International Emergency Nursing 54 (2021) 100950

Contents lists available at ScienceDirect

International Emergency Nursing

journal homepage: www.elsevier.com/locate/aaen

Situational awareness during a full-scale exercise in an underground mine: A qualitative single-case study of the ambulance incident commander

Annika Eklund [a,*], Britt-Inger Saveman [b,c], Lina Gyllencreutz [b,c]

[a] Department of Health Sciences, Section for Advanced Nursing, University West, 461 86 Trollhättan, Sweden
[b] Department of Surgery and Perioperative Sciences, Section for Surgery, Umeå University, 901 87 Umeå, Sweden
[c] Department of Nursing, Umeå University, 901 87 Umeå, Sweden

ARTICLE INFO

Keywords:
Emergency medical management
Exercise
Underground mine incident
Preparedness
Situational awareness
Qualitative observational study

ABSTRACT

Introduction: Underground environments present challenges for providing and managing effective emergency care. Situational awareness **(SA)** has been suggested as a critical process to the management of care.
Aim: This study aims to explore the process of SA in the tasks of an ambulance incident commander (AIC) during a fullscale underground mine exercise.
Methods: Data consisted of video recordings, audiotapes and fieldnotes; these were subjected to content analysis based on the categories from the Busby Theory of Situational Awareness in Multi-casualty Incidents.
Results: The results show that the underground mining environment presented the AIC with specific challenges for the SA process with respect to aspects such as situational information about the scene and the victims, as well as with making decisions for ambulance personnel so they could perform their work safely, and having a structured manner to counteract information overload. Both technical and non-technical aspects influenced the process.
Conclusion: The AIC's situational awareness was largely built through coordinated communications and actions with collaborating actors. The results of this study can be used for further exploration of how to train and support people in medical leadership roles on aspects of SA in emergency care, as well as on how to evaluate educational outcomes through exercises.

1. Introduction

Incidents in underground environments are rarely ideal situations for emergency medical services (EMS) to provide and organize care [1,2]. Underground incidents have been reported to pose specific challenges for rescue operations due to safety issues at the scene, heat and smoke [3], technical and non-technical communication [4], lack of work experience in such environments, and difficulty reaching patients [1,5,6], among other issues. Simulations and multiagency exercises are common methods used to increase emergency preparedness, to test plans and procedures, to develop collaboration and communication, and to improve clinical decisions in major incidents [7,8,9,10]. Full-scale exercises are performed to practice and gain experiences in a safe learning environment that is designed to replicate a real emergency as closely as possible [10,11]

Thousands of fatalities occur every year in coal, hard-rock and metal mines around the world [12]. Yet major incidents in mining environments are decreasing internationally, but when they do occur the consequences can be disastrous [12,13]. Incidents in mines typically involve fires, traffic incidents, and rockfalls [12,14]. Emergency medical services personnel have considered mining environments to be unfamiliar and unsafe, and they became passive during operations [15]. Preparedness was higher among EMS personnel who had received training or education, or who had real-life experience in such environments [16].

The rates of mining incidents in Sweden has decreased over the past decades, still there are about 100 mining incidents every year that results in incidents causing sick-leave for mine workers for at least one day, and an average of six severe injuries every year in the nine Swedish underground mines [17]. Sweden has no specially trained mine medical teams, which means that any EMS personnel might be dispatched to a mining incident [15]. The on-scene EMS management functions on-scene are shared between two roles: an ambulance incident commander (AIC) and a medical incident commander (MIC). Personnel from the

* Corresponding author.
E-mail addresses: annika.eklund@hv.se (A. Eklund), britt-inger.saveman@umu.se (B.-I. Saveman), lina.gyllencreutz@umu.se (L. Gyllencreutz).

https://doi.org/10.1016/j.ienj.2020.100950
Received 2 July 2020; Received in revised form 8 October 2020; Accepted 20 October 2020
Available online 14 December 2020

first ambulance to arrive at an incident are assigned these roles. The AIC lead the operation on site in collaboration with the police incident commander (PIC) and the fire officer in charge (FOC). The main responsibilities of the AIC are to create the structure and conditions to coordinate efforts at the incident site. More specifically, the AIC's primary tasks are to conduct a scene safety assessment, make decisions, develop an action plan, distribute and request additional resources if needed, and collaborate with other rescue organizations [18]. The AIC's role and tasks are significantly different from the everyday competences that EMS medical personnel use in their daily work. This means it is critical to further explore the prerequisites for handling these tasks, and how personnel can develop them through exercises.

Researchers have emphasized situational awareness (SA)—defined as "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and projection of their status in the near future" [19]—as a key component for the successful management of major incidents [8,20,21]. Yet we know relatively little about how to build and develop SA for prehospital management in environments where it is difficult to reach the incident site and location of victims during the initial operation. This study contributes to this research field by exploring the SA process from the perspective of an AIC, during a full-scale exercise in an underground mine environment.

1.1. Theoretical framework

Several studies have highlighted the relevance of situational awareness in the context of complex rescue operations due to the dynamic circumstances of actual or potential change [20,21,22]. Busby and Witucki-Brown [20] developed a theory for the process of SA in the context of major incidents. More specifically, they describe that the process of SA in such incidents involves establishing and maintaining control over dynamic, and contextually based situations against a background of experience and preparatory actions such as exercises. Their theory puts emphasis on the tasks that provide a relatively safe environment in which patient care is provided. The theory categorizes 12 properties that are used to build SA (Table 1). [20]

Their theory describes the development of SA in major incidents as an iterative process where every piece of information informs new actions. This theory, and its 12 categories, forms the basis for exploring the process of SA for AIC in an underground mine exercise [20].

Table 1
Categories and properties in the Busby Theory of Situational Awareness in Mass Casualty Incidents.

Experience	Significance of experience, Benefit derived from experience
Interval Action: ongoing	General preparation
Interval Action: proximal	Actions based on particular response efforts
Contextually based incident	Mechanism of injury, Number of injured, Location
Appreciating context and complexity	Dynamic nature of events, Anticipating and envisioning the scene, Perceiving the scene, Geographic and environmental conditions
Establishing and maintaining control	Degree of control, Accepting responsibility, Establishing priorities, Coordinating efforts, Decision-making
Handling information	General, Initial information, Receiving updates, Communications, Professional roles, Team roles
Roles and relationships	Interaction roles, Relationships with and among providers
Managing resources	Personnel, Equipment, Time
The human element	Emotions experienced and the impact on responders, Methods for managing
Safety	Goals and priority of safety, Threats to safety, Actions to provide safety
Patient care	Triaging, Caring, Disposition

2. Method

2.1. Design and setting

Due to the complexity of a SA process, the study was designed as a qualitative single-case observational study of the response and evaluation phases in a full-scale exercise in an underground mine. A case study design is appropriate when the aim is to gain an in-depth understanding of a specific phenomenon in its actual context [23].

The full-scale exercise took place in an underground mine in northern Sweden. The overall aim of the exercise was to improve collaboration between the organizations that typically are involved in underground mine incidents. The exercise was produced in a larger project (Safety and Security Test Arena) and was one activity among others to develop an educational program for rescue operations during major fire incidents in underground mines. All miners, EMS and rescue service personnel knew the date of the exercise but received no further information in advance. The scenario and timeline of the exercise is presented in Fig. 1.

2.2. Data collection and analysis

The exercise was recorded through audio, video, on-site observations, and fieldnotes of the exercise and the evaluation performed directly after the exercise. Using multiple data sources to study the same phenomenon can enhance the reliability and validity of the results [23]. Observations included both physical and communication aspects of the exercise. For example, the layout and use of the command and control room where the managers coordinated their activities, and the shared information resources. Such observations provide a context for using the data to understand the details of the AIC's activities and aspects of work that constitute fundaments for SA. Four cameras and one microphone were placed in the command and control room. Audio and video recording devices were worn by the AIC, the MIC, and the FOC. The different types of data made it possible to ensure internal consistency, as what was noted in the fieldnotes could be checked against the audio and video recordings and vice-versa [22]. The field notes and audio

The scenario simulated a burning mining vehicle 370 meters below ground. One miner announced the fire (340 meters below ground), and evacuation of the mine was initiated following the standard operating procedure for cases of fire. Miners who were not able to evacuate went to the nearest underground rescue chamber. Those who were able to evacuate on their own went to the above-ground assembly point. The scenario included seven realistic injury victims with such injuries as fractures, internal bleeding, burn injuries, cardiac symptoms, and smoke inhalation. Two of the severely injury victims became trapped underground in separate rescue chambers, together with eight uninjured miners. When the vehicle fire was announced (7.50 am.), the mine crisis group assembled and set up a command and control room with a large table and an emergency management template that displayed information such as the number of victims, their positions, and a map of the mine on a screen. The dispatch center received the alarm and alerted the rescue services and the EMS. The first ambulance crew arrived on site at 8.34 am. The first injury victim was transported from the assembly point 112 minutes after the first ambulance arrived. Twenty-five minutes later, the assembly point was cleared of injury victims. However, due to time limit for the exercise (maximum 4 hours) the underground rescue chamber was not evacuated before the end of the exercise and only preliminary time for evacuation was calculated (13.00-13.30 pm).

Fig. 1. Detailed description of the scenario and timeline of the exercise.

recordings were transcribed verbatim and used in the analysis.

All text was analyzed using manifest qualitative content analysis [24]. First, the researchers read through the texts several times to gain an impression about the content. Then the texts were divided into meaning units, including both quotations and observation notes from data, focusing on the AIC's functions and activities. After that, these meaning units were deductively coded according to the SA categories from the Busby Theory of Situational Awareness in Multi-Casualty Incidents [20] (Table 1). The codes were sorted into the SA categories based on the properties of each category suggested in the theory. The results section presents the content that built meaning units, showing how SA is processed in the AIC role. The content is divided into nine of the theoretical categories. There was no content that could be categorized as "Ongoing interval action", "Proximal interval action" (covering general preparation in terms of e.g. education and particular prior response efforts) "Human element," (covering emotions and methods for managing emotions), as our data did not cover these perspectives. Thus these categories are not included in the analysis. The analysis process is exemplified in Table 2.

2.3. Ethical considerations

In accordance with the Helsinki Declaration [25], all participants in the exercise received written information, about the aim of the exercise and evaluation methods (i.e. video, audio, and on-site observations) and that their data will be confidentially treated. They participated at their own free will, and approved that the research group analyzed and presented the data. Informed written consent was received from all participants prior to the exercise. They received an email with a consent form to fill in and return to the research group. Consent forms were also available at the exercise site if someone forgot to fil it in before. The study is not covered by the Swedish Act concerning the Ethical Review of Research Involving Humans, and therefore approval from the Regional Ethical Review Board has not been sought for this study.

3. Results

The procedures and events throughout the exercise are presented according to nine of the 12 categories in the Busby Theory of Situational Awareness [20]. The results do not follow the chronological timeline of the exercise. Both injured and non-injured are here referred to as "victims", yet the injured are referred to as "injury victims".

3.1. Experience

After they were dispatched to the incident, the AIC and MIC agreed that in their experience, the core challenges when caring for injury victims is the underground environment and not the care itself. Based on the AIC's previous experiences with rescue operations in mine environments, the AIC decided on the way to the incident that no ambulance personnel should be sent underground to provide care. Also based on experience, the AIC also decided they were not in a position to prepare or make further decisions until they could get a visual overview of the actual environment upon arrival.

3.2. Contextually based incident

The AIC gathered information about the victims from several sources. After they had been dispatched and during their transportation to the mine, the AIC contacted the dispatch center to ask about the number, severity of injuries, and location of the victims. Based on this information, the AIC ordered extra resources, e.g. ambulance personnel, equipment, and vehicles. The AIC and MIC also concluded that the arrival time for the other ambulances remained unclear.

When they reached the command and control center, the FOC and the mine crisis group manager provided the AIC with more-detailed information about the victims, their location, and their initial triage of those located in the rescue chambers. The data reveal that the AIC thereafter based their initial general assessments and medical decisions on this secondhand information without verifying that the information was correct.

Information about the victims and their locations was also presented on the shared emergency management template. However, the AIC recurrently asked for collaborating actors to provide the number and location of the injury victims and their types of injuries. This remained an issue for the AIC throughout the exercise, even though the victims in the rescue chambers (and information about them) did not change, and they could not leave the chambers before evacuation.

3.3. Appreciating context and complexity

Initially, the AIC was dependent on information from collaborators

Table 2
Analysis process. Examples of categories and properties of the Busby theory, with codes and selected exemplars of meaning units from data.

Category	Properties	Codes	Meaning units (selected exemplars)
Handling information	General Initial information Receiving updates Communications Professional roles Team roles	Managing radios Constant information flow Sort out info Prioritize info Management template Timelines Grasping the number of injured Disrupted communications	"We are currently suspecting a major incident, due to an underground fire, and people are underground" "We have received information about 15 victims, two injured, five on their way up and two are above ground" Verbal information from FOC and mine manager, using management template and mine map Cell phone discharged AIC failed when trying to connect with actors using different radio devices When and where resources arrived (far from incident site) Many persons passing the room with questions and information Open radios meant constant information flow Open radios meant all actors received the same information Recurring discussions about time to evacuation (difficulties reaching chambers) "I need to try to get through, do we have nine left underground now?" "…remaining underground are two red priorities, above ground we have…" [disrupted]
Managing resources	Personnel Equipment Time	Ordering personnel Ordering and distributing medical equipment Vehicles for transport Delayed order Available equipment in rescue chamber Overview of resources Transportation in collaboration	Ordering personnel, helicopter and medical equipment on their way out Inventing resources (personnel, medical equipment, vehicles) Lacking suitable equipment in the ambulance Difficulties in contact with official-on-standby led to delayed order of resources "The ambulance , where is it? Is it empty [medical equipment]? "You send three Cyanokits' [hydroxocobalamin], did I get that correct?" Instructing personnel to bring oxygen and antidote underground "The ambulances can't drive down here, only personnel? How do we get there?" Decisions on transportation underground depended on collaboration with FOC (how, when and where)

(i.e. FOC and mine crisis group manager) in order to assess the context, since they could not get a view of victims or their location due to the underground environment and smoke. By using the shared emergency management template and the mine map, the FOC and the mine manager provided the AIC with an overview of how the rescue services were proceeding in their operations as they approached the rescue chambers, and where the EMS personnel should be transported to care for the underground injury victims.

The AIC followed the prehospital management routine and directed the arriving EMS personnel to the command and control room, although it was quite far from the mine itself and the personnel needed guidance within the mine area.

3.4. Establishing and maintaining control

The AIC focused on two main issues: which of the injury victims should be triaged first and whether EMS personnel should go underground to provide care in the mine and how to do so safely. Continuous updates from the FOC regarding progress on the rescue operation were fundamental for establishing priorities and decisions. The AIC stated that the most severe injury victims should be prioritized. However, this decision was based on old information that was initially provided by the FOC and the mine crisis group manager. Furthermore, the FOC emphasized that the amount of breathing air in the rescue chambers needed to be considered when reaching a decision about prioritizing the victims. The data revealed that this was not further collaborated on, thus the AIC allowed the FOC to take the lead in deciding about triage.

Due to the nature of the exercise scenario much of the medical operation involved waiting for the rescue operation underground to begin. Thus, communication about progress on the operation was largely driven by the FOC, who continuously explained and updated the rescue operation and its timeline. However, the AIC did not provide the FOC with additional information about plans and organization of the medical operation. This was only communicated with the MIC and the hospital official-on-standby.

3.5. Handling information

Based on the initial information from the dispatch center, the AIC concluded that the alarm concerned a suspected major incident caused by an underground fire, a conclusion that formed the basis for their initial decisions. Much of the information passing between the AIC and the MIC concerned the number, status, and triaging of injury victims. The AIC ordered resources based on the information from the MIC about the medical assessments (personnel, medical equipment, and vehicles). Yet the data revealed that the AIC faced challenges in getting updated information and a clear perception of when and where those resources arrived. For example, the AIC found it difficult to coordinate the arrival of drugs, e.g. the antidote Cyanokit (hydroxocobalamin) that can counteract poisoning such as smoke inhalation, and whom it should be sent to. In addition, they used both the name of the ambulance home city and the ambulance call-number when ordering resources, which caused confusion regarding arrival of personnel, and what equipment was available and when it arrived.

Much of the communication between the AIC and collaborators concerned the timing of various activities or the arrival of resources. On a few occasions the AIC tried to establish contact with the hospitals involved, but encountered problems with the mobile phone or no one answered.

The AIC took notes in a personal binder as a way to manage information. The managers used both the emergency management template and verbal communication to share information and updates throughout the course of the exercise. The AIC used face-to-face verbal communication, the authority radio network (RAKEL), and mobile phone calls with several individuals to receive updates and provide others with information. The managers chose to use open-channel radios (except the AIC, who used a mobile phone for closed calls), meaning that it was easy to overhear the latest updates. However, this also meant a constant flow of information and made it difficult to interpret data, as the individual actors had to constantly evaluate and sort out which information was relevant to their actions.

In addition, a large number of individuals (such as newly arriving ambulance personnel) came in and out providing information and asking questions; this sometimes interrupted ongoing discussions between the collaborators. When communication channels became overloaded, the AIC did not succeed in taking control or prioritizing in the flow of information. This meant that information needed to be restated several times and sometimes they did not remember what they had talked about before they were interrupted.

3.6. Roles and relationships

The AIC and the MIC were initially guided to the assembly point instead of to the command and control room, where a management group that included the FOC and the mine manager had already been established. The AIC and the MIC were seated together in the command and control room. This closeness ensured opportunities for cooperation because it made it easy to share and discuss information, ask pressing questions, and overhear conversations. However, the data reveal that the AIC took a more prominent role in carrying out the tasks that were specifically assigned to the AIC role, rather than engaging when the MIC wanted to discuss medical priorities or ideas about actions.

The AIC suggested regular meetings with the collaborators, but took few initiatives to reconcile and take updates on how the operation was proceeding and timelines for evacuation. The AIC took a restrained approach regarding cooperation with collaborating actors. This was exemplified by the AIC repeatedly asking the FOC if rescue services needed anything from the healthcare services, instead of providing the FOC with information about what the AIC wanted the rescue services to do for the EMS's part of the operation. However, their collaboration and their roles became clear in some decisions: for example, those concerning whether rescue personnel were ready to go down in the mine and when they would do so. The AIC based these decisions on the availability of oxygen and forms transportation for the EMS personnel, while the FOC was responsible for safety and ensuring that the environment was safe to provide care.

3.7. Managing resources

Much of the AIC's work involved getting an overview regarding the need for resources. On the way to the mine, the AIC had already ordered extra resources, such as ambulance personnel, a helicopter (including a physician and a nurse), a primary healthcare team, and drugs and antidotes. The AIC instructed the arriving personnel to bring the equipment that was needed (such as oxygen) to the assembly point, and they gave the departure time for going down into the mine. However, the observation notes reveal that the AIC found it difficult to establish contact with the official-on-standby at the hospital. This meant that although the AIC determined the need for resources, the order was delayed.

Managing resources also included coordinating decisions and actions with collaborators. For example, the decision about how and when EMS personnel and their equipment would be transported into the mine depended on collaboration between the AIC and the FOC. How close to the incident site the ambulance personnel could go and when and where they would be able to have the access to patients depended on collaborators' procedures and available resources.

3.8. Safety

When the collaboration started, the AIC and the FOC had different opinions about whether ambulance personnel should be present in the mine to care for the injury victims. The AIC stated, while driving to the mine, that no ambulance should go underground. The FOC stated that there was a need for medical competence closer to the incident site and told AIC that outside the smoke-filled area the environment was safe enough for the ambulance personnel. Based on the FOC's safety assessment, the AIC chose to send two ambulance personell underground, transported in the rescue services vehicle. The AIC initiated no further questions regarding safety or possible threats for the victims or personnel, either within own organization or with the rescue service and mine company.

3.9. Patient care

An inventory of the number of victims and injury victims, their medical status, and triage priority was done rather quickly as the AIC continuously received information from the mining crisis group manager, the non-injured victims in the rescue chambers, and the ambulance personnel at the assembly point.

The AIC planned for transportation to hospitals and healthcare centers and informed the hospital official-on-standby, and presented a departure time plan considering when the persons in the rescue chambers were expected to reach the assembly point above ground. When they arrived at the assembly point, patients with green priority were transported to a nearby healthcare center together with a healthcare team. The patients with red priority were transported to the appropriate hospital via ambulance or helicopter. The first patient (red priority) was transported from the assembly point 112 min after the first ambulance arrived on site. All patients were transported from the assembly point after 137 min had transpired.

4. Discussion

This case study shows that SA is a foundation for the tasks of an AIC in an underground mine incident exercise. It found that effective collaboration among those in leaderships roles was fundamental for the SA process in the AIC function, but also showed that a lack of SA seemed to adversely affect patient outcomes due to time delays in decision-making, or even failure to make decisions at all. Furthermore, the underground environmental conditions presented a range of specific challenges that affecting the process of SA, such as processing situational information about the scene and the victims, making decisions regarding when and how ambulance personnel could perform their jobs safely, and counteracting an overload of information in a structured manner.

Research has shown that being familiar with the environment where an incident occurs is essential in order to carry out an effective rescue operation [1,15,26]. This study illustrates the significance of experience in similar environmental conditions; this was a central component in the initial decision to not send ambulance personnel to work underground also in the exercise context. Moreover, the AIC's situational awareness was clearly dependent on information and safety judgements from the rescue service and mine crisis group, since the AIC was not able to view the scene personally. Considering that the managers had somewhat diverging ideas regarding the environmental conditions and safety, the study revealed surprisingly few discussions about personnel safety. Even so, the decision to not send ambulance personnel underground was changed during the exercise. The SA aspect of safety must be balanced with the risks for patient care [20], which could be of particular importance in an underground environment. A lack of SA can lead to uncertainty regarding the balance between ensuring a totally safe environment and an environment which is safe enough for personnel [27]. Altogether, these aspects highlight the need for persons in medical leadership roles to have experience from mine environments and to have opportunities to re-evaluate their experiences in exercises as a part of the SA process.

Situational awareness has been described as a primarily non-technical skill [21], but the results of this study indicated that technical skills (such as using various radio communication devices) are essential for the SA process. Multiple radio communication devices were needed to share information due to long distances involved, yet the AIC had problems handling the devices, and frequent communication over the radio made it difficult for the AIC to capture, sort, and prioritize the flood of information. A large number of actors, a multiplicity of channels, a loud environment, and a failure to confirm information are described as factors that lead to poorer SA [15,28]. Having enough information, and of the right type, is described as a fundamental aspect of SA [28]. This study found that information gaps, lack of clarity, and information overload hindered the process of developing SA. This points to the need for technical and non-technical training to handle and prioritize information.

In this study, the SA that the AIC needed to establish and maintain control depended on coordinated communications and actions taken by collaborators. This highlighted that a collective effort was required to ensure a safe work environment, provide information, define the timing of critical events such as evacuation, and determine where care could be delivered safely. In light of this, SA is understood to be located in a shared practice rather than in the minds of individuals performing one role [22]. One way for the AIC to use shared knowledge in order establish and maintain control might be additional training on the use of tools for coordination, such as radio communication devices and the emergency management template [29].

These results cover both the specific function and tasks of the AIC, as well as the collaborative aspects that facilitate an effective operation. In light of the Busby Theory of Situational Awareness in Mass Casualty Incidents [20], these results indicate the value of directing exercises towards SA processes. We need to further explore how to implement exercises that improve the SA needed to manage medical leadership roles in incidents in confined environments and to study how SA can reduce delays in decision-making and actions.

5. Methodological considerations

The results of this study should be interpreted with some caution. This is a single-case study that focused on only one AIC. Although some researchers [30] argue for the weaknesses of case studies, they highlight unique elements and allow for the in-depth manifestation of a phenomenon [23]. In addition, a theoretical model was used to shape the deductive analysis. Sorting the data into categories entails a risk of fragmentation when trying to capture a complex process. The different data collection strategies made it possible to analyze the same phenomenon in real-time, from various perspectives, which could increase internal consistency and was used as a source for validation of the fieldnotes. However, observational data does not provide any information on aspects such as the effects of fictional moments or motives for decisions as part of the SA process, which could be important to address in further studies.

6. Conclusion

This study identified a number of challenges that the AIC faced in the SA process, associated with both technical and non-technical skills, and their impact on decision-making in a complex underground mine environment exercise. In a context of a confined environment with limited communication with the victims, those in leadership roles may not be able to view the scene and are required to handle a large stream of information from which they must make decisions; in such a scenario, effective collaboration is fundamental for developing leaders' SA. The results of this research can be applied to the design of future exercises that use the fundaments of SA to define aims and evaluate educational outcomes in performing effective emergency care.

Ethical statement

In accordance with the Helsinki Declaration, all participants in the exercise received written information about the aim of the exercise and the evaluation methods, and were informed that their data would be de-identified, and that they participated of their own free will. All participants provided written informed consent and approved for the research group to analyze and present the data.

Funding source

Support for this project was received from the Swedish National Board of Health and Welfare along with the European Regional Development Fund under the Safety & Security Test Arena project.

CRediT authorship contribution statement

Annika Eklund: Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing - original draft. **Britt-Inger Saveman:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing - review & editing. **Lina Gyllencreutz:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing - original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Lockey DJ, Mackenzie R, Redhead J, Wise D, Harris T, Weaver A. London bombings July 2005: the immediate pre-hospital medical response. Resuscitation 2015;66(2): ix–xii.
[2] Holgersson A, Eklund A, Gyllencreutz L, Saveman B-I. Emergency medical response in Mass Casualty Tunnel Incidents – with emphasis on prehospital care. J. Human Security 2020;16(1):3–15.
[3] Rosmuller N, Van den Brand R. Emergency response possibilities at freight railway tunnel accidents. Int J Emergency Manage 2003;1(4):374–96.
[4] Tokuda Y, Kikuchi M, Takahashi O, Stein GH. Prehospital management of sarin nerve gas terrorism in urban settings: 10 years of progress after the tokyo subway sarin attack. Resuscitation 2016;68(2):193–1120.
[5] Lyon RM, Sanders J. The swiss bus accident on 13 march 2012: lessons for pre-hospital care. Crit Care 2012;16(4):138.
[6] Karlsson S, Gyllencreutz L, Engström G, Björnstig U, Saveman B-I. Preparedness for mining injury incidents: interviews with Swedish Rescuers. Safety Sci. Monitor 2017;20:1–10.
[7] Ashkenazi I, Lennquist Montan K, Lennquist S. Mass Casualties Incident: Education, Simulation, and Training. In: Kluger Y, Coccolini F, Catena F, Ansaloni L. (eds) WSES Handbook of Mass Casualties Incidents Management. Hot Topics in Acute Care Surgery and Trauma. Springer, Cham; 2020, p. 167–175.
[8] Wilson MH, Habig K, Wright C, Hughes A, Davies G, Imray CHE. Pre-hospital emergency medicine. Lancet 2015;386(10012):2526–34.
[9] Hansen R. Design of fire scenarios for Australian underground hard rock mines – applying data from full-scale fire experiments. J Sustainable Min 2019;18(4): 163–73.
[10] Skryabina E, Reedy G, Amlôt R, Jaye P, Riley P. (2017). What is the value of health emergency preparedness exercises? a scoping review study. Int J Disaster Risk Reduct, 2017; 21(March): 274–283.
[11] Abelsson A. Learning through simulation. Disaster Emergency Med J 2017;3(2): 125–8.
[12] Engström G, Angrén J, Björnstig U, Saveman B-I. Mass-casualty incidents in the underground mining industry: the Haddon's matrix applied on an integrative literature review. Disaster Med Public Health Prep 2018;12(1):138–46.
[13] Bealko S, Alexander D, Chasko L, Grayson R. Mine rescue training facility inventory – compendium of ideas to improve US coal mine rescue training. Trans Soc Min Metall Explor 2011;328:517–24.
[14] Santos-Reyes J, Beard A. An analysis of the emergency response system of the 1996 Channel tunnel fire. Tunnel Underground Space Technol 2017;65:121–39.
[15] Karlsson S, Gyllencreutz L, Saveman B-I. The medical perspective on mining incidents. Int J Emergency Services 2019;8(3):236–46.
[16] Alex J, Lundin H, Joansson C, Saveman B-I. Preparedness of Swedish EMS personnel for major incidents in underground mines. J Health Sci 2017;5:239–43.
[17] Swedish Mining Industry's Health and Safety Committee. Occupational injuries and sick-leave in the Swedish mining and mineral industry 2015. Stockholm, Sweden. Swedish Association of Mines, Metal and Mineral Producers. 2016.
[18] Rimstad R, Braut GS. Literature review on medical incident command. Prehospital Disaster Med 2015;30(2):205–15.
[19] Endsley MR. Toward a theory of situation awareness in dynamic-systems. J Human Factors Ergon Soc 1995;37(1):32–64.
[20] Busby S, Witucki-Brown J. Theory development for Situational Awareness in multi-casualty incidents. J Emerg Nurs 2011;27(5):444–52.
[21] Norri-Sederholm T, Kuusisto R, Kurola J, Saranto K, Paakkonen H. A paramedic field supervisoŕs situational awareness in prehospital emergency care. Prehospital Disaster Med 2014;29(2):151–9.
[22] Seppänen H, Mäkelä J, Luokkala P, Virrantaus K. Developing shared situational awareness for emergency management. Saf Sci 2013;55:1–9.
[23] Yin RK. Case Study Research and Applications: Design and Methods. Sixth ed. Thousand Oaks: SAGE Publications; 2018.
[24] Graneheim UH, Lundman B. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. Nurse Educ Today 2004;4(2):105–12.
[25] World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. J Am Med Assoc 2013;20:2191–4.
[26] Aylwin C, König T, Brennan N, Shirley P, Davies G, Walsh M. Reduction in critical mortality in urban mass casualty incidents: analysis of triage, surge and resource use after the London bombings on July 7, 2005. Lancet 2006;368(9554):2219–25.
[27] Hylander J, Saveman B-I, Björnstig U, Gyllencreutz L. (2019). Prehospital management provided by Medical on-Scene Commanders in tunnel incidents in Oslo, Norway – an interview study. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine 2019; 27(78).
[28] Norri-Sederholm T, Paakkonen H, Kurola J, Saranto K. Situational awareness and information flow in the prehospital emergency medical care from the perspective of paramedic field supervisors: a scenario-based study. Scand J Trauma, Resuscit Emerg Med 2015;23(4):1–9.
[29] Karlsson S. Saving Lives During Major Underground Mining Incidents. Becoming Prepared for a Collaborative Response.. Dissertation. Umeå University Umeå: CityPrint i Norr AB; 2020.
[30] Hartley J. Case study research. In Cassell, C., Symon, G. eds., Essential guide to qualitative methods in organizational research. London: Sage Publications Ltd, 2004, p. 323–333.