:** [www.high-altitude-medicine.com](http://www.high-altitude-medicine.com)  
  Information on altitude illness and other health issues for travelers and their physicians. Has a practical tutorial on field hyperbaric treatment, and comparisons of the various portable hyperbaric bags. |
| **EMedicine:** [www.emedicine.com/emerg/environmental.htm](http://www.emedicine.com/emerg/environmental.htm)  
  Written in a brief, easy-to-review format; targeted at physicians. The cerebral and pulmonary syndromes of altitude illness are covered in separate ‘chapters’. |
| **Web MD:** [www.webmd.com](http://www.webmd.com)  
  Has separate consumer and physician sections, and extensive medical info for consumers. Online chat rooms cover various topics including altitude illness and travel medicine. |
| **ICAR-MEDCOM:** [www.mountainmedicine.org/mmed/icarmedcom/papers.html](http://www.mountainmedicine.org/mmed/icarmedcom/papers.html)  
  A collection of articles on medical management of mountaineering emergencies, including a suggested alpine medical kit. Presented by the International Commission for Mountain Emergency Medicine. |
| **Wilderness Medical Society:** [www.wms.org](http://www.wms.org)  
  Complete archives of Wilderness and Environmental Medicine and the prior *Journal of Wilderness Medicine*. Archives are open, but the current issue is only accessible to subscribers and WMS members. |
| **Bibliography of High Altitude Medicine:** [annie.cv.nrao.edu/habibqbe.htm](http://annie.cv.nrao.edu/habibqbe.htm)  
  A searchable bibliography of important work in high altitude medicine. |

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