Advances in the Prevention and Treatment of High Altitude Illness

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KEYWORDS

• Altitude • Acute mountain sickness • High altitude pulmonary edema
• High altitude cerebral edema • Prevention • Treatment

KEY POINTS

- Acetazolamide remains the best choice for prevention of acute mountain sickness (AMS).
- The best treatment for all high altitude illness is descent or oxygen, or both.
- Dexamethasone is excellent for treating moderate to severe AMS, and for high altitude cerebral edema (HACE).
- Supplemental oxygen is first-line therapy for high altitude pulmonary edema; descent is primary therapy if oxygen is not available.
- Descent is the definitive treatment for HACE and should not be delayed. Dexamethasone and supplemental oxygen are important adjunctive treatments for HACE until descent can be facilitated.

INTRODUCTION

High altitude illness (HAI) comprises a spectrum of conditions that occur at elevation as a result of hypoxia, and includes acute mountain sickness (AMS), high altitude cerebral edema (HACE), and high altitude pulmonary edema (HAPE). Whereas AMS is self-limited, HACE and HAPE represent true emergencies that require timely intervention and stabilization. This review focuses on recent advances in the prevention and treatment of these conditions.

Background

The concentration of oxygen in air remains constant at 21% regardless of the altitude. However, the partial pressure of oxygen decreases with increasing altitude, resulting

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in alveolar hypoxia, hypoxemia and eventual tissue hypoxia. In the lower Rocky Mountain resorts of Colorado (2500 m/8000 ft), there is one-quarter less available oxygen than at sea level. At Everest Base Camp (5300 m/17,500 feet) there is one-half the available oxygen, and on the summit of Mount Everest there is only one-third. Although a given elevation primarily determines oxygen availability, barometric pressure also decreases with increasing latitude, the winter season, and with low-pressure storm fronts. Accordingly, these effects may combine to raise the effective altitude by hundreds of meters, resulting in an increased risk of HAI.

The high altitude environment is roughly organized into stages according to physiologic stress and resultant pathology.

- *Intermediate altitude* (1520–2440 m/5000–8000 ft): Increased compensatory ventilation occurs along with a decrease in exercise performance. However, blood oxygen saturation is typically preserved at greater than 90%. For most susceptible individuals, AMS will occur above 2100 m.
- *High altitude* (2440–4270 m/8000–14,000 ft): Most HAI occurs in this range owing to the easy availability of overnight tourist facilities at these elevations. In this altitude range, oxygen saturation can be less than 90%, and hypoxemia worsens during exercise and sleep.
- *Very high altitude* (4270–5490 m/14,000–18,000 ft): Abrupt ascent is dangerous. A period of acclimatization is required to prevent HAI. Rates of HAPE and HACE are increased.
- *Extreme altitude* (>5490 m/18,000 ft): Marked hypoxemia and hypocapnia are present. Hypoxic stress leads to progressive physiologic deterioration that eventually overwhelms the body's ability to acclimatize. Long-term human habitation is, therefore, impossible.

Table 1 summarizes the effect of increasing altitude on barometric pressure, blood oxygen saturation, and arterial concentration of P_{O_2} and C_{O_2}.

Acclimatization

A full discussion of high altitude acclimatization is beyond the scope of this review. Several excellent publications cover this topic in full detail.[1,2] **Table 2** provides a basic summary of the acclimatization process organized by organ system.

Table 1
Effects of increasing altitude on respiratory physiology

Altitude	Equivalent	Pb (mm Hg)	Estimated Pao_2 (mm Hg)	Estimated Sao_2 (%)	$Paco_2$ (mm Hg)
Sea level	—	760	90–100	97–99	38–42
5280 ft (1610 m)	Denver	623	65–80	93–97	32–42
8000 ft (2440 m)	Machu Pichu	564	45–70	88–95	31–36
12,000 ft (3660 m)	La Paz, Bolivia	483	42–53	80–89	24–34
17,500 ft (5330 m)	Everest Basecamp	388	38–50	65–81	22–30
29,000 ft (8840 m)	Everest Summit	253	28–32	54–62	10–14

Pressures expressed in mm Hg.

Abbreviations: Pb, barometric pressure; Sao_2%, arterial oxygen saturation.

Adapted from Roach CR, Lawley JS, Hackett PH. The physiology of high altitude. In: Auerbach PS, editor. Wilderness medicine. Philadelphia: Elsevier; 2016. p. 3.