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 Hermes 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 Speleologico (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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Submitted for publication September 2017.

Accepted for publication February 2018.

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 members²: 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 recovery³ 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, PCO₂, PO₂, HCO₃⁻, base excess, and oxygen arterial saturation. No gas exchange alterations were reported.

Figure 1. The e-FAST scanning.

After opening the splint, the linear ultrasound transducer was placed transverse to the longitudinal axis of the extremity midway along the distance between the iliac spine and the patella. The saphenous nerve appeared as a hyperechoic structure lateral to the artery in the adductor canal. Three milliliters of saline was injected to expand the canal, and 15 mL of levobupivacaine 0.25% was injected around the saphenous nerve for a single shot adductor canal block.⁴ The analgesic procedure was performed trying to respect sterile conditions.

Twelve minutes after block performance, complete somatic pain relief was obtained (VAS 2). Cold and touch test were used to assess skin sensitivity, and the patient reported a complete sensory loss of the knee extending from the superior pole of the patella to the proximal tibia. The Bromage scale (grade 0: no motor block; grade 1: inability to raise extended leg, able to move knees and feet; grade 2: inability to raise extended leg and move knee, able to move feet; grade 3: complete motor block of lower limbs)⁵ was used to measure the motor blockade. No noticeable loss of quadriceps strength was reported, and the patient could move his legs and feet (Bromage score was 0). The splint was then closed.

After 20 min, the patient tried spontaneously to stand up, and he walked with the splint. He was able to exit the cave by himself, only assisted by the physicians and the technicians of CNSAS. The patient did not report paresthesia or anesthesia of the ankle or foot; proprioception was not altered, and ambulation was not difficult. No supplementary opiates or other local anesthetic agents were administered. Additionally, no complications of the block were recorded.

After 2 h, the patient was outside the cave and into the AMP, and he was then finally hospitalized. Pneumothorax, pericardial/pleural effusion, and intra-abdominal fluid were not noted. The patient had a long effective analgesia with pain relief (VAS 4) for 6 h during his hospital stay without needing other analgesic drugs. He was extremely satisfied with the rescue and with the anesthetic procedure.

Two weeks later, a magnetic resonance imaging scan revealed an anterior cruciate ligament rupture in the right knee.

Discussion

Trauma care during cave rescue is a medical challenge.⁶ Several logistical factors limit therapeutic options and transport of the patient and can also influence survival and the outcome of the rescue operation.

In this experience, the medical rescue team was equipped with relatively advanced medical

technology; it was possible to create a sort of “operative” AMP directly in the cave. The AMP is a tent-type structure where volunteer doctors and nurses operate. In case of cave rescue, the Italian CNSAS recommends that an AMP be quickly activated and then dismissed after the emergency. Here, complete monitoring of vital parameters was possible, in accordance with the Association of Anaesthetists of Great Britain and Ireland recommendations.³

The wireless handled probe scanner enabled the USG-ACB to be performed. Normally, the USG-ACB is performed after total knee arthroplasty.⁷ The choice to perform this analgesic block is due to the necessity of quickly evacuating the patient from the cave while trying to avoid stretcher evacuation in confined spaces because it requires dozens of rescuers and rope systems through canyons and vertical drops. The ultrasound-guided locoregional analgesic procedures could improve the quality of cave rescue, providing an effective and long-lasting analgesia in trauma patients, in accordance with the experience of Pasquier et al⁸ and the indications of Gregoretti et al.⁹ Therefore, it may be possible to decrease narcotic analgesic drug consumption, which could be dangerous in this austere environment.

The e-FAST protocol could be considered useful in emergent evaluation of trauma patients. Although there is moderate evidence that supports prehospital physician use of ultrasound for trauma patients,¹⁰ it could become integrated into the trauma care cave rescue. The development of handheld, wireless, and low-weight ultrasound machines has created the possibility of bringing ultrasound to the prehospital setting.¹¹

Ultrasound-guided locoregional analgesic procedures could be decisive for quick diagnosis and therapy in trauma patients; it is then possible to reduce the time of patient's recovery and evacuation from the extreme conditions of the cave.

The iSTAT system is the only handheld blood analyzer approved by the Cave Medical Rescue Committee of the Italian CNSAS because it has been considered suitable for blood analyses during emergencies, especially in a cave; it provides data to evaluate gas exchange alterations due to thoracic trauma. This technology could accelerate patient care decision making, improving quality and increasing efficiency of trauma care during cave rescue.

In this experience, 3 volunteer CNSAS anesthetists trained in USG-LRA were immediately available, and 2 of them quickly reached the patient. On the contrary, it is common in cave rescue for the arrival of the rescue team to be delayed,⁶ and medical personnel in general do not have extensive training and practice in adverse conditions to make case-specific decisions in a short

time. Thus, personnel availability can be considered one of the limits of this case report.

Another limit of this experience is that the patient did not have severe lower extremity injuries. He could walk by himself, only assisted by the CNSAS physician and the technicians because the distance from the cave entrance (1.5 km) was not great and any vertical drops were not significant.

Communication inside the cave and with an external dispatch center are an enormous challenge. In this experience, the use of a digital data transmission system (Ermes) allowed the real-time transmission of patient data and ultrasound-guide procedures, allowing a multi-disciplinary approach. Despite the lack of international guidelines and standard protocols,⁶ our medical choices and the technique support were successful and the patient was quickly evacuated under continuous medical assistance.

In conclusion, the aim of this report is to show that the use of handheld, low-weight, multiparametric monitor and ultrasound machines can help the management of a trauma patient in a harsh environment. These modern technologies, associated with the new way of data transmission, could be decisive for a fast and efficient rescue. The portable sonographic device can facilitate patient management decision making in settings with limited resources,¹² and it might also be useful in performing analgesic peripheral blocks, with sparing use of opiates.

Further studies are needed to determine whether our suggestions may provide a valid and useful scientific basis to develop a standardized protocol for trauma patient management during a cave rescue.

Acknowledgments: We thank all of the CNSAS volunteers for their support; in particular we are grateful to Rem-Picci Antonietta, Raciti Guido and Longo Domenico (members of the caving technical commission [CTS] of CNSAS) for their technical support during the rescue. We thank Giovanna Scatena for the language support.

Author Contributions: Study concept and design (EP, BP, PF); drafting of the manuscript (GC); critical revision of the manuscript (PS, SDC); approval of final manuscript (EP, BP, PF, GC, PS, SDC, AS).

Financial/Material Support: None.

Disclosures: None.

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