CASE REPORT

Use of the Gamow Bag by EMT-Basic Park Rangers for Treatment of High-Altitude Pulmonary Edema and High-Altitude Cerebral Edema

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As part of an emergency medical system protocol, national park service rangers certified at the level of an emergency medical technician-basic (EMT-B) are taught to recognize and treat high-altitude pulmonary edema and high-altitude cerebral edema. In Sequoia and Kings Canyon National Parks, this is done with the assistance of physician on-line medical control as a backup. High-altitude pulmonary edema and high-altitude cerebral edema are both potentially fatal altitude illnesses that can be particularly problematic in the backcountry, where evacuation may be delayed. We report a case of high-altitude pulmonary edema and high-altitude cerebral edema occurring at moderate altitude that was successfully treated by park rangers with the Gamow Bag.

Key words: altitude sickness, hyperbaric, national park, EMT-basic, HACE, HAPE

Introduction

The Gamow Bag is a lightweight portable hyperbaric chamber that can produce an environment for the patient inside equivalent to descending more than 5000 feet (~1500 m). It has been reported to be successful in the treatment of high-altitude pulmonary edema (HAPE) and high-altitude cerebral edema (HACE) at altitudes exceeding 11 500 feet (~3500 m) in popular trekking areas worldwide, such as the Himalayas, South America, Alaska, and Africa.^{1–8} In these cases, a physician member of the expedition team has traditionally been responsible for treating and arranging evacuation of the victim.^{2,3,6} Here we report a case of HAPE and HACE in a US national park and treated with the Gamow Bag as part of the emergency medical response. This case was unique because park rangers certified at the level of an emergency medical technician-basic (EMT-B) (requiring a minimum of 110 hours of prehospital medical training) used the Gamow Bag as part of their protocols with on-line medical control provided by base-hospital physicians trained in emergency medicine. Sequoia and Kings Canyon National Parks maintain an emergency medical

service (EMS) system with EMT-Bs as the first providers for most backcountry calls. Because a large number of visitors have easy access to altitudes ranging from 8000 to 14 000 feet (2400–4300 m), altitude illness is common. Several helicopter evacuations occur each year for HAPE or HACE, with frequent transport delays caused by flight restrictions (D. Brenchley, oral communication, March 2004). For this reason, the Sequoia and Kings Canyon National Parks EMS system has incorporated the Gamow Bag into the EMT-B scope of practice (Table). For situations where evacuation is delayed, the Gamow Bag is brought (usually by foot) to the patient, and temporizing treatment is administered until evacuation is feasible. The ensuing case demonstrates the efficacy of a treatment procedure incorporating the Gamow Bag as part of a protocol for treatment of altitude illness. To our knowledge, no case has been reported in which a nonphysician treated HAPE or HACE with a Gamow Bag as part of an EMS system protocol.

Case Report

EMT-Bs employed as rangers in Sequoia and Kings Canyon National Parks received a call at approximately 1930 hours in late July for a 24-year-old woman complaining of a severe headache, hallucinations, and a deep

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Sequoia and Kings Canyon National Parks' prehospital protocol for the use of the Gamow Bag in management of high-altitude illness*

Gamow Bag

Scope of practice: EMT and paramedic

Indications: High-altitude illness (HACE, HAPE)

Contraindications: Patient unable to protect his or her airway

Equipment: Gamow Bag

Procedure:

- 1) Confirm indication for Gamow Bag use (high altitude illness).
- 2) Confirm that descent is not immediately available.
- 3) Confirm that the patient can protect his or her own airway.
- 4) Explain procedure to the patient. Establish an emergency signal indicating need to get out of the bag. Tell the patient to notify you of ear or facial pain (because of increased pressure).
- 5) Have the patient void, if able.
- 6) Place bag on as smooth a surface as possible. If the patient has orthopnea, the bag can be situated with the head propped up.
- 7) Attach pump to gray intake valve.
- 8) Ensure valve stem is in a closed position.
- 9) Place the patient in the bag. Use clothing or sleeping bag to ensure warmth.
- 10) If patient is in severe distress, he or she may be placed on low-flow oxygen while in the bag (Oxygen administration). Place the oxygen tank inside the bag with the patient with the regulator dial visible. If pulse oximeter is available, titrate oxygen delivery to saturation above 94%. Note: The enriched oxygen supply inside bag increases the risk of combustion. Maintain meticulous precautions against sparks and fire.
- 11) Tell the patient to breathe normally. Have him or her clear his or her ears by swallowing. Advise him or her that if the bag should accidentally deflate, he or she should exhale.
- 12) Pull the zipper completely closed.
- 13) Begin inflation with foot pump.
- 14) Check that the nylon straps are not twisted and are in proper location.
- 15) Inflate to 1.5 psi on gauge.
- 16) Maintain eye contact with the patient at all times.
- 17) Continue pumping 15 times per minute at all times to clear excess carbon dioxide.
- 18) See above for duration of treatment. The patient may be removed from the bag for a few minutes every hour to allow him or her to void and have vitals reassessed.
- 19) To deflate the bag, depress and turn valve stem to locked down position and allow air to escape.
- 20) Undo the zipper.
- 21) Re-evaluate the patient.
- 22) Return valve stem to closed position.
- 23) Document procedure (indications, duration, pressure, etc.), vital signs, and response to treatment.

* EMT indicates emergency medical technician; HACE; high-altitude cerebral edema; and HAPE, high-altitude pulmonary edema.

cough. She had been hiking above 10 000 feet (3000 m) for 3 days. On the day preceding this incident, she had ascended one of the peaks in the area to ~12 000 feet (4000 m) and was, at the time of the call, at an elevation of 10 300 feet (3100 m). Her medical history consisted only of posttraumatic migraines, and her only medication was an acne cream.

The first ranger arrived on scene at 2100 hours and noted that the woman appeared to be ill and in moderate distress. She was alert but slow to respond to questions. Her initial vital signs were blood pressure of 170/100, pulse of 120 beats/min, respiratory rate of 15, and Glas-

gow Coma Score (GCS) of 15. Pulse oximetry was not available. Her exam was significant for shallow labored breathing with bilateral wheezes and nonreactive pupils (as noted in the prehospital care report). Gait was not tested because she was in respiratory distress. The EMT-B recognized the signs and symptoms and treated the patient per the altitude illness protocol for HAPE and HACE. He applied oxygen via nasal cannula and titrated the rate to 3 L·min⁻¹. The Gamow Bag, which is stored at a backcountry ranger station where most high-altitude illness cases have occurred, was requested. Because the patient was located in a geographic basin, she could not

be evacuated by ground without significant elevation gain, and nightfall delayed her air evacuation.

At 2200 hours, the patient was noted to have a blood pressure of 168 palpable, pulse of 108 beats/min, respiratory rate of 15, and was more lethargic with a GCS of 14. The Gamow Bag arrived and the setup was complete at 2310 hours, at which time the patient was placed inside. To conserve oxygen, the administered rate was reduced from 3 to 0.5 L·min⁻¹. At this reduced rate, the D oxygen tank can last 6 times longer (up to 9.5 hours). Vital signs before entering the Gamow Bag consisted of a blood pressure of 140 palpable, pulse of 116 beats/min, and a respiratory rate of 12. The patient was noted to have continued wheezing, shallow respirations, and nonreactive pupils.

The patient exited the Gamow Bag at 0015 hours to urinate. At that time, she was coughing less and reported that her headache had diminished. Vital signs were blood pressure of 140/90, pulse of 100 beats/min, respiratory rate of 12, and GCS of 15. Examination revealed less wheezing and sluggishly reactive pupils. Treatment in the Gamow Bag was then resumed. At 0115 hours, the patient complained of nasal irritation and light epistaxis, prompting discontinuation of oxygen therapy. Her vital signs at that time were a blood pressure of 140 palpable, pulse of 108 beats/min, respiratory rate of 14, and GCS of 15. She continued to have bilateral wheezes and shallow labored breathing. Pupils were noted to be reactive.

Treatment in the Gamow Bag continued until approximately 0700 hours. Vital signs and exam were updated at 0230, 0345, 0500, and 0615 hours with no significant changes noted. Throughout the night, the patient complained of "liquid in the lungs" and intermittent headache. At 0730, she was noted for the first time to no longer be tachycardic. Vital signs at that time were a blood pressure of 140/80 and pulse of 88 beats/min. Respiratory rate was not recorded, but she was noted to have continued shallow respirations and wheezes. Her GCS was 15.

At 0730, the patient was evacuated by helicopter and flown 10 minutes to the nearest hospital. Upon hospital arrival, she had a blood pressure of 122/60, pulse of 90 beats/min, respiratory rate of 18, and an oxygen saturation on room air of 82%. She was diagnosed with HACE and HAPE and was treated with oxygen, furosemide, dexamethasone, and intravenous fluids. Upon discharge at 2323 hours, she stated that she felt "100% better" and was noted to be ambulating and doing well. Discharge vital signs were a blood pressure of 96/60, pulse of 88 beats/min, respiratory rate of 18, and an oxygen saturation on room air of 94%.

Discussion

High-altitude pulmonary edema is responsible for most high-altitude illness deaths.⁹ Incidence is related to the rate of ascent, altitude ascended, individual susceptibility, altitude of residence, and exertion. Individual risk is increased in persons with abnormal cardiopulmonary circulation, such as systemic or pulmonary hypertension.¹⁰ Most commonly, symptoms begin on the second night at a new altitude and rarely occur after 4 days at altitude.¹⁰ Symptoms initially consist of fatigue, dyspnea, and dry cough that can progress to marked weakness, productive cough, and, as hypoxemia worsens, coma and death.⁹ Clinical findings include tachycardia and tachypnea, which both become more pronounced as the disease progresses.¹⁰ Cerebral symptoms and signs are common, for 50% of persons with HAPE also have acute mountain sickness and 14% also have HACE.¹⁰

High-altitude cerebral edema is usually associated with pulmonary edema or acute mountain sickness and is characterized by altered mental status, ataxia, stupor, and, if untreated, progression to coma.^{9,10} Associated findings found as a result of elevated intracranial pressure include papilledema, retinal hemorrhage, signs of global encephalopathy, and, rarely, focal cranial-nerve palsies.¹⁰ Symptoms of both HAPE and HACE are not always preceded by symptoms of acute mountain sickness, such as headache, weakness, and nausea, and usually occur at altitudes over 10 000 feet (3000 m) in unacclimatized persons who ascend rapidly.^{9,10}

Although fatalities have occurred as low as 8200 feet (2500 m), both HAPE and HACE are rare at altitudes below 11 500 feet (3500 m).^{9,11} The incidence is reduced further if ascent above 10 000 feet (3000 m) is gradual at a rate of no more than 1000 feet (300 m) per day.¹¹ The pathophysiology of high-altitude illness is believed to be hypoxemia-driven overperfusion and capillary leakage from the cerebral and pulmonary microcirculation.¹⁰ High-altitude pulmonary edema is associated with pulmonary hypertension and elevated capillary pressure. High-altitude cerebral edema similarly is associated with cerebral vasodilatation and elevated capillary pressure.¹⁰ Increased capillary permeability caused by endothelial inflammation may also contribute to pulmonary and cerebral edema.¹⁰ The highest priorities of treatment for both HAPE and HACE are descent and oxygen. When descent is not available, optimal treatment includes hyperbaric therapy.¹⁰⁻¹³

The Gamow Bag is a windowed cylindrical portable hyperbaric chamber constructed of nonpermeable nylon that requires constant pressurization with a foot pump attached to the bag. It can provide an environment for the patient equivalent to descent of up to 9000 feet (2800

m). Simulated descent of only 1500 to 3000 feet (500–1000 m) may be all that is necessary for symptoms of high-altitude illness to resolve. The complete device is 7 feet (213 cm) long, has a diameter of 21 inches (53 cm), weighs 14.9 pounds (6.8 kg), and inflates to a volume of 17 cubic feet (0.48 m³).¹¹ Supplemental oxygen is not required. The increased ambient pressure produced in the bag helps counteract pulmonary hypertension and increases the partial pressure of oxygen, thereby improving ventilation and reducing hypoxemia.¹¹

The vast areas of moderate to high altitude in Sequoia and Kings Canyon National Parks have prompted institution of a protocol for Gamow Bag use in selected patients with altitude illness. Most affected persons are not members of an expedition. Rather, they are weekend visitors to the park and therefore are often not acclimatized. National park service rangers, trained to the level of EMT-Bs, respond to calls, recognize, treat, and evacuate victims of HACE or HAPE by protocol. With base-hospital physician medical control via radio, the rangers can competently use a Gamow Bag as part of treatment when evacuation is delayed. This case demonstrates the successful use of the Gamow Bag as part of an EMS system to treat HAPE and HACE at moderate altitude. Although this suggests that the Gamow Bag can be safely and effectively used by EMT-Bs, we believe that a tightly written procedure with on-line physician medical control is advisable until further research supporting this practice has been reported.

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