Medical incident commander leadership during a full-scale exercise in an underground mining environment: a qualitative single-case study

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Abstract: Swedish underground mines are constantly improving their safety. However, major incidents still occur, and the extreme environment poses challenges during rescue operations. The aim of this study was to evaluate prehospital medical management during a full-scale exercise in an underground mine in order to gain knowledge on the leadership and decision-making of the medical incident commander. We used a qualitative single-case study design following a full-scale exercise that included emergency medical services (EMSs), rescue services, and a mining company. The exercise was documented through on-site observation notes, audio recordings, and video recordings, all of which were written out as text and analysed using qualitative content analysis. The results showed that few decisions were made, and without all available medical information, and that they were made by others than the medical incident commander. This resulted in a delay in decision-making, in vital treatment, and in transport of patients from the site. Clearer leadership and more active decisions might have resulted in a different outcome for the injured parties.

Keywords: decision-making; disaster; extreme environment; mining environment; medical leadership; full-scale exercise; case study.

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1 Introduction

In Sweden there are nine underground mines in which the work takes place under the surface in complicated dark environments and with steep passages, and this presents many challenges during a rescue operation.

One particular challenge, critical to the patient's survival, is the time between injury occurrence and the appropriate care at a hospital. Based on the patient's injuries, this could be more or less than 1 h (c.f. golden hour). It is therefore critical that the emergency service personnel quickly assess the injured and identify those in need of immediate transport to hospitals (National Association of Emergency Medical Technicians, 2014). However, in the extreme environment of an underground mine, often located in a rural area, it can take a long time for the emergency services to reach the mine and the site of the incident. Although the rescue service and emergency medical service (EMS) are located close to the mine, the rescue could still be extensive, as seen during the Quecreek incident in which the rescue took 72 h (Frank, 2002). Thus, mining company personnel might not be rescued for an extended period of time.

Mining companies constantly work to improve safety conditions for their employees in order to avoid incidents that are often caused by vehicles, fires, or rock falls. However, working in an underground mine still is an occupation associated with significant risk for injury, as well as a general increased risk for major incidents and disasters compared to other occupations (Engström et al., 2018).

In some countries, if a major incident occurs, the mining industry has their own mine rescue teams that provide advanced medical care to injured persons (Lehnen et al., 2013). In other countries, the mining industry and the emergency service organisations must support each other and collaborate because, no single organisation possesses all the relevant information and resources to resolve the problem on its on (Karlsson et al., 2017, Kristiansen et al., 2019). Thus, major incidents put high demands on leadership (Lennquist and Lennquist Montán, 2017) and on what decisions and within what timeframe decisions are made by the leaders (Gyllencreutz et al., 2020).

There are several different medical management systems for major incidents (National Board of Health and Welfare, 2009; Mackway-Jones, 2012), and they all support principles that help effectuate a rapid and coordinated rescue response in specific situations. This is done by having standardised actions for management functions, mostly including clear communication and accountability (Rüter et al., 2013). A common framework for the Swedish EMS is that the first ambulance crew that arrives establishes the prehospital medical management on site, comprising the Medical Incident Commander (MIC) and the Ambulance Incident Commander (AIC) (Lennquist, 2009; Nilsson and Örtenwall, 2009). The AIC is responsible for the overall EMS operation, including collaborating with the commanders of the other emergency services, ensuring the safety of EMS personnel, and handling resources and communication both internally and externally. The MIC is responsible for the medical care provided at the incident site, for example, triage, as well as for the evacuation and transportation of patients to the hospital (Nilsson and Örtenwall, 2009). A summary of the AIC and MIC's responsibilities are presented in Figures 1 and 2.

Figure 1 The MIC's responsibilities during a major incident

- Create an inventory of casualties
- Provide the AIC with medical information in order to make decisions
- Establish the level of medical ambition, sot that no unnecessary resources are put where it is not needed
- Be responsible for triage
- Provide instructions and directions for treatment to the ambulance teams
- Make sure the patients are being transported from the site and to adequate health care institutions
- Document the incident

Medical management at the incident site requires the leaders (the MIC and AIC) to direct other ambulance personnel, rescue services, and police on how patient-related work is to be prioritised (Gunnarson and Warrén Stomberg, 2009). Emergency medical service personnel have been found to perceive the prehospital medical management role as difficult (Aléx et al., 2017; Karlsson et al., 2019). Furthermore, if prehospital medical management fails on site, EMS personnel will not receive relevant information or will be assigned irrelevant duties, which can result in devastating outcomes in terms of mortality and morbidity (Contino, 2004; Lennquist, 2007).

Figure 2 The AIC's responsibilities during a major incident

- Park as close to the incident location as possible
- Leave sirens and warning lights turned on
- Give a "through-the-window-report" (METHANE) to dispatch center
- Ensure trustful cooperation with the MIC
- Put on leadership-vest
- Start making notes
- Perform a general assessment and make goals for the medical ambition together with the MIC
- Provide the dispatch center with a complete METHANE report
- Make an inventory of resources needed and be responsible for transport
- Cooperate with rescue services and police
- Identify an appropriate placement for ambulance vehicles and an assembly point for casualties

Exercises are performed in order to increase individual and organisational preparedness for major incidents by creating a response practice and thus reducing the risk of errors (Swedish Civil Contingencies Agency, 2010; Miller, 2016). During both realistic table-top and full-scale exercises it is possible to evaluate and identify knowledge gaps and deficiencies in the current practices, thereby providing an opportunity to change the organisational practice (Swedish Civil Contingencies Agency, 2010) and increase learning (Karlsson et al., 2020).

The prehospital medical management on site can be evaluated through different criteria (Mackway-Jones, 2012) and protocols (Gryth et al., 2009). However, these criteria and protocols seldom take into consideration incidents that take place in extreme environments or in sparsely populated areas. There is a lack of evaluating research centred on medical organisational performance. Therefore, more knowledge on prehospital medical management at these types of incident locations is needed.

The aim of this study was to evaluate prehospital medical management during a full-scale exercise in an underground mine in order to gain knowledge on the leadership of the MIC.

2 Materials and methods

2.1 Design

This study had a qualitative single-case study design, which is appropriate for gaining an in-depth understanding of a phenomenon in its real-life context (Hartley, 2004).

2.2 Description of the context – Exercise development and scenario

A full-scale exercise took place in 2018 at an underground mine in Sweden as part of another project with the overall aim to improve collaboration between the participating organisations and to develop an educational program. The scenario for this full-scale exercise was set up by representatives from Umeå University, the EMS, the rescue services, and the mining company. The representatives' diverse competences improved the credibility of the scenario and made it possible to create a realistic scenario of a vehicle fire 360 m below ground. Seven live persons were used to act as the victims. Two of the persons, who were pretending to be seriously injured, were positioned in each underground rescue chamber. The types of injuries in the scenario represented realistic types of trauma in relation to the scenario, e.g., fractures, internal bleeding, burn injuries, and smoke inhalation injuries. The participants knew the date of the exercise but received no further information in advance. All personnel acted in their normal professional role and were familiar with what should to be done according to their disaster plan and treatment guidelines.

2.3 Data collection and analysis

The full-scale exercise was recorded with both audio and video devices. Four cameras and one microphone were placed in the command centre, and audio and video recording devices were placed on the AIC and MIC. The rescue chambers were equipped with GoPro cameras. On-site observations were also performed and produced content-rich field notes. The on-site observations were performed by one observer (the second author) who followed the MIC very closely but without disturbing the exercise. The observer continuously noted what the MIC did and how he did it. The observer wrote down as much as possible during the exercise with the aim of describing the role of the MIC. The closeness to the participant made it possible to gain very rich descriptions in the field notes. Field notes were also taken from a group evaluation that, was performed directly after the exercise.

The different types of data collection ensured internal consistency because what was observed and noted in the field notes could be verified in the audio and video recordings and vice-versa. To increase confirmability, the authors also discussed inconsistencies throughout the analysis in order to reach consensus.

The combination of records also made it possible to take a quantitative approach by analysing the timestamps of all activities regarding medical management. For this analysis, the Performance Indicators Protocol developed by Gryth et al. (2009) was used. This protocol provides the correct actions to be taken within a timeframe that supports the victim rescue process. The indicators ($n = 11$) mainly concern the work done by the AIC but summarise the entire medical management during the exercise. Points are scored for practical indicators as well as for indicators for good cooperation. The scores of 0, 1, or 2 are based on the level of fulfilment of each process indicator. A score of 0 indicates that the standard was not met, 1 indicates that the standard was met but not with adequate content or not within the specified timeframe, and a score of 2 indicates the correct performance within the correct timeframe (Gryth et al., 2009). The second author performed the analysis and scored the performances for all 11 indicators based on the information derived from the video recordings and if necessary confirmed by the audio recordings and/or the observational notes. These are presented as Quality Indicators in the first part of the results.

The field notes and audio recordings were transcribed verbatim into text and analysed according to their content (Graneheim and Lundman, 2004; Kohlbacher, 2006).

First, the text was read through several times to gain an impression about what the text contained, and then the text was divided into meaning units. Several meaning units describing the same content were sorted into codes, and the codes were then gathered and deductively sorted into the criteria for the MIC's function (Figure 1) as described in the Major Incident Medical Management and Support (MIMMS) concept (Mackway-Jones, 2012). The MIMMS is a universal concept developed in Great Britain and concerns, as its name indicates, strategies for medical command during a major incident with multiple casualties. Sweden adopted the concept and modified it to Swedish conditions, and all Swedish EMS personnel are educated in the concept (Rüter et al., 2004). The results of the content for each MIC criterion are described in the second part of the results section.

2.4 Ethical considerations

In accordance with the Helsinki Declaration (World Medical Association, 2013), all participants in the full-scale exercise were informed in writing about the aim of the study and the evaluation methods (i.e., video, audio, and on-site observations). They received an email with a consent form to fill out and return to the research group. The participants participated of their own free will and had no dependency on the researchers. The text used in the analysis was anonymised so that no one from the exercise can be identified. During and after the exercise, attention was paid to see if any of the participants might start to physically or psychologically react and if so to ensure that all involved organisations had plans to take care of them afterwards.

3 Results

At 7:50 a.m., the alarm went off and the first ambulance arrived on site at 8:34 a.m. to assume their roles as AIC and MIC. They immediately established contact with the rescue service commander and began formulating a picture of what had happened.

First, the results from the quality indicator protocol will be described. Next, the results from the MIC's efforts during the exercise and the responsibilities listed in the MIMMS will be described. Finally, because communication is common to all responsibilities in the MIMMS, the results concerning communication will be summarised.

3.1 Quality indicators

The scoring of the AIC and MIC from the quality indicator protocol is shown in Table 1. They scored 12 out of 20 possible points. Points were lost for not repeating updates of the strategic command and for not accomplishing four tasks within the allotted time, such as evacuating the first patient. The protocols state that transport should begin within 15 minutes after the first ambulance arrives with the AIC and MIC, but from the observation notes it is clear that, no other ambulance teams had arrived at the assembly point within that time, thus making transport impossible.

Table 1 Observation protocols

No.	*Performance Indicators*	*Standard* (*timeframe in minutes from arriving at the scene*)	*Score* *2: Done on time* *1: Done, but not on time* *0: Not done*
1	Putting on a vest	Directly	2
2	First report to dispatch	2 min	2
3	Content of first report	METHANE (major incident, exact location, type of incident, hazards, accessibility, number of casualties, emergency services)	2
4	Formulate guidelines for response	3 min	1
5	Establish contact with strategic level of command	5 min	1 (after 8 min)
6	Liaison with fire brigade and police	5 min	2
7	Second report from scene	10 min	0
8	Content of second report	Verifying first report	0
9	Establish level of medical ambition	10 min	1 (decision was made after 23 min)
10	First patient evacuated	15 min	1 (first patient transported after 112 min)
11	Information to media on the scene	30 min	(this was not exercised)
		Total	12 out of 20 (points for medial contact excluded due to not being practiced during the exercise) (Approval level >11pts)

3.2 MIMMS criteria

3.2.1 Inventory of casualties

The observation notes revealed that there was no active request for information regarding casualties. However, on several occasions during the exercise information was delivered through the radio about the medical status of casualties from the mining personnel and the ambulance teams at the assembly point. With that information, the number of casualties and their priority according to triage were quickly determined and an inventory was completed. The inventory of casualties was not communicated in a clear way, and it was difficult to get an overview of how many casualties there were. This resulted in a momentary discrepancy between the MIC and AIC concerning the inventory of casualties. The observation notes did not reveal the exact moment that this discrepancy was corrected. However, as seen in the notes from the post-exercise evaluations, the inventory was clearer toward the end of the exercise.

3.2.2 Providing medical information to make decisions

Medical information came from communication with both injured and non-injured mine workers in the rescue chambers. During the first 58 min, communication was made by the mine commander, and the medical decisions were based on this information. The first piece of information was that there was a more severely injured mine worker in one of the rescue chambers than in the other rescue chamber. This information was relayed to the MIC upon arrival.

When direct contact with the mine workers in the chambers was established by the MIC, few questions regarding the medical status were raised. However, the information indicated that there had to be a shift in prioritising the injured mine workers because the medical status of one of the mine workers had deteriorated.

The information about shifting priority was not communicated further. The rescue decision therefore did not include all of the medical information that was available. It is also unclear who made the final decision regarding which of the injured should be rescued first. The observation notes showed that the gathered medical information could have led to a different prioritisation of the injured mine workers in the rescue chambers.

Another decision requiring medical information would be the decision for the ambulance personnel to go down in the mine to a point as close as possible to the injured persons, but safe enough for the ambulance personnel, i.e., at least outside of smoke-filled areas. The aim of this would be to get the treatment closer to the injured. However, the decision to go down into the mine was not based on medical information nor was it communicated, resulting in a decision being made without support.

3.2.3 Establishing the level of medical ambition

In order to make sure that no unnecessary resources are employed where they are not needed, it is important to establish a level of medical ambition. The decision was to keep medical interventions at a ‘normal level’ aboveground, but those injured underground needed to be evacuated before any normal level of intervention could be provided.

3.2.4 Responsibility for triage

Triaging in the rescue chambers came from the information given by mine workers to the mine commander via radio, and this resulted in the injured underground being marked as red priority (in need of immediate care). Triaging at the assembly point was not directly ordered from the MIC, but was still performed by some personnel on site. The triage generated four green priorities (care can wait more than 2 h) and one yellow priority (to be cared for within 2 h). Triage sorting followed 13 min later and resulted in three red and two green priorities, pursuant to the guidelines set by the planning committee of the exercise. The results from this triage were then reported to the MIC via radio. This resulted in the decision to treat and transport the red patients at the assembly point first.

3.2.5 Instructions for treatment

No discussion or instructions to the ambulance crew regarding treatment were revealed. However, two ambulance teams together with a helicopter crew including a physician treated the injured on site at the assembly point. The physician made most of the medical decisions and determined what treatment the injured would receive without communication to the MIC prior to the decisions.

No discussion about treatment took place with the ambulance crew who went down into the mine to get as close as possible to the injured mine workers. This resulted in the treatment recommended for inhalation injuries, such as a Cyanokit (Hydrokobalamin), not being brought underground. All injured persons were treated with oxygen, one was treated at the assembly point with Cyanokit (Hydrokobalamin), and one was treated via inhalation of short-acting beta-receptor agonists.

3.2.6 Transport

The first injured person was transported from the assembly point 112 min after the first ambulance arrived on site, and the assembly point was cleared of patients at 137 min. Further information about the transport of the injured mine workers is summarised in Table 2.

No transport leader at the assembly point was selected, which forced other personnel to make decisions about transportation. For example, the physician decided that the transport of one of the most severely injured should go to the nearest university hospital in order to obtain the right level of care on the first go, despite being a longer transport time, instead of going to the nearest hospital (30 min compared to 5 min). The MIC was informed of this decision via radio and agreed to it being an adequate plan.

In addition to not having a transport leader, the ambulance crew at the assembly point felt insecure about making transportation decision. They did not know how many injured would come out from the mine with the rescue services or when they would arrive. Therefore, in this decision they sought help from the MIC, who decided on further transports as soon as more ambulances arrived.

Altogether, all patients were transported, or had a plan to be transported from the scene, and no deaths were reported.

3.3 Communication disrupting decision-Making

Communication was seen as a problem rather than a foundation for making decisions, and there was so much traffic on the different radio channels that medical decision-making was frequently disrupted. For example, the MIC communicated with the AIC, other ambulance teams, the rescue service commander, the mine commander, and the mine workers in the rescue chambers via two types of radio (RAKEL and a mine industry radio). Furthermore, face-to-face communication was also necessary.

Table 2 Injuries, location, and transport of patients in the exercise

Patient no.	*Priority/Injuries*	*Location*	*Means of Transport*	*Time (minutes from the first ambulance arriving)*
1	RED – inhalation of smoke, burn injuries to one arm, circulation unstable	5th rescue chamber, underground	Helicopter to the nearest university hospital	~ 12:00 (206)
2	RED – inhalation of smoke, trauma to the skull, unconsciousness	10th rescue chamber, underground	Ambulance (planned) to the nearest regional hospital	was not exercise, but approximately between 13:00 and 13:30
3	RED – crushing injuries to the face, airway complications, inhalation of smoke	Assembly point for casualties	Helicopter to the nearest university hospital	10:26 (112)
4	RED – central chest pains, inhalation of smoke	Assembly point for casualties	Ambulance to the nearest regional hospital	10:51 (137)
5	RED – inhalation of smoke, decreased consciousness	Assembly point for casualties	Ambulance to the nearest regional hospital	10:51 (137)
6	GREEN – inhalation of smoke	Assembly point for casualties	With mobile medical team to the nearest healthcare centre	10:35 (121)
7	GREEN – inhalation of smoke	Assembly point for casualties	With mobile medical team to the nearest healthcare centre	10:35 (121)

4 Discussion

The MIC should function as a leader in order to make sure that the on-scene medical response is suitable in pursuit the goal of helping as many as possible within the shortest possible timeframe. Therefore, decisions should be made to push the response in that direction (Mackway-Jones, 2012). Despite the MIMMS proclaiming that decision-making is a significant part of the MIC's role, the main result of this study indicates that very few decisions were made by the MIC. Furthermore, the results show that decisions were made without all medical information and/or by other personnel, which affected the medical rescue effort.

In the present study, radio communication was described as difficult due to the amount of radio traffic. One decision that suffered from this was concerning personnel going down into the mine. Difficulties in communication are the factor most often described in previous research about management of major incidents (Nagata et al., 2006; Lowes and Cosgrove, 2016; Eklund et al., 2021). Previous literature describes communication problems such as, different agencies use a variety of communication channels, busy radio traffic makes it difficult to communicate, personnel are working in a loud environment and there is unclear communication and a failure to confirm information. Other persons than the leaders handling radio communication might make decision-making easier. However, the question remains as to whom that person should be within the EMS organisation. Another ambulance nurse could assist, but with limited resources a nurse might not always be available. A more comprehensive approach to this issue could be to provide a specific, dedicated medical commander function with specialist education in medical management and communication (Hylander et al., 2019; Hylander et al., 2020).

The present results show that even though a decision was made to go down into the mine, there was still a delay of approximately 90 min before vital treatment could be provided to the injured personnel needing inhalation medication. The guidelines say that the Cyanokit should be administered as soon as possible after burn and smoke inhalation (Swedish Poisons Information Centre, 2017), and the present results indicate that this would have been possible upon first contact with the injured. Because getting treatment closer to the injured would be the reason to go down into the mine, it is not clear why they decided not to treat the patient with the Cyanokit there. It is possible that an earlier discussion regarding treatment, even from the start of the exercise, might have led to the Cyanokit being brought down into the mine and the injured getting the treatment sooner.

In the present results, the MIC was not informed beforehand about decisions made regarding treatment for the injured at the assembly point. These decisions were made by the physician arriving at the scene by helicopter. The ambulance crew at the assembly point expressed uncertainties in leadership, and this might be an indication of a lack of leadership. Härgestam et al. (2016) show that when communication varies, as is the case with ambiguity, teamwork suffers. Further, they also describe that when the leader has control, other members in the trauma team gain a sense of control of their roles and tasks. It is important, though, to point out that not only personal factors influence leadership and decision-making. External factors such as expectations, insufficient information, and collaboration problems also complicate leadership and decision-making in the prehospital setting (Gunnarsson and Warrén Stomberg, 2009).

In the present results, the transport of the injured was delayed due to no ambulance arrived at the assembly point until 20 min after the first ambulance. Because this exercise was carried out in an extreme environment and in a rural area, it would not have been possible to reach the assembly point within the allotted time of 15 min, which represents the current quality indicator (Gryth et al., 2009). Notably, the first injured miner was not transported from underground until 137 min after the arrival of the rescue services (Table 2). Thus, this is clearly an unrealistic quality indicator in this mining environment meaning that there is a need for more appropriate indicators for this kind of extreme environment. Another reason for delayed transport seen here was a lack of decision-making. Appointing one person to assume responsibility for decisions regarding transport, which is recommended in the MIMMS (Mackway-Jones, 2012), might have resulted in earlier evacuation of the injured, at least from the assembly point. Early evacuation has been proven to positively improve the outcome for critically-ill persons (Driscoll and Kent, 1999; Enright et al., 2016).

Many lessons can be learned from our results concerning this exercise. Several exercises are required to increase the capacity of managing major incidents (Laere and Lindblom, 2019), and it is therefore recommended that the Swedish EMS participate in exercises like the one in this study. This could be compared with what Stjerna Doohan et al. (2019) describe regarding the importance of participating in planning and participating in major incidents in extreme environments. All in all, to gain the tools necessary for management, medical leadership and critical decision-making need to be established in the event of a real incident in the mining environment.

4.1 Methodological considerations

A strength of this study is the use of different data collection strategies that increase internal consistency and can be used as a source for validation of the field notes. If some information seemed to be missing in the field notes, it was sought in the video or audio recordings, and vice-versa, to get the best overview possible. Although some researchers may argue for the weaknesses of qualitative single-case studies, they enhance the unique elements and enable the manifestation of a phenomenon (Hartley, 2004, Yin, 1981, 2014), and the results can be transferred to similar contexts (Graneheim and Lundman, 2004). The methods used were effective in gaining the knowledge pursued by the study.

5 Conclusions

Lessons learned from exercises such as the one described in this study can lead to organisational improvements. Good leadership and adequate decision-making are critical when facing a major incident. In a context where collaboration is needed, the medical commander function must take responsibility for the medical perspective in collaborative decisions. This study indicates that specific competence in communication and decision-making is of importance for this to happen. Practicing in an extreme environment enables the EMS medical response to improve their capacity during a real major incident.

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References

Aléx, J., Lundin, H., Joansson.C. and Saveman, B-I. (2017) 'Preparedness of Swedish EMS personnel for major incidents in underground mines', *Journal of Health Science*, Vol. 5, No. 5, pp.239–243.

Contino, D.S. (2004) 'Leadership competencies: knowledge, skills, and attitudes nurses need to lead organizations effectively', *Critical Care Nurse*, Vol. 24, No. 3, pp.52–64.

Driscoll, P. and Kent, A. (1999) 'The effect of scene time on survival', *Trauma*, Vol. 1, pp.23–30.

Eklund, A., Saveman, B. and Gyllencreutz, L. (2021) 'Situational awareness during a full-scale exercise in an underground mine: a qualitative single-case study of the ambulance incident commander', *International Emergency Nursing*, Vol. 54, pp.100950, https://doi.org/10.1016/j.ienj.2020.100950

Engström, K.G., Angrén, J., Björnstig, U. and Saveman, B-I. (2018) 'Mass casualty incidents in the underground mining industry: applying the Haddon matrix on an integrative literature review', *Disaster Medicine and Public Health Preparedness*, Vol. 12, No. 1, pp.138–146.

Enright, C.A., Harman, C.S. and Brune, J.F. (2016) 'Advanced life support in the mining environment', *Paper Presented at the Society of Mining, Mettalurgy and Explorating Annual Conference and Exhibition*, February, Phoenix, AZ, pp.749–752.

Frank, I.C. (2002) 'Miracle of the miners: the quecreek rescue from an ED perspective', *Journal of Emergency Nursing*, Vol. 28, No. 6, pp.544–548.

Graneheim, U.H. and Lundman, B. (2004) 'Qualitative content analysis in nursing research; concepts, procedures and measures to achieve trustworthiness', *Nurse Education Today*, Vol. 24, pp.105–112.

Gryth, D., Rådestad, M., Nilsson, H., Nerf, O., Svensson, L., Castrén, M. and Rüter, A. (2009) 'Evaluation of medical command and control using performance indicators in a full-scale, major aircraft accident exercise', *Prehospital and Disaster Medicine*, Vol. 2, No. 25, pp.118–123.

Gunnarson, B.M. and Warrén Stomberg, M. (2009) 'Factors influencing decision making among ambulance nurses in emergency care situations', *International Emergency Nursing*, Vol. 17, No. 2, pp.83–9.

Gyllencreutz, L., Rådestad, M. and Saveman, B. (2020) 'Templates for handling multi-agency collaboration activities and priorities in mining injury incidents: a Delphi study', *International Journal of Emergency Services*, Vol. 9, No. 3, pp.257–271.

Härgestam, M., Hultin, M., Brulin, C. and Jacobsson, M. (2016) 'Trauma team leaders' non-verbal communication: video registration during trauma team training', *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, Vol. 24, No. 37, pp.1–10.

Hartley, J. (2004) 'Case study research', in Cassell, C. and Symom, G (Eds.): *Essential Guide to Qualitative Methods in Organizational Research*, Sage, London, pp.323–333.

Hylander, J., Saveman, B., Björnstig, U. and Gyllencreutz, L. (2020) 'Senior ambulance officers in Swedish emergency medical services: a qualitative study of perceptions and experiences of a new management role in challenging incidents', *BMJ Open*, Vol. 10, No. 12, pp.e042072–e042072, https://doi.org/10.1136/bmjopen-2020-042072

Hylander, J., Saveman, B-i., Björnstig, U. and 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*, Vol. 27, No. 78, pp.1–7.

Karlsson, S., Gyllencreutz, L., Engström, G., Björnstig, U. and Saveman, B-I. (2017) 'Preparedness for mining injury incidents: interviews with Swedish rescuers', *Safety Science Monitor*, Vol. 1, No. 29.

Karlsson, S., Saveman, B., Hultin, M., Eklund, A. and Gyllencreutz, L. (2020) 'Expansive learning process of exercise organizers: the case of major fire incident exercises in underground mines', *Sustainability*, Vol. 12, No. 14, pp.5790.

Karlsson, S., Saveman, B-I. and Gyllencreutz, L. (2019) 'The medical perspective on mining incidents: interviews with emergency medical services (EMS) personnel', *International Journal of Emergency Services*, Vol. 8, No. 3, pp.236–246.

Kohlbacher, F. (2006) 'The use of qualitative content analysis in case study research', *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, Vol. 7, No 1.

Kristiansen, E., Håland Johansen, F. and Carlström, E. (2019) 'When it matters most: collaboration between first responders in incidents and exercises', *Journal of Contingencies and Crisis Management*, Vol. 27, No. 1, pp.72–78.

Laere, J. and Lindblom, J. (2019) 'Cultivating a longitudinal learning process through recurring crisis management training exercises in twelve Swedish municipalities', *Journal of Contingencies and Crisis Management*, Vol. 27, pp.38–49.

Lehnen, F., Martens, P.N. and Rattmann, L. (2013) 'Evaluation of European mine rescue and its need for internationalization', *Fourth International Symposium Mineral Resources and Mine Development, Aachen International Mining Symposia*, RWTH Aachen University, Institute of Mining Engineering I, Germany, pp.175–186.

Lennquist, S. (2007) 'Management of major incidents and disaster: an important responsibility for the trauma surgeons', *Journal of Trauma*, Vol. 62, No. 6, pp.1321–9.

Lennquist, S. (2009) 'Sjukvårdsinsats i skadeområde [Medical response at the incident site]', in Lennquist, S. (Eds.): *Katastrofmedicin [Disaster Medicine]*, 3rd ed., Liber, Stockholm, pp.81–102.

Lennquist, S. and Lennquist Montán, K. (2017) 'Händelser med många skadade [Mass-casualty incidents]', in Lennquist, S. (Eds.): *Traumatologi [Traumatolog]*, 2nd ed., Liber, Stockholm, pp.563–598.

Lowes, A.J. and Cosgrove, J.F. (2016) 'Prehospital organization and management of a mass casualty incident', *BJA Education*, Vol. 16, No. 10, pp.323–328.

Mackway-Jones, K. (2012) *Major Incident Medical Management and Support the Practical Approach at the Scene/Advanced Life Support Group* [online], Blackwell, Publishing Ltd., http://healthindisasters.com/images/Books/Major-Incident-Medical-Management-and-Support-Third-Ed.pdf

Miller, K.T. (2016) 'Emergency medical services scene management', in Koenig, K.L. and Shult, z.C.H. (Eds), *Koenig and Shultz's Disaster Medicine Comprehensive Principles and Practice*, Cambrideg University Press, Cambrigde, pp.321–329.

Nagata, T., Rosborough, S.N., VanRooven, M.J., Kozawa, S., Ukai, T. and Nakayama, S. (2006) 'Emergency medical preparedness and response to a Singapore airliner crash', *Prehospital Disaster Medicine*, Vol. 21, No. 5, pp.345–52.

National Association of Emergency Medical Technicians, U.S. (Naemt) (Eds (2014) *PTHLS. Prehospital Trauma Life Support*, Jones and Bartlett Publishers, Inc., Burlington.

National Board of Health and Welfare (2009) 'Föreskrifter för ambulanssjukvård [Regulations for ambulance care]', *SOSFS 200*9, p.10.

Nilsson, H. and Örtenwall, P. (2009) 'Ledning av sjukvården på olika nivåer '[Medical management at dirrerent levels]', in Lennquist, S (Eds.): *Katastrofmedicin* [*Disaster Medicine*], Liber, Stockholm. pp.185–198.

Rüter, A., Kurland L., Ahmadreza, S., Rådestad, M. and Gryth, D. (2013) 'Evaluation of disaster preparedness based on simulation exercises, the comparison of two different models', *Prehospital Disaster Medicine*, Vol. 28, p.87.

Rüter, A., Nilsson, H. and Wikström, T. (2004) 'Prehospital sjukvårdsledning-en konceptutbildning med certifiering [Prehospital management-a certified training concept*]'*, *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, Vol. 12, pp.148–149.

Stjerna Doohan, I., Saveman, B-i. and Gyllencreutz, L. (2019) 'Limited medical perspective at a strategic level in relation to mass casualty incidents in Swedish tunnels', *International Journal of Emergency Management*, Vol. 15, No. 4, pp.360–374, https://doi.org/10.1504/IJEM.2019.104205

Swedish Civil Contingencies Agency (2010) *Handbok Utvärdering Av Övningar* [*Manual for Evaluation of Exercises*], Swedish Civil Contingencies Agency, Karlstad.

Swedish Poisons Information Centre (2017) *Brandrök [Fire Smoke]*, https://giftinformation.se/lakare/substanser/brandrok (Accessed 20 February, 2021).

World Medical Association (2013) 'World medical association declaration of helsinki: ethical principles for medical research involving human subject', *Journal of the American Medical Association*, Vol. 310, No. 20, pp.2191–2194.

Yin, R.K. (1981) 'The case study crisis: some answers', *Administrative Science Quarterly*, Vol. 26, No. 1, pp.58–65.

Yin, R.K. (2014) *Case Study Research, Design and Methods*, 5rd ed., Sage, Thousand Oaks, CA.