encounters occurred. Those who had an open wound were more likely to receive pain medication vs those who did not have an open wound (46% vs 7%, $P < .001$). There was a trend toward more pain medications administered to penetrating wounds vs blunt trauma (28% vs 14%, $P = .07$). If an antibiotic was given, the patient was more likely to receive pain medication (66% vs 19%, $P < .001$). Patients transported by AIREVAC were more likely to receive pain medication (35% vs 20%, $P = .004$). If a tourniquet was placed, patients were more likely to receive pain medication (47% vs 32%, $P < .001$). Medical officers were more likely to administer pain medications (43% vs 17%, $P < .001$).

Conclusions.—There were higher rates of pain medication administration for open wounds vs closed wounds, penetrating trauma vs blunt trauma, co-administration of antibiotics, AIREVAC vs ground evacuation, tourniquet placement, and treatment by a medical officer. A more detailed analysis by analgesia agent and whether the agents were within TCCC guidelines will be performed.

Medical Problems of Casualties and Rescuers in the 2014 Volcanic Eruption in Japan

Kazuo Oshiro^{1,2}; Yuji Watanabe³; Tomikazu Muarakami²

¹Cardiovascular Center Hokkaido-Ohno Hospital, Sapporo, Japan,

²The Hokkaido Prefectural Police, Sapporo, Japan, ³National Center for Mountaineering Education, Toyama, Japan

Introduction.—There are many active volcanoes worldwide that are popular destinations for tourists and trekkers. Mt. Ontake (3067 m), the second highest volcano in Japan and a popular mountain because it is a relatively easy climb, erupted without apparent warning and led to a heavy loss of life on September 26, 2014. Volcanic eruption disaster is an uncommon medical emergency and practical medical experience is limited in the medical literature.

Objective.—To consider the medical role and develop medical planning for emergencies during volcanic mountain disasters.

Methods.—Collected data included photos and movies provided by military, national police, and fire defense agency sources, in addition to publicly available data from the cabinet office.

Results.—Fifty-seven deaths, 6 losses, and at least 26 rescued. The primary cause of death was trauma by abrupt fallen rocks; victims died instantly. Survivors also experienced trauma due to abruptly fallen rocks. The location of dead bodies was concentrated on the mountain trails within a 1 km-radius from the craters. More than 20,000 rescuers engaged in a search and rescue for 20 days, until winter set in. No deaths of rescuers occurred, but some had acute mountain sickness and hypothermia on missions.

Conclusions.—The volcano erupted violently and rapidly, leaving little or no time for people to escape or take shelter. Emergency medical care played a small role in this severe volcanic eruption. On the other hand, precautionary education about health hazards and medical care for rescuers is necessary and helpful.

Canyoneering-Related Search and Rescue in Zion National Park from 2005-2015

Heather Beasley¹; Scott McIntosh²

¹University of New Mexico School of Medicine, Albuquerque, NM,

USA, ²University of Utah Division of Emergency Medicine, Salt Lake City, UT, USA

Introduction and Background.—Canyoneering is an increasingly popular outdoor activity within Zion National Park (ZNP) in Utah, yet the burden of this particular activity on search and rescue (SAR) resources is relatively unknown. ZNP maintains records from all SAR activations. Although a recent review of canyoneering rescue operations in Spain has been published, there has been no review of canyoneering SAR records in the United States until now.

Objectives.—To examine demographics of parties involved, relevant injury patterns, and cost of SAR response in canyoneering-related SAR activations in ZNP from 2005 to 2015.

Methods.—ZNP provided 221 SAR records for incidents in which the activity was noted to be “canyoneering” between January 1, 2005 and December 31, 2015. Annual reports of all ZNP SAR activations from 2005 to 2015 also were obtained.

Results.—Out of 221 SAR activations from 2005 to 2015, there were 562 people involved. There was a male ($n = 283$) to female ($n = 104$) ratio of 2.7:1 for activations in which the sex of canyoneering parties was noted. One hundred

eighteen people were recorded as ill or injured; there were 72 ill/injured men and 37 ill/injured women. The most common injuries were ankle injuries (25.2%), followed by other lower extremity injuries (15.9%), knee injuries (11.2%), and illnesses attributable to environment/exposure (11.2%). The most common age range of 378 canyoneers with recorded ages was 20-29 ($n = 137$, 36.2%). There were 11 total fatalities in the 10-year period, with primary contributing factors to deaths being flash flooding ($n = 7$), falls ($n = 3$), and drowning vs exposure ($n = 1$). Average cost of canyoneering-related SAR operations was \$3483.33 over the 10-year period.

Conclusions.—Canyoneering-related SAR contributes significantly to use of ZNP resources, with canyoneering-related SAR expenses making up 40.4% of the 10-year total SAR cost. Injury occurred in 51% of all canyoneering SAR activations in the 10-year period. Canyoneers should take measures to prevent lower extremity injuries as well as illness related to environment and exposure and should be prepared to manage such issues if they arise. Medical providers in national parks where canyoneering occurs should familiarize themselves with these injury patterns and methods to manage them in the backcountry.

Direct Measurement of Intracranial Pressure in Hypobaric Hypoxia: Implications for Acute Mountain Sickness

Justin Lawley^{1,2}; Louis Whitworth²; Benjamin Levine^{1,2}

¹Institute for Exercise and Environmental Medicine, Dallas, TX, USA,

²U.T. Southwestern Medical Center, Dallas, TX, USA

Introduction.—Despite decades of research, the pathophysiology of acute mountain sickness (AMS) is unknown. The classic hypothesis is that persistent and/or transient elevations in intracranial pressure (ICP) cause AMS.

Objective.—To make continuous, direct, invasive measurements of ICP alongside AMS (Lake Louise Questionnaire [LLQ]) in hypobaric hypoxia (4500 m).

Methods.—To date, we have recruited three men who had previously been cured of a hematologic malignancy and as such had an Ommaya reservoir implanted. A needle was placed inside the Ommaya reservoir for direct measurement of intraventricular pressure.

Results.—Participant 1: ICP at sea level was 13 mm Hg. After 9 hours at altitude, mean ICP remained normal (14 mm Hg), but large fluctuations in ICP (>20 mm Hg) were observed, alongside symptoms of AMS (LLQ, 6). Administration of 100% O₂ stabilized ICP and symptoms resolved. With removal of 100% O₂, ICP pressure waves began and symptoms returned. Participant 2: ICP decreased slightly at altitude (SL, 11 vs altitude, 6.6 mm Hg) and no pressure waves were observed over the first 9 hours. This subject reported only a very mild headache. During sleep, ICP fluctuated in opposition to oscillations in SaO₂. The participant woke with mountain sickness (LLQ = 10), which declined by 24 hours (LLQ = 4), where ICP was below the sea level value (3 mm Hg). Participant 3: ICP at sea level was 16 mm Hg. After 9 hours at altitude, ICP was substantially elevated (26 mm Hg) with symptoms of AMS (LLQ = 5). ICP was persistently >20 mm Hg while asleep, and the participant woke with muscle paralysis and severe AMS. Administration of 100% O₂ reduced ICP (11 mm Hg) and resolved symptoms. This study was ended because of the possibility of mild cerebral edema.

Conclusions.—These preliminary observations suggest that persistent or transient elevations in ICP preceded the onset of AMS.

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Metal Accumulation in Horseshoe Crab (*Limulus polyphemus*) Eggs, Embryos, and Larvae From Potentially Contaminated Public Beaches

Aaron Bakker¹; Jessica Dutton²; Nicholas Santangelo¹

¹Hofstra University, Hempstead, NY, USA, ²Texas State University,

San Marcos, TX, USA

Introduction.—In many coastal ecosystems, humans and marine organisms are confronted with heavy metal contamination. Thus, such organisms could be used as a bioindicator to understand uptake pathways and the potential risks of these habitats to marine organisms and human health.

Objective.—To relate 13 different trace metal concentrations between surrounding habitat and accumulation levels across early life stages of horseshoe