Serious Altitude Illness at the South Pole

John S. Rose; Jennifer Law; Richard Scheuring; Matthew H. Ramage; James J. McKeith

BACKGROUND: Gradual ascent is impractical for personnel deploying to the South Pole due to logistical challenges. Prevention of altitude illness relies on prophylactic medications such as acetazolamide and behavioral modifications including hydration and avoidance of overexertion. We present three recent cases of altitude illness that occurred in previously healthy individuals at the South Pole.

CASE REPORTS: 1) A 52-yr-old woman not on prophylactics presented with headache and intractable vomiting 7 h after arriving and hiking around the station. She was treated with acetazolamide, dexamethasone, oxygen, and supportive care. Her symptoms resolved during the evacuation flight. 2) A 23-yr-old man presented with dyspnea at rest 3 d after arriving without prophylactic treatments. He had a S_aO_2 of 49%, wheezes and crackles on lung exam, and interstitial infiltrates on chest X-ray. His treatment included oxygen, nifedipine, acetazolamide, and dexamethasone. His symptoms resolved during the evacuation flight. 3) A 40-yr-old man presented with dyspnea after a series of strenuous workouts since his arrival 5 d prior. He had a S_aO_2 of 41%, and his chest X-ray was consistent with high altitude pulmonary edema. He was treated with oxygen, nifedipine, and fluids before descent to sea level, where his symptoms fully resolved 4 d later.

DISCUSSION: These patients illustrate that altitude illness may develop despite medical screening, participant education, and availability of prophylactic medications based on published guidelines. These cases could be attributed to noncompliance and misinformation, bringing to light some of the challenges with managing more diverse populations that deploy to remote environments.

KEYWORDS: Acute mountain sickness, high altitude cerebral edema, high altitude pulmonary edema, Antarctica.

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The Amundsen-Scott South Pole Station, located at 9300 ft (2835 m) on the Antarctic plateau,[1] houses approximately 150 scientists and support staff during the austral summer (November 1–February 15) and 40 staff during the austral winter (February 15–October 31) in support of world-class scientific investigations. Due to the Earth's rotation, the global atmosphere is an elliptical spheroid, thicker at the equator and thinner over the poles. Consequently, barometric altitudes at South Pole are higher than the physical altitude. In one study conducted in 2006–2007, the highest daily average barometric altitude was 11,040 ft (3365 m).[1] A low-pressure front moving through the Pole can raise the barometric altitude significantly in a matter of hours. With relative humidity close to 0% and temperatures averaging −43°C,[1] the polar environment poses additional stress on the body.

Acute altitude illness is a significant medical concern at South Pole and ranges from sleep disruption to acute mountain sickness (AMS), high altitude cerebral edema (HACE), and high altitude pulmonary edema (HAPE). AMS and HACE are part of a continuum that affects the cerebral circulation. AMS is characterized by headache—generally considered its cardinal symptom—as well as nonspecific symptoms such as nausea, loss of appetite, dizziness, and insomnia; these symptoms usually develop 4–12 h after arrival at altitude.[5] AMS can transition into HACE, the most severe and life-threatening form of altitude illness. Typically presenting as altered mental status and truncal ataxia, HACE represents an encephalopathy induced by altered cerebral blood flow, disruption of the blood-brain barrier, and cerebral swelling with resulting increased intracranial pressure which, if untreated, leads to brain herniation and death within 24 h.[2,5]

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HAPE is primarily a pulmonary condition separate from AMS and HACE. Its hallmarks include exertional dyspnea, cough, chest tightness, crackles on auscultation, and low oxygen saturations; these typically start within 1–5 d of ascent to altitude.[5] At altitude, pulmonary vasoconstriction occurs in response to hypoxia, resulting in increased pulmonary artery pressure. It is thought that in those with HAPE, this hypoxic pulmonary vasoconstriction is uneven and leads to leakage of fluid into the alveoli and noncardiogenic pulmonary edema 2.

The main risk factors for altitude illness are ascent to altitudes greater than 9186 ft (2800 m) in one day, prior history of altitude illness, and lack of preacclimatization.[4,5] The incidence of AMS does not appear to be related to physical fitness, gender, previous altitude experience, smoking, alcohol intake, and preexisting medical conditions such as coronary artery disease or diabetes mellitus. Limited evidence suggests that exercise can increase the risk of AMS, as can oral contraceptives, underlying lung disease, and obesity.[3,5,6]

Guidelines exist to help clinicians prevent and treat altitude illness.[4] For prophylaxis of AMS and HACE, the Wilderness Medical Society recommends gradual ascent, acetazolamide 125 mg every 12 h for individuals with more than low risk, or dexamethasone 4 mg every 12 h if there is a history of intolerance or allergy. For HAPE, prophylaxis with nifedipine should only be considered for those with a prior history. Treatment recommendations include descent, supplemental oxygen or portable hyperbaric therapy, acetazolamide 250 mg every 12 h and/or dexamethasone 4 mg every 6 h for AMS or HACE, and nifedipine 30 mg every 12 h for HAPE.[4]

South Pole participants travel from McMurdo Station (sea level) to Amundsen-Scott Station via USAF LC-130 Hercules aircraft in 3 h, nominally with a cabin altitude of 5000–7500 ft (1524–2286 m). This short transition makes gradual ascent impractical. A number of participants are deployed for only a short period of time to complete a specific assignment on station. This results in a relatively constant turnover of new personnel to the station and risk of altitude illness during much of the austral summer season.

Participants are medically screened prior to deployment to Antarctica.[7] All those going to South Pole are given a predeployment briefing on altitude illness and strongly encouraged to take acetazolamide for prophylaxis per published guidelines, unless contraindicated. They are encouraged to remain well hydrated and to minimize activities the first 2 d at altitude. Despite these preventive measures, not all participants, who are either confident in their ability to acclimate to altitude or have other personal reasons, elect to adopt the recommendations.

The following are three cases of altitude illness that occurred over a 4-d period during the austral summer season 2018–2019 at Amundsen-Scott South Pole Station. The barometric altitude was about 11,000 ft (3340 m) during this period. All three individuals were previously healthy, with no prior history of altitude illness. Each case illustrates a variation on a known risk factor for altitude illness and provides a valuable lesson for future expeditions.

CASE REPORTS

Patient 1

A 52-yr-old woman presented with severe global headache and intractable vomiting 7 h after arriving on station. Shortly after her arrival, she reportedly hiked 1 mi cumulatively for station orientation and to take ceremonial photographs at the South Pole marker. Within 2 h of arrival, she noted the onset of the headache, progressing over the next 2 h to dizziness and profound fatigue. Within an hour of attempting to rest in her room, she vomited twice. Upon presentation to the medical clinic, she vomited three more times. She reported never having a headache like this before. She denied shortness of breath.

The patient had no past medical history and was on no medications. Since she had been to altitude previously without problems, she elected not to take acetazolamide prior to her trip. She acknowledged that she had rushed her deployment and pushed her activity upon landing to meet program needs. She had eaten and slept poorly during her travels from the continental U.S. and had decreased fluid intake and little rest between her Antarctic arrival and travel to South Pole.

On exam, she appeared in significant distress. She kept her eyes closed due to dizziness. Her initial vital signs were: blood pressure (BP) 134/80, pulse 110, respiratory rate (RR) 20, temperature 36.3°C, and oxygen saturation (S_aO_2) 90%. Extraocular eye movements were normal and pupils were symmetric and reactive at 4 mm. Neck was supple. Her lung fields were clear. Her heart exam was normal except for tachycardia. Abdomen and extremities were unremarkable. Neurologically, she was alert and oriented, cranial nerves II–XII were normal, gait was steady, and strength was normal in all extremities.

After consideration of the differential diagnosis of headache and vomiting at altitude, a presumptive diagnosis of AMS was made given her symptom cluster and time of onset. Acetazolamide 250 mg, ibuprofen 600 mg, ondansetron 4 mg, and fluids were given orally in a staggered sequence in order to minimize vomiting risk. However, she vomited again 20 min later. An intravenous catheter was then placed, and 1 L of Lactated Ringers was infused. She was given ondansetron 4 mg and ketorolac 15 mg intravenously, and 2 L oxygen by nasal cannula. She felt better after 30 min and was redosed with acetazolamide 250 mg and dexamethasone 4 mg orally to facilitate acclimatization. She felt much better after 90 min. Her headache improved, and nausea resolved. It was then noted that her oxygen saturation had decreased to 71%. She still denied shortness of breath. She was placed on oxygen by nasal cannula at $4\ L \cdot min^{-1}$ to maintain S_aO_2 above 90%. Due to concern of possible early HAPE, medical evacuation (MEDEVAC) protocol was activated.

The MEDEVAC team arrived within 4 h and the patient was flown back to McMurdo. With the cabin altitude lowered to 2000 ft (610 m), her headache and dizziness began to improve and she became asymptomatic by the time she landed. At McMurdo, she was observed for 4 h and then discharged to her room. She remained symptom-free. She was able to return to South Pole 10 d later after rest, hydration, and acetazolamide

125 mg twice daily starting 24 h before altitude. Her second stay at South Pole was uneventful.

Patient 2

A 23-yr-old man with no significant past medical history and taking no medications presented with severe dyspnea at rest. He had arrived at South Pole 3 d prior to presentation. He had never been to altitude previously and declined acetazolamide, having been told by friends that the medication could be harmful. He started strenuous work upon arrival, even though he was cautioned to reduce energy output for the first few days of arrival. He wanted his team to know he "was there to work hard" so he disregarded the recommendations, thinking that being young and physically fit would protect him from altitude illness.

The patient started noticing shortness of breath at rest the next day and left work early. He noted difficulty sleeping with development of a dry cough and wheezing at night. On the third day, he felt too ill to go to work and presented to Medical. He denied fevers or chills.

On physical exam, he was obviously short of breath. His vital signs were remarkable for S_aO_2 49%, pulse 120, and RR 36. His exam was notable for wheezes and crackles throughout the right lung field. Bedside thoracic ultrasound showed diffuse hyperechoic comet tail streaking (i.e., sonographic pulmonary B lines) which was consistent with interstitial edema. Chest X-ray demonstrated patchy interstitial infiltrates primarily on the right middle lobe (**Fig. 1**). Although other conditions were considered in the differential of shortness of breath at altitude, the findings were consistent with HAPE.

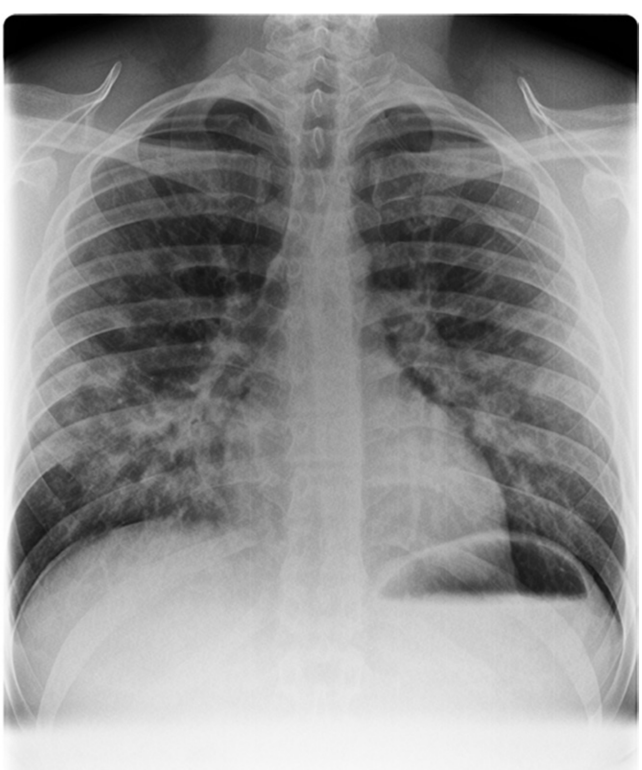

Fig. 1. Chest X-ray for Patient 2 at presentation, read as pulmonary edema with opacities mostly in the right lung.

The patient was started on high-flow oxygen by nonrebreather mask at 15 L $\cdot$ min^{-1}. His S_aO_2 improved to 95%. He was also given nifedipine 30 mg, acetazolamide 250 mg, dexamethasone 4 mg, ibuprofen 600 mg, and 2 L of Lactated Ringers. Over the ensuing 2 h, his shortness of breath improved, and he was weaned to 6 L $\cdot$ min^{-1} by nasal cannula over the next 6 h while MEDEVAC was arranged. At time of transfer, his S_aO_2 was 93% on 2 L $\cdot$ min^{-1}, pulse 76, and RR 18. C-130 cabin altitude during transport was maintained at 2000 ft (610 m). Patient had significant improvement in oxygen saturation and respiratory status after 30 min enroute. He was observed with normal saturations and no symptoms for 4 h at McMurdo then discharged to his room. He returned to work the next day and remained at sea level for the rest of the season.

Patient 3

A 40-yr-old man presented with acute dyspnea after attempting a strenuous cardiovascular workout. He had arrived on station 5 d prior to presentation, and exercised vigorously daily beginning the day after arrival. Given that he had deployed to South Pole before without problems, he felt he was not at risk for developing altitude illness. He took acetazolamide the day before he arrived at South Pole and stopped the day of arrival.

At presentation, he was severely dyspneic, speaking two- to three-word sentences. He had obvious accessory muscle use and cyanosis around his lips. His initial vital signs were as follows: BP 160/100, pulse 142, RR 32, S_aO_2 41%. His exam was remarkable for wheezes on the right side. His electrocardiogram revealed sinus tachycardia with normal intervals, and no ST or T wave abnormalities. His chest X-ray (**Fig. 2**) was consistent with HAPE, with interstitial patchy infiltrates right more than left. Electrolytes and complete blood count were unremarkable except for a hematocrit of 60%, presumably due to hemoconcentration.

The patient was initially placed on oxygen by nasal cannula at 6 L $\cdot$ min^{-1} with a corresponding S_aO_2 of 71%. He was then placed on a nonrebreather mask and high-flow O_2, which increased his S_aO_2 to 93%. He was given 20 mg of oral nifedipine. An intravenous line was established, and he was given 1 L of Lactated Ringers to correct his hemoconcentration. He was also given acetazolamide 250 mg to facilitate acclimatization. Within 90 min, he felt significantly better and his work of breathing had decreased. Repeat vital signs after 2 h were BP 128/80, pulse 90, RR 20, and S_aO_2 95% on high-flow oxygen. Patient was transitioned to nasal cannula oxygen at 6 L $\cdot$ min^{-1} over the next few hours.

The patient was medically evacuated to McMurdo on the same day. After cabin pressurization to 2000 ft (610 m), his effort of breathing decreased. During the flight, he was weaned off oxygen with S_aO_2 94–97% on room air, but he continued to be tachypneic with rate 20–32, so he was placed back on 4 L $\cdot$ min^{-1} by nasal cannula. Upon arrival at McMurdo Medical, he was noted to have difficulty speaking full sentences, and his S_aO_2 on room air would drop with conversation or ambulation.

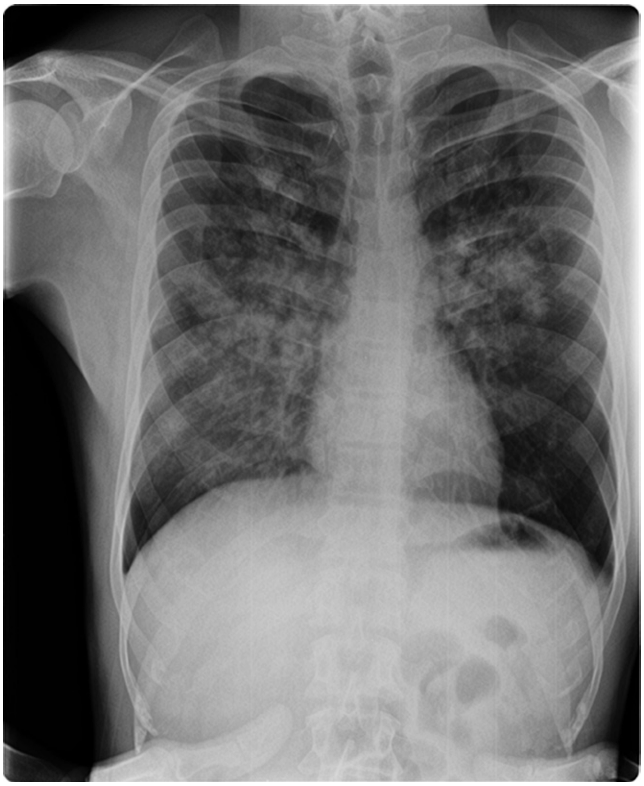

Fig. 2. Chest X-ray for Patient 3 at presentation, with notable pulmonary edema.

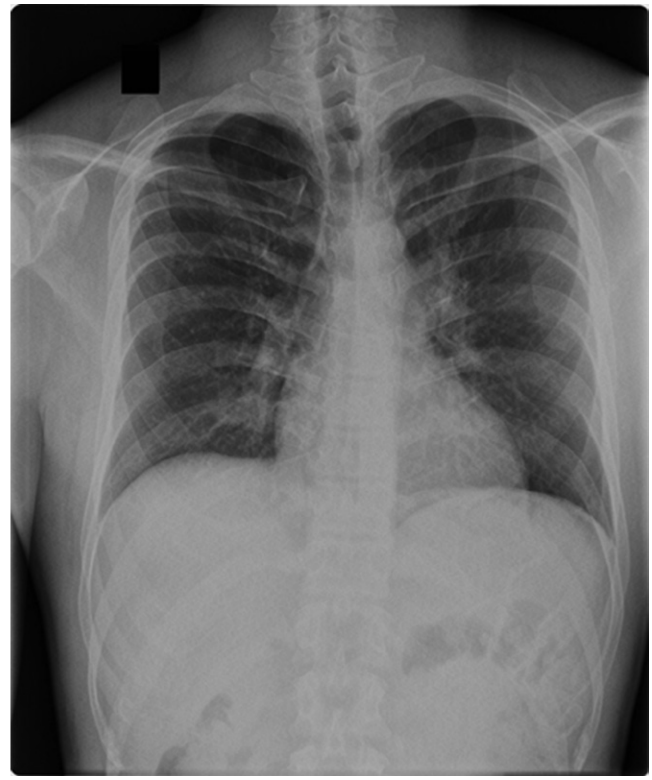

Fig. 3. Chest X-ray for Patient 3, 4 d after presentation, showing nearly resolved pulmonary edema.

He was admitted and weaned off 2 L oxygen by nasal cannula overnight. He was discharged to his room and followed daily. Nifedipine 20 mg every 8 h was continued for 2 d until he was able to speak full sentences without dyspnea and his RR and S_aO_2 normalized. He was returned to light duty and instructed to avoid exercise during this time. Use of incentive spirometry was encouraged. By the fourth day, he was completely symptom-free. Repeat chest X-ray demonstrated resolution of the pulmonary edema (**Fig. 3**). Patient reported feeling back to normal and had no dyspnea when walking up the steps. He was returned to full duty 1 d later.

DISCUSSION

The Antarctic Study of Altitude Physiology previously reported that 52% of the South Pole workers who participated in the study met the definition of AMS at some point during their deployment, and seven individuals were evacuated for HAPE during the 2006-2007 season, prompting more aggressive intervention starting in the following season.[1] The three patients presented in this case report showed that despite medical screening, predeployment education on altitude illness, and the availability of prophylactic medications based on published guidelines, serious altitude illness could still develop. Although all three cases developed within a 4-d period, the barometric pressures during that period were not atypical, and the patients did not share any commonalities in terms of age, gender, medical history, occupation, or flight to South Pole. What did seem to be common among them was misinformation leading to noncompliance.

Noncompliance to prophylactic medications appears to be due to several reasons. Some participants elect not to start medication because they have been to altitude before and never had any problems. Some are given misinformation or exaggerated risks from their friends and consequently decline to take medication. Other participants think they do not need prophylaxis since they are only on station for a few days, or they are protected by their age or fitness level. All of these rationalizations are myths. Despite detailed prebriefings on the risks of altitude illness including a handout (**Fig. 4**) and a discussion of many common myths, dangerous misinformation still persists and may be unavoidable in the Internet Age.

The South Pole Station is an excellent example of a remote environment that has transitioned from being staffed by a few, highly selected personnel to a larger and more diverse group to fulfill increasingly complex scientific missions. It serves as an illustrative analog for other remote settings, such as civilian expeditions to austere destinations, or the transition from government-sponsored spaceflight to commercial space tourism. Even when specific medical recommendations are available, participants may be noncompliant due to misinformation or other reasons. Programmatically, it may be prudent to consider the risks versus benefits of mandating certain prophylactic measures. In the case of South Pole in the summer, medical evacuation can generally be arranged within a few days, but

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- Altitude illness occurs most often at altitudes greater than 8,000 feet (South Pole Station is 11,100 feet).
- There are three forms of altitude illness: Acute Mountain Sickness (AMS), High Altitude Pulmonary Edema (HAPE), and High Altitude Cerebral Edema (HACE). HAPE and HACE are life threatening and have occurred at South Pole Station.
- Common symptoms of AMS include headache, dizziness, loss of appetite, fatigue, nausea, difficulty sleeping, and shortness of breath.
- AMS is made worse and more likely to progress to HAPE and HACE when there is increased physical activity. **AVOID UNNECESSARY PHYSICAL ACTIVITY (INCLUDING EXERCISE) FOR THE FIRST WEEK AT ALTITUDE**.
- Diamox (Acetazolamide) is given to help prevent altitude illness. Take 125 mg twice per day starting 24 hours before going to altitude. Continue for 3 days after arriving or until you descend. If you are allergic to sulfa or taking certain other medications, your provider will prescribe an alternative medication called Dexamethasone.
- **DRINK PLENTY OF FLUIDS**. Antarctica is very dry, plus Diamox is a mild diuretic.
- Minor headaches and shortness of breath are not uncommon at high altitude. However, if you experience severe shortness of breath and/or headache not relieved with over the counter medications, please report to Medical immediately for evaluation.

Fig. 4. Handout on altitude illness given to South Pole participants prior to deployment.

other settings may not have this capability or the ability to evacuate single individuals without ending the entire expedition.

In this case report, we described three patients who developed severe altitude illness at South Pole that required medical evacuation. They could be attributed to noncompliance to medical recommendations on prophylactic medications, hydration, and avoiding physical overexertion. These cases bring to light some of the challenges with managing larger and more diverse populations that deploy to remote environments.

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