ADVANCED LIFE SUPPORT IN THE MINING ENVIRONMENT

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Abstract

The mining environment presents challenging and complex situations for the application of medical care. The combination of remote locations, difficult access and longer response times may create an increase in morbidity and mortality in the event of serious accidents. The U.S Mine Safety and Health Administration (MSHA) has only minimal requirements of first aid training for mine workers. For mine rescue team members, MSHA requires medical training at the Emergency Medical Responder (EMR) level, as only prescribed by mine rescue contest rules.

This paper examines, based on mine accident statistical information, whether a higher level of medical training, for example at the Emergency Medical Technician (EMT) or at the Advanced Life Support (ALS) level can better address injuries most commonly disabling or leading to the death of miners in the United States.

Background

Prehospital emergency medical care for the sick and injured has evolved considerably from first inception. Ambulances used to be staffed by persons with little training and equipment and prehospital care was focused largely on the rapid transport of the injured person to a hospital and. The modern prehospital care model was initially developed in military applications, where medics were responsible for some treatment on the battlefield and rapid transport to the care of a physician.

In 1965, the National Academy of Sciences and National Research Council Committees on Trauma and Shock published *Accidental Death and Disability: The Neglected Disease of Modern Society* (National Research Council Committees on Trauma and Shock, 1966). This white paper laid out the consequences of the insufficiency of the Emergency Medical System (EMS) in the United States at that time. According to this paper, in 1965, 107,000 people were killed from accidental injury, with another 400,000 injured with permanent disability. The authors estimated that approximately 50% of ambulance services were provided by local morticians that were not capable of rendering advanced life support. The paper states that, based on experiences in the Vietnam war, seriously wounded soldiers had a better chance of survival in the battle field compared to traffic accident victims with similar traumatic injuries because the military was capable of providing first aid and efficient transportation to emergency care facilities. The white paper states that death rates from battle injuries declined significantly from 8% in World War I to 2% in Vietnam.

The publication of this white paper is credited for the broad evolution and rapid advance of the civilian EMS system after 1965. It eventually lead to the creation of the National Highway Transportation Safety Administration (NHTSA) National Standard Curricula (NSC) for emergency medical care in 1985. Training, and therefore required skill and knowledge for prehospital emergency care has continued to grow to reach the current standard.

Current Standards (2015)

In 2015, the United States maintains four levels of training and certification for prehospital medical care providers, with additional training opportunities for basic first aid without certification.

First aid trainings are available for the general public and can be variable in scope, depth and up-to-date content. First aid is also taught to new miners as part of 24- and 40-hour trainings under 30 CFR §48. First aid training generally includes basic cardiopulmonary resuscitation (CPR), splinting and bandaging. Instruction programs are certified by a variety of non-governmental entities, including the American Red Cross, the National Safety Council, and the American Heart Association. Some variation exists in the actual content of the training and there is little oversight in the content of training provided. Basic first aid trainings are not formally recognized as part of the general EMS system.

The formal entry level certification is Emergency Medical Responder (EMR), formerly known as First Responder. An Emergency Medical Responder is responsible for the basic assessment and treatment of traumatic injuries, recognition of medical emergencies and some limited treatment that includes oxygen administration and immobilization. EMRs are expected to have basic knowledge of anatomy and physiology, pathophysiology of shock, and basic medical conditions (NHTSA, 2014). This is the minimum certification held by most firefighters. Mine rescue contest rules, (MSHA, 2015) require this level of competency for members of mine rescue teams in both the metal/non-metal and coal industries.

The next higher skill level is the Emergency Medical Technician (EMT) certification. EMT certification requires approximately 100-200 hours of classroom instruction and practice with approximately 24 hours in a clinical setting. It requires a comprehensive knowledge of trauma treatment, assessment and treatment of medical emergencies, administration of certain medications, an understanding of pathophysiology with shock, and EMS operations (NHTSA EMS Program, 2014) (NHTSA EMS Program, 2007). Emergency Medical Technician is the fundamental level of skill for EMS operations. EMT is the standard for most firefighters and is the minimum skill level for an ambulance crew. For members of Mine Rescue Teams, EMT is considered a high level of care. Most corporate mine rescue teams have at least one EMT certified member.

Above the EMT is the Advanced EMT (AEMT) certification. AEMT was created to act as a bridge between the EMT and Paramedic levels. The scope of practice for the AEMT includes intravenous therapy, administration of nitroglycerine, dextrose, naloxone and epinephrine. AEMTs take additional hours of clinical education to gain an expanded depth and breadth of knowledge of emergency medical care. While AEMTs are rarely used at their scope of practice or as ALS providers in EMS systems (Mogg, 2015), some large corporate mine rescue teams employ AEMTs as senior medical staff members within their organization.

The Paramedic level of certification is the highest level of training for prehospital care in the United States. Paramedics have the broadest scope of practice and maximum training for EMS. They are permitted the broadest scope of practice in the pre-hospital environment, in some cases at a scope above that of a nurse and closer to that of a Physician's Assistant. Paramedics are permitted to administer a broad range of medications, including opiate analgesics, benzodiazepine sedatives, and are qualified to perform a broad set of emergency interventions for patient care. Paramedics are able to perform intubation (oral and nasal), surgical percutaneous cricothyrotomies, transcutaneous pacing, cardioversion, manual defibrillation, and other advanced care procedures (Colorado Dept of Public Health and Environment, 2014, McVaney et al., 2015). Paramedics also maintain a comprehensive and broad scope of knowledge regarding medical care and trauma care, and a detailed knowledge of advanced medical conditions and their behavior. Paramedics

routinely practice as the leading member on an ambulance crew, or in the hospital emergency department as an advanced care technician, and are permitted to work with minimal oversight from their physician medical director. To the knowledge of the authors, no mine rescue teams use Paramedics as routine team members, though some Teams work with physicians and Paramedics in a larger-scale cooperative agreement.

U.S. Mining Regulatory Requirements

U.S. regulations applicable to surface and underground metal, nonmetal, and coal mines require first aid training for at least one person per working shift at each mine. This "capable person" must have the ability to perform patient assessment and artificial respiration; control bleeding; and treat shock, wounds, burns, and musculoskeletal injuries based on 30 CFR §56.18010 and §57.18010. 30 CFR §75.1713 and §57.18014 require mine operators to arrange for emergency medical assistance and transportation for injured persons once they have been brought to the surface.

U.S. mining regulations or MSHA program policy do not incorporate the qualifications required by the NHTSA EMS. MSHA inspectors are merely required to verify the scope of the qualified person's training and the currency of their training (MSHA, 2014).

Evaluation Methodology

To evaluate whether more advanced emergency medical qualifications will improve the survivability or lessen the impact of traumatic injuries, common and critical medical emergencies among mine workers, researchers have considered the most common patterns for severe injuries based on MSHA accident and injury database information. Researchers compared the treatment plans for these injuries under the scope of practice for varying EMS certification levels. Researchers then related the time to transport and recover injured persons from an underground mine location to the scope of treatment possible in the time before reaching definitive care at a trauma center.

Injury and Illness Statistics for US Mines

Researchers examined the MSHA Part 50 mine accident and injury database (MSHA, 2015) and classified serious and fatal injuries 2010-2014 by nature of injury (NOI). These injuries led to either death, disability or days lost from work. For the time period evaluated, there were a total of 20,042 injuries recorded. These included 230 fatalities, with 120 of them attributed to multisystem trauma, as illustrated in Figure 1.

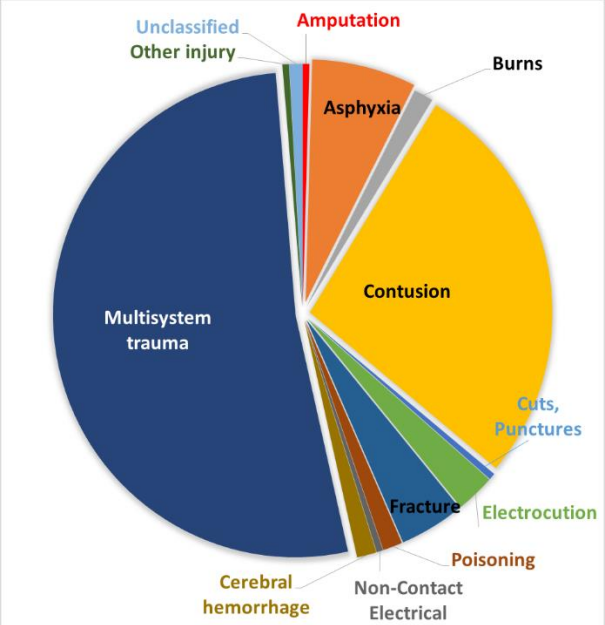

Figure 1: Fatal injuries in the U.S. mining industry, by nature of injury, 2010 - 2014

There were 16,875 non-fatal, permanently disabling or lost time injuries over this time, with 10,163 reported cases of strains, sprains, and fractured bones as the leading NOI, as seen in Figure 2. Sprains and strains make up 43% of these injuries, and fractures were the second NOI, at 18%.

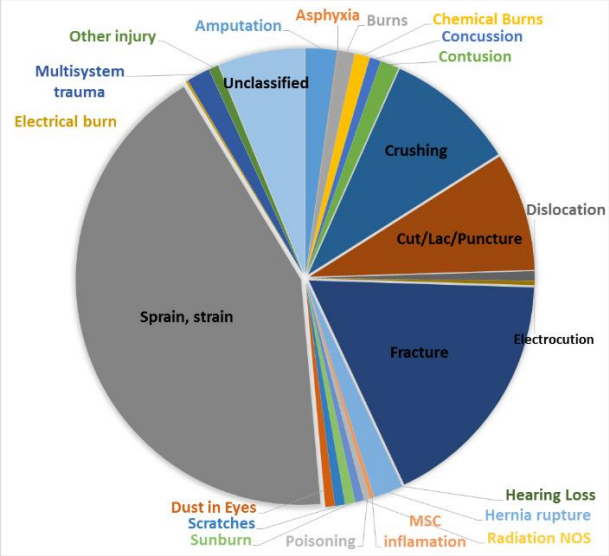

Figure 2: Non-Fatal Days Lost and Disabling injuries in the U.S. mining industry, by nature of injury, 2010 - 2014

Injury Treatment

The following injuries and conditions were evaluated and appropriate treatment indicated as follows:

1. Multisystem Trauma
2. Crushing
3. Amputation
4. Asphyxia
5. Contusions
6. Musculoskeletal injuries (sprains, strains, fractures)
7. Electrocution
8. Myocardial infarction
9. Lacerations, Abrasions, Punctures
10. Burns
11. Head injuries

Prehospital emergency medical care is centered on ensuring basic life functions continue, fundamentally leading to the circulation of oxygenated blood containing essential nutrients to the tissues of the body. High priority (life support) medical care includes:

- Control of hemorrhage
- Management of airway, often including endotracheal intubation
- Artificial respiration
- Cardiopulmonary resuscitation, including the administration of cardiac medications and manual defibrillation
- Intravenous fluid resuscitation to boost circulatory system function

Secondary to this basic life-support process, medical care is focused on the comfort and long-term recovery of the patient. While not as time-critical, these interventions lead to better long term outcomes when coupled to life support care. Supporting care includes:

- Pain management, often using opioids
- Splinting of fractured and sprained limbs
- Wound cleaning and bandaging, key to preventing infection

The scope of practice required to deliver the most effective treatment for a traumatically injured patient is based on the specific treatments provided. Basic life support providers (EMT and AEMT) can administer some of the care required, including hemorrhage control, limited airway management, splinting and wound management, and AEMTs may begin fluid resuscitation (NHTSA EMS Program, 2007). The maximum scope of treatment in the prehospital environment is limited to Paramedics, particularly administration of any medication, and invasive treatments.

Based on the national education standard and the accepted national scope of practice from the NHTSA EMS program, treatments were evaluated and the minimum scope of practice to provide effective intervention to the medical emergency. This is summarized in Table 1.

Injury	*Recommended Scope*	*Time Sensitivity*
Multisystem Trauma	AEMT	High
Crushing	Paramedic	High
Amputation	AEMT	High
Asphyxia	Paramedic	High
Contusions	EMT	Low
Musculoskeletal injuries (sprains, strains, fractures)	EMT	Moderate
Electrocution	Paramedic	Moderate
Myocardial infarction	Paramedic	High
Lacerations, Abrasions, Punctures	AEMT	Low
Burns	AEMT	Moderate
Head injury	AEMT	Moderate

Table 1: Recommended scope of practice and time sensitivity for different types of injuries.

Time Considerations

Generally, treatment and transportation protocols for trauma care are based around ensuring continuing life functions during transport and rapid handoff to a receiving trauma center. A majority of mine sites are not within the 'golden hour' transport time from even a lower capability trauma center. Overall trends show that longer travel times require an increasingly higher scope of practice from responding and treating medical providers.

Most difficult to reach are fly-in, fly-out mine sites that can take several hours to access even via air. In these scenarios, providing advanced care to critically injured patients requires advanced-level medical care and facilities on-site.

Other industries working at remote sites, including the oil and gas industry, use Paramedics trained in remote medicine who are stationed at the remote locations. Their charge is to provide ALS care and intervention on site, as well as doing general occupational healthcare for employees who are on site for an extended period of time. This model may be suited for remote fly-in, fly-out mine sites as well.

Recommendations

Based on the research and evaluation of injuries, their treatment and the complication of extended response or evacuation times, researchers make the following specific recommendations:

1. All miners should be trained in CPR and AED usage, and certification should be required for employment.
2. Mines within a 30 minute response time from an EMS agency and within 1 hour ground transport time from a level II trauma center should maintain at least one EMR on duty with each shift.
3. Mines within one hour of EMS arrival and within two hours of a level II trauma center should maintain at least one EMT on each shift.
4. Mines with longer than one hour EMS response time should keep a Paramedic and an EMT on site on each shift.
5. Mines with longer than one hour transport time to a level II trauma center should establish and maintain an agreement with helicopter aeromedical evacuation for rapid transport of patients.
6. Mines with longer than three hours transport time to a level III trauma center should develop ground or air transportation capability for patients, with a Paramedic and EMT on site covering each shift.
7. Mine rescue teams should maintain a Paramedic as their team medic, with all team members certified as EMTs. Mine rescue training should be improved to focus more on providing advanced levels of pre-hospital care for injured miners.

Conclusions

Mines represent a unique set of hazards, where catastrophic injury is possible in remote and austere locations. Mines need to be prepared for the care and transportation of critically injured or ill patients. Based on mining accidents and injuries 2010 to 2014, researchers have evaluated the required level of care for typical injury types in mining accidents. Emergency pre-hospital care for the seriously injured or ill miner is best done by a Paramedic, especially in remote locations where the "golden hour" of pre-hospital care cannot be maintained.

Having an EMT on each shift is generally recommended to ensure minimum standard of care. In addition, all miners should be trained in First Aid. This expanded scope of practice allows the implementation of advanced and more definitive care for the injured. Researchers believe that this may lead to a reduction in morbidity and mortality of the seriously injured. A shortened response window from the time of accident to the arrival of trained first responders and rapid transportation to the hospital will positively impact the outcomes of the seriously injured.

References

Centers for Disease Control and Prevention, 2009. Crush Injury and Crush Syndrome. Atlanta: American College of Emergency Physicians, 2009.

Colorado Dept. of Public Health and Environment, 2014. Comparison Educational Standards and Colorado Scope of Practice. Denver, Colorado, CDPHE EMTS, 2014.

McVaney, Kevin, et al., 2015. Denver Metropolitan Prehospital Protocols. Denver Metro EMS Medical Directors, 2015. http://www.dmemsmd.org/protocols

Mogg, Matthew, 2015. Personal Interview. October 30, 2015.

MSHA, 2007. National EMS Scope of Practice. NHTSA EMS Program. March 1, 2007. http://www.ems.gov/pdf/EMSScope.pdf

MSHA, 2014. First Aid - 30 CFR 56.18010, 57.18010, 77.1703, 75.1713:. Mine Safety and Health Administration (MSHA). [Online] July 18, 2014. [Cited: October 20, 2015.] http://www.msha.gov/STATS/Top20Viols/tips/18010.htm.

MSHA, 2015a. Mine Rescue Contests. Mine Safety and Health Administration. November 2, 2015. [Cited: November 2, 2015.] http://www.msha.gov/minerescue/contest

MSHA, 2015b. MSHA - Part 50 Data: Self-extracting Files Home Page. Mine Safety and Health Administration (MSHA). July 29, 2015. http://www.msha.gov/STATS/PART50/p50y2k/p50y2k.HTM

NHTSA, 2014. Education Standards. NHTSA EMS Program. August 21, 2014. http://www.ems.gov/EducationStandards.htm

National Research Council Committees on Trauma and Shock, 1966. Accidental Death and Disability: The Neglected Disease of Modern Society. Washington: National Academy of Sciences, 1966.

Salomone, Jeffrey P, et al., 2014. PHTLS Prehospital Trauma Life Support: Military Edition. Burlington: Jones & Bartlett Learning, 2014. ISBN: 978-1284061567.