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CASE REPORT

Wireless and Low-Weight Technologies: Advanced Medical Assistance During a Cave Rescue: A Case Report

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Trauma care in cave rescue is a unique situation that requires an advanced and organized approach with medical and technical assistance because of the extreme environmental conditions and logistical factors. In caving accidents, the most common injuries involve lower limbs. We describe an advanced medical rescue performed by the Italian Corpo Nazionale del Soccorso Alpino e Speleologico, in which extended focused assessment with sonography for trauma and an ultrasound-guided adductor canal block were performed on a patient with a knee distortion directly in the cave. The rescue team inside the cave shared data on patient monitoring and the ultrasound scanning in real time with rescuers at the entrance, using a video conference powered by the new Ermes system. The use of handheld, battery-powered, low-weight, multiparametric monitors, ultrasound machines, and digital data transmission systems could ensure complete medical assistance in harsh environmental conditions such as those found in a cave.

Keywords: e-FAST, ultrasound-guided adductor canal block, handheld ultrasound, wireless communication

Introduction

The lower extremities are the most common anatomic sites of injury in caving incidents.[1]

Trauma care in cave rescue is a unique situation that requires an advanced approach with medical and technical assistance. The extreme environmental conditions and many logistical factors can limit therapeutic options; this can also influence the outcome of the patient. During a cave rescue, the use of wireless and handheld technologies could be helpful for patient management decisions in settings with limited resources, which could improve levels of care.

In these conditions, portable ultrasound machines are useful for evaluation of traumatic abdominal and thoracic pain; they can also offer guidance in performing locoregional analgesic blocks in trauma patients. The use of a wireless system for data transmission could also be a good way to improve communication between the rescuers inside and outside the cave.

Written informed consent was obtained for this case report.

Case report

We describe an advanced medical rescue by the Italian Corpo Nazionale Soccorso Alpino e Speleogico (CNSAS), in which extended focused assessment with sonography for trauma (e-FAST) and the ultrasound-guided adductor canal block (USG-ACB) were performed directly in the cave in a patient with a ligamentous tear.

On June 3, 2017, during periodic caving training for the volunteers of the Italian CNSAS in the Grotta di Monte Cucco (latitude: 43°22′05.88″N; longitude: 12°44′44.52″E; altitude entrance: 1400 m above sea level; total length: 30,000 m; total depth: 929 m), one of the volunteers fell from a height of 4 m, injuring his chest

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and lower limbs on the rocks. He was at a depth of about 120 m and a distance of 1.5 km from the cave entrance.

He had his personal protective equipment. Ten CNSAS speleologists were in the cave; they were not paramedics and were not trained in prehospital trauma life support protocol.

The patient was immediately reached by 5 volunteers; the others exited the cave to activate rescue operation with medical support. Outside of the cave, an advanced medical presidium (AMP) was stationed. AMP is a medical post similar to an emergency room.

The Ermes system, a new digital data transmission system designed to operate during a cave rescue operation, provided an Ethernet connection between the rescue team of the AMP and the rescue team inside the cave, where a tablet was connected to Ermes through a Wi-Fi hotspot.

Ermes was designed by the caving technical commission of the CNSAS in the last 2 years to improve communication between the medical teams inside and outside of the cave, who need to exchange a lot of information. Ermes provides a standard transmission control protocol/internet protocol connection (Ethernet) between the 2 ends of a pair of twisted copper wires (telephone line), one at the cave's entrance and the other close to the injured party (into the cave). Because of its Ethernet port, Ermes allows any medical electronic equipment to transfer data. The picture archiving and communication system was not used.

The victim was put in a hard cervical collar and backboard by the rescuers; the right lower limb was immobilized with a splint. The patient was kept in a tent and insulated from the ground to prevent hypothermia. The medical rescue team reached the patient after 1 h; in this time, several interventions were performed.

Two anesthetists trained in USG locoregional anesthesia and experts in cave rescue and 2 emergency nurses were in the medical rescue team. The following data were collected and transmitted to the AMP rescue team via wireless system by the volunteers in accordance with the recommendations of basic first aid for rescue service members[2]: The patient had chest pain (visual analogue scale [VAS] 5) and could not move his right lower limb because of severe knee pain (VAS 8). The patient's respiratory rate was 28 breaths $\cdot$ min^{-1}, arterial oxygen saturation estimated with pulse oximetry was 96%, blood pressure was 155/80 mm Hg, and heart rate was 95 beats $\cdot$ min^{-1}. Acetaminophen 1000 mg was administered per os; consistent pain relief was not obtained. Standard association of anesthetists of Great Britain and Ireland monitoring recommendations for recovery[3] were applied using the Schiller ARGUS PRO LifeCare 2 multiparametric monitor (Schiller AG, Baar, Switzerland), in accordance with medical monitoring and recovery protocol, by our local cave rescue medical department. The Glasgow Coma Scale was 15. A peripheral venous access (16 G) was obtained, and a total of 250 mL of crystalloid solution was intravenously administered. No clinical signs of spinal cord injuries were noted by the medical rescue team.

The e-FAST was possible by means of a convex (3.5 MHz) wireless transducer (Philips Ultrasound 2d Portable Ultrasound Probe/Scanner C10; Philips SpA, Milan, Italy). This wireless probe scanner was connected to the tablet, carrying out the functions of an ultrasound scanner. The diagnosis of knee sprain was made on the basis of clinical evaluation and signs because it was not possible to have a clear ultrasound knee assessment due to edema.

The e-FAST scanning and the anesthetic procedure under ultrasound guidance were transmitted in real time to the AMP via video conference. Here, an anesthetist trained in advanced trauma life support protocol and prehospital trauma life support protocol interpreted the ultrasound scan. There was no evidence of pneumothorax, pericardial/pleural effusion, or intra-abdominal fluid. No advanced airway control was required (Figure 1).

A linear (7.5 MHz) wireless transducer was also connected to the tablet. The following blood gas tests were performed using the iSTAT handheld blood analyzer (iSTAT 53 Handheld; Abbott Point of Care Inc, Princeton, NJ): sodium, potassium, ionized calcium, glucose, hematocrit, hemoglobin, pH, PCO_2, PO_2, HCO_3^-, base excess, and oxygen arterial saturation. No gas exchange alterations were reported.

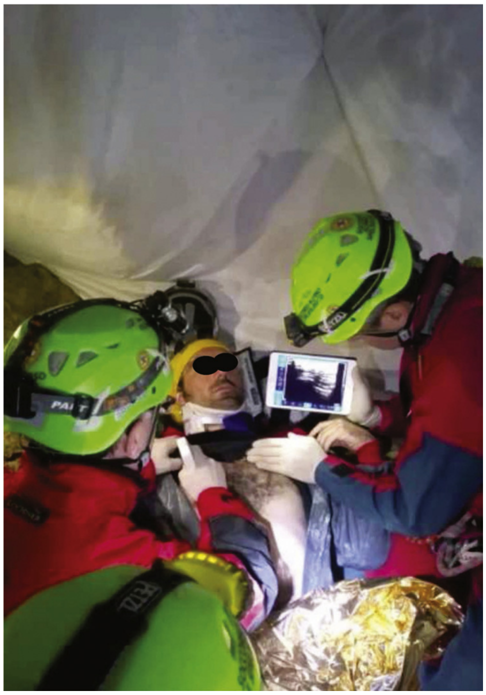

Figure 1. The e-FAST scanning.