Communication in sudden-onset major incidents.

Patterns and challenges.

A scoping review.

Faculty of Health Sciences

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STAVANGER ……..

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Preface

My first knowledge of the master in prehospital critical care at University of Stavanger was through a native Norwegian colleague working in Danish Air Ambulance, who told me about this course he was going to attend. It sounded very intriguing and fit perfectly with my long-lasting interest in prehospital emergency medicine and with what I had been doing for so many years. I applied and was accepted for the part-time course in 2018 and it has been a truly joyful journey for me to attend the modules in Stavanger and unfortunately but necessarily on-line due to the Covid pandemic. Those trips to Stavanger along with the people from all over the world have been so inspiring and something I was really looking forward to.

At the February 2021 module in major incidents, I came to realize that my master's thesis should be on major incidents. Having experienced some major incidents and one large-scale over the years, the course directed by Marius Rehn convinced me that this was my primary interest.

Marius accepted to become my supervisor on the thesis, and I started working on a case report from a tragic Danish major incident from 2019. Communication issues were a matter of concern in that incident, and therefore, we published a case report in Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine. Further, I decided to investigate communication in major incidents in a broader perspective by means of a scoping review.

Marius, you have provided invaluable input and support throughout the process. Your expert knowledge on major incidents and your previous work in the field has supported my work substantially. Your scientific and personal skills have made it so easy to work with you. Even though we only got together in real life recently for the 2022 major incidents module, I have felt a personal relationship with you. I am honoured to have been a very small part of the faculty in Oslo for that module.

Per Kristian Hyldmo, the course director; thank you for steering the M-PHCC course through dire straits during the Covid pandemic. It must have been a tough job that you have mastered perfectly. Your enthusiasm and expert knowledge have come to shine during the sessions.

The informal discussions at Ydalir Hotel after hours have always been joyful and your personal concern when I became temporarily incapacitated for one semester touched me very much.

Norwegian Air Ambulance Foundation: the fact that you provide an almost free master's programme is still unique to the world. When I asked my boss for the possibility to attend the M-PHCC, he could hardly believe that NAAF paid for the programme.

My colleagues at Danish Air Ambulance have always been very enthusiastic about my M-PHCC and the progression. Especially Lars Greve-Wilms with his expert knowledge on TETRA radios. Sanne Bjerre, Trond Nuland Fedoq and Knud Jepsen for the trips to Stavanger and socializing during time-off.

Finally, and foremost, my family. My beautiful wife, Kristina; Thank you for keeping it all together, for your stamina and love. You have always been there for me and supporting my everlasting quest to become just a little bit wiser. My beloved children: Johanne, Mikkel and Jakob. You make me so proud every day and you are the apples of my eye. There is nothing I would not do for you little ones.

The more I work and practice, the luckier I seem to get

Gary Player

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Abstract

Major incidents and disasters are rare occurrences that challenge society and health care systems substantially. The mobilization of extraordinary resources calls for robust preparedness plans, regular training and funding. Command & control is essential in major incident management. To achieve, maintain and execute command & control, communication within emergency medical services and between authorities involved in major incident and disaster management is paramount.

The main aim of the master thesis is to explore communication between emergency medical services professionals in sudden-onset major incidents in a broader perspective. The thesis focuses on previous patterns and challenges in communication to provide policymakers with data for the improvement of future major incident preparedness. A scoping review of existing scientific and non-indexed literature describing communication in sudden-onset major incidents provides the sources of information in the thesis.

Based on the included literature, this scoping review has found that the patterns in major incident communication are frequent breakdown with potential and actual consequences for patient survival, outcome and management and for the expedited return to a normal state. The challenges in major incident communication are predominantly inter-authority communication difficulties, system overload and lack of introduction and training in the use of communication devices. Cross-border incidents challenge communication substantively.

The scoping review has shown that focus has been on describing the operational and tactical approach in sudden-onset major incidents and that communication challenges have not been assessed systematically. A general agreement that communication has been challenging exists; however, it remains mainly unquantified and improvised means of communication have been used extensively.

Abbreviations

ACRM: Aeromedical Crew Resource Management

CAD: Computer Aided Dispatch

CRED: Centre for Research on the Epidemiology of Disasters

EHAC: European HEMS & Air Ambulance Committee

EMCC: Emergency Medical Communication Centre

EM-DAT: Emergency Events Database

EMS: Emergency Medical Services

EU: European Union

EUPHOREA: European Pre-Hospital Research Alliance

HEMS: Helicopter Emergency Medical Services

ILCOR: International Liaison Committee on Resuscitation

LOE: Level of Evidence

MI: Major Incident

MIMMS: Major Incident Medical Management Support

PCC: Population, Concept, Context

PICO: Population, Intervention, Comparison, Outcome

PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analysis

PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analysis Extension for Scoping Reviews

SA: Situation Awareness

TECC: Tactical Emergency Casualty Care

TEMS: Tactical Emergency Medical Service

UHF: Ultra High Frequency

VHF: Very High Frequency

1. Introduction

1.1 General introduction

Sudden-onset major incidents (MI) may be defined as incidents that require mobilization of extraordinary emergency medical services (EMS) resources (1). Mono- and interdisciplinary communication within and between authorities is essential to acquire, maintain and execute command & control in MI management. The sheer process of creating and sharing information and facts between humans to reach a common understanding is essential.

In MI, chaos may hinder everyday communication routines and challenge the professionals in obtaining essential information about their tasks, risks and their ability to command the team.

Communication breakdown is frequent in MI for various reasons (2, 3) and may have affected patient outcome, safety of personnel and the expedited return to a normal state. Communication in MI has been sparsely quantified until recently in a case report by Hansen et al. (4). This master thesis aims to review current literature on communication in the immediate medical response to sudden-onset MI to improve future MI management.

1.2 Definition of major incidents and disasters

MI and disasters may be defined in several ways. In this master thesis, MI will be defined as an incident that requires the mobilization of extraordinary resources and is identified as a MI in that system (5).

The sheer definition of MI and disaster is hard to embrace and is defined in several ways with only small differences. The main challenge seems to be to grasp the diverse circumstances that encompass the development from an incident into a major incident into a disaster, depending on the dynamics in the accident scene, the availability of resources and the complexity derived from uncontrollable circumstances, e.g., weather phenomena, external threats such as terrorism, lack of resources, local legislation or EMS organization. Furthermore, the presence of non-governmental organizations (6) in MI may further complicate command & control and the management of MI in natural disasters, such as the 2010 earthquake in Haiti (7).

1.2.1 Definition of major incidents

In the Danish major incident management concept REFIL (8), it is stated that an everyday incident such as a road traffic incident, may develop into a major or even more complex incident. Therefore, it is essential that the interdisciplinary MI management reflects on the direction of which an incident may go and if the combined leadership structure may need reinforcement. Thus, the tasks ahead in MI management may demand the establishment of additional leadership functions and additional cooperating agencies. This statement mirrors the dynamics in MI that depend on external and internal factors such as resilience, resources and level of training.

The MI definitions by majorincidentreporting.net (5) and Major Incident Medical Management and Support Courses (MIMMS) (9) focus on the availability of extraordinary resources. Therefore, the geo-political and socio-economic setting is paramount, i.e., an EMS response to road traffic incident in Finland may be standard due to ample resources, whereas the similar injury mechanism may represent a MI in Sudan. In conclusion, a uniform, consensus derived MI definition will ease both management and research in MI in the future.

The applied definition of a MI in this thesis was a result of the assembly of an expert panel that agreed upon a uniform MI reporting style including a definition of MI. Even MI and disaster terminology remains a challenge and a potential bias or limitation in literature search (10). Furthermore, even between Scandinavian countries, definitions vary slightly (11, 12). However, the definitions all carry the same message; a MI is when extraordinary resources are required by the circumstances, but where and how it occurs may vary.

Table 1. Selected major incident definitions

Source	Definition
MI Medical Management and Support Courses [9]	In health service terms a major incident can be defined as any incident where the location, number, severity, or type of live casualties requires extraordinary resources
Danish Emergency Management Agency (REFIL) [8]	Although relatively few major incidents and disasters occur, extraordinary incidents do take place. Some incidents are so severe, extensive, prolonged or complex that they require crisis management
Safety Investigation Act of Finland (SIAF) [11]	An accident which, due to deaths or injuries, the extent of harm incurred by the environment, property or assets, or the nature of the accident, is to be deemed particularly serious
Swedish National Board of Health and Welfare [12]	Special incidents where resources available do not meet the immediate demands, but where redistribution of resources may enable the maintenance of normal levels of quality

1.2.2 Definition of disasters

According to the Red Cross and Red Crescent definition (13), "Disasters are serious disruptions to the functioning of a community that exceed its capacity to cope using its own resources. Disasters can be caused by natural, man-made and technological hazards, as well as various factors that influence the exposure and vulnerability of a community". However, the distinction between a MI and a disaster may also challenge authors of MI literature. One can say that although diverse, the definitions all state that irrespective of where and what society the disaster takes place in, the consequences to government and social life are immense.

Like MI, disaster struggles with a uniform definition (14), complicating research and the sharing of experience in the aftermath for future disaster management, irrespective of their origin and mechanism. Different initiatives (15) to overcome this challenge strive to achieve a common definition. The impact of a lacking common definition has not been scientifically addressed but is believed to obstruct a common understanding.

In different wordings, the various definitions (16-19) all mention that disasters cause both human, material, environmental and economic losses. The European Union Civil Protection Mechanism definition (17) also includes the potential impact of disasters on cultural heritage.

Table 2. Selected disaster definitions

Source	Definition
The Emergency Events Database (EM-DAT) [16]	A situation or event that overwhelms local capacity, necessitating a request at the national or international level for external assistance
European Union: Civil Protection Mechanism [17]	Any situation which has or may have a severe impact on people, the environment, or property, including cultural heritage
UN Office for Disaster and Risk Reduction (UNDRR) [18]	A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts
World Health Organization [19]	A sudden ecological phenomenon of sufficient magnitude to require external assistance

1.3 Classification of major incidents and disasters

1.3.1 Natural MI and disasters

A disaster may develop very quickly, e.g., earthquakes, landslides and hurricanes and therefore, they are characterized as sudden-onset disasters. On the other hand, slow-onset disasters such as droughts develop over a longer period, and therefore have to be categorized and managed in completely different ways. The sudden-onset disasters are events that are more complex since they are unforeseen and requires resilience. In Denmark, Danish Emergency Management Agency issues Risk & Vulnerability analyses (20) regularly, based on fourteen pre-defined types of incidents. Furthermore, early-warning systems are available in relation to weather phenomena. Similar risk assessment analyses are available in e.g., Finland (21) and the majority of World Bank (22) high-income countries.

1.3.2 Man-made MI and disasters

The concept of man-made disasters includes technological disasters that comprises industrial, transport and miscellaneous accidents, such as the Chernobyl (1986) and Fukushima (2011) nuclear accidents and the Beirut port explosion (2020).

1.3.3 Simple MI and disasters

Simple MI and disasters refer to the situation when critical infrastructure such as hospitals, communication systems and transportation are unaffected by the incident itself. Therefore, the MI or disaster response to the MI is not complicated by such circumstances.

1.3.4 Complex MI and disasters

Complex MI and disasters are defined as the situation where infrastructure is either damaged or severely affected because of the incident, e.g., roads closed due to congestion from a transport accident, power loss from fire, deliberate actions to shut down authority communication, etc. Consequently, a simple MI may develop into a complex incident.

1.3.5 Compensated MI and disasters

Compensated MI and disasters are handled according to contingency plans and through the mobilization of extraordinary resources as per the MI definition by Fattah et al. (5) applied in this thesis.

1.3.6 Uncompensated MI and disaster

When the mobilization of all available extraordinary resources is unable to manage the immediate or short-term needs, an uncompensated MI or disaster is happening. Similar to complexity, the definition is dynamic, i.e., when sufficient resources are available, the uncompensated incident may return to a compensated state.

Table 3. Classification of major incidents and disasters

Type of MI and disaster	Characteristics of disaster
Natural	Development varying; e.g. earthquake, landslide, flooding, slow or sudden-onset; simple or complex
Man-made	Technological, transport, sudden-onset; complex
Simple	Infrastructure unaffected
Complex	Infrastructure affected
Compensated	Handled according to contingency plans, sufficient resources
Uncompensated	Insufficent resources

1.4 Epidemiology of major incidents and disasters

1.4.1 Global major incident and disaster epidemiology

In the period 2000 - 2020, data from CRED (23) and EM-DAT (24) indicated that 7 348 disasters inflicted 1.23 million deaths, with more than 4 billion persons affected. The total cost was estimated at 2.97 trillion US dollar. In 2020, 389 natural disasters were reported in EM-DAT, killing 15 080 people, affecting 98.4 million others and costing 171.3 billion USD. The world has seen an increase in reported disasters, which may mirror better reporting or the effects of climate change.

Disasters tend to occur in countries with high-density populated areas such as China and Southeast Asia, that have less sophisticated response resilience compared to Europe and the Western hemisphere in general.

Although transport accidents accounted for 2/3 of all technological disasters, industrial disasters affected 1.4 million people, comprising 64 % of the victims in 5 143 reported technological disasters from 2000-19 (23).

Floods and storms account for the majority of reported natural disasters (25) in the 2000 – 20 period, whereas one third is technological disasters including transport and industrial incidents; the latter accounted for the majority of victims; meanwhile road traffic incidents is ranked one (23) in causes of major incidents.

1.4.2 Scandinavian major incident and disaster epidemiology

Meteorological disasters such as storms and flooding remain main causes for the recorded disasters (23, 25) in Scandinavia, killing fewer than 100 persons and injuring more than 5 000 people. Landslides in Norway and severe forest fires in Sweden have been costly to society and affected thousands of people and caused fatalities. Technological disasters such as the losses of the ferries Scandinavian Star (108) and Estonia (109), killing 1 011 people in total, are among the most spectacular industrial disasters events in recent years along with the capsizing of the Alexander Kielland crew rig in Norwegian sector in 1980 and the crash of a Russian aircraft at Svalbard in Norway in 1996.

However, man-made disasters such as the Oslo/Utøya twin terrorist attack (2,95,116) and several lone terrorist attacks in Denmark, Finland, Sweden and Norway have demonstrated the need for MI preparedness including robust communication systems along with training and experience in MI management. The threats from an active shooter, i.e., a perpetrator not secured by police forces, to rescue personnel and other MI authorities represent a clear and present danger. The TEMS (Tactical Emergency Medical Services) concept is fully implemented in Finland (26) since decades and in Denmark, a TEMS unit is an integrated part of the Copenhagen area physician-manned mobile emergency care units (27), however not disseminated to the rest of the country. In Norway, an interdisciplinary concept to counteract on-going life-threatening incidents (28) is functional.

Apart from these civilian initiatives, special forces within all the Scandinavian countries have specially trained units like the Police Action Force (29) unit in Denmark, using military transport and armed police to engage e.g., active shooters. Cooperation between military and civilian units has historically been challenging as the result of different communication systems and the fact that transportation of the units can be time consuming, seen in a lone terrorist attack in Copenhagen in 2015 against a Muhammed cartoonist and a Jewish synagogue. A recent active shooter incident in a Copenhagen mall was handled very successfully, reassuring the effectiveness of the Copenhagen TEMS (27) concept.

1.5 Response to major incidents and disaster

1.5.1 Guideline for major incident response

EMS organizations are obliged by law to have guidelines for MI response, often derived from government level, e.g., Danish REFIL (8) concept for interdisciplinary MI response and Finnish legislation for preparedness (30) that describes the organization in a MI or disaster. A similar plan for the organization of an incident scene is available in Norway (31). The purpose of the guidelines is to provide the authorities including EMS, police, fire & rescue, military and ad hoc participants with adjuncts to establish and maintain command & control in MI management. Both Danish, Norwegian and most international guidelines rely on the same seven principles (32), which are outlined in table 4.

Table 4. Principles applied in crisis management.

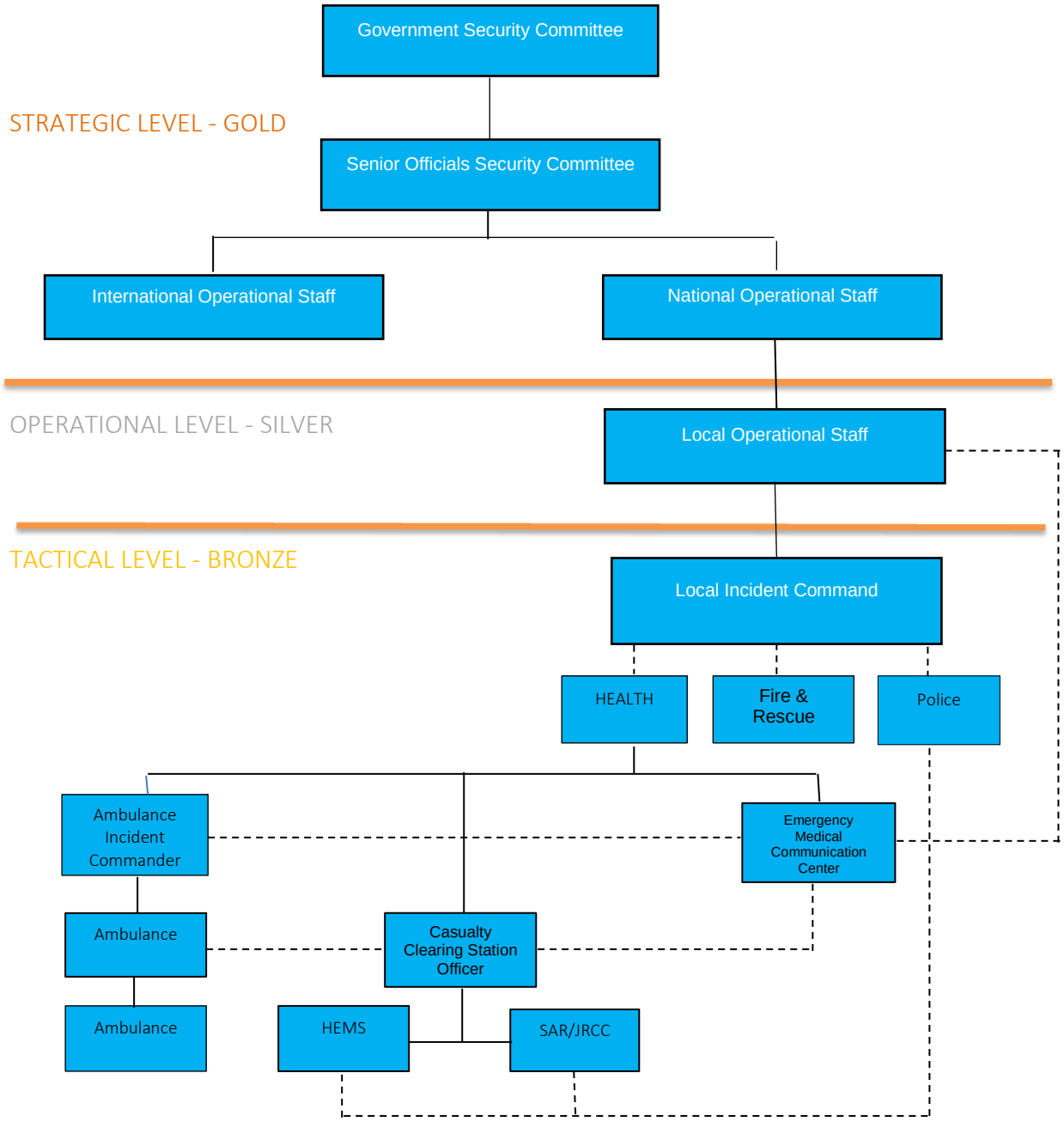
Principle	Actions
Sector-responsibility principle	Agencies responsible for a similar type of incident in a smaller scale will remain responsible in a major incidident
Cooperation principle	Both public services and non-government organizations have a responsibility to cooperate in the rescue effort; i.e. both in the preparedness and incident management phases
Similarity-principle	Organizational structure in major incident management must remain similar to the daily structure
Proximity-principle	Tasks in the major incident management should be undertaken as close as possible to citizens and at the lowest possible organizational level
Flexibility principle	Actions and decisions taken by an major incident authority should be adapted to the current situation, i.e. the task dictates the actions taken
Action principle	In an uncertain situation with insufficient information, major incident management and preparedness should be raised. Every authority is obliged to act
Direction principle	Actions of major incident management should be derived from strategic intentions, e.g. form prepared plans at hand

They represent a framework that is supposed to counteract human factors such as option paralysis, startle effect and decision fatigue for MI commanders, providing detailed information about the tasks and inter-disciplinary cooperation in MI management at the tactical level. Human factors will be elaborated upon later in the thesis.

On the strategic and operational level, authorities are involved in MI management. Danish National Crisis and Major Incident Management System is outlined in figure 1.

Figure 1.

Danish National Crisis and Major Incident Management System. From Hansen et al(4).



HEMS: Helicopter emergency medical service; SAR: Search and rescues; JRCC: Joint Rescue Coordination Center

1.5.2 Guideline for major incident communication

Each EMS, voluntary or similar organization ideally publish and update a guideline for their plan for MI communication. It should be transparent, easy to use and updated to suit current communication technology in use. It should provide a communication grid that encompasses all intra-disciplinary communication within the organization and inter-disciplinary communication between different authorities involved in MI management.

In Denmark, the responsibility to secure the operation and development of the emergency radio communication is in the hands of the Centre of Emergency Communication (CFB) (32, 33), under the Danish National Police. The Danish REFIL (8) clearly describes the communication pathways in MI management and Norway, there are guidelines as well, issued and managed by Norwegian Board of Health (34).

1.5.3 Resilience and counter measures in major incident communication

Obviously, communication in MI is easier for the trained and experienced professional. Therefore, education in the physical use of communication devices is essential for all EMS professionals. As part of the initial training in EMS, the use of communication devices such as radios and digital tablets is mandatory. However, on higher command levels such as medical incident commander, resilience and counter measures may be under prioritized at the cost of medical technical skills, described in a study by Holm (35). Ongoing training and user-friendly interface design of the devices in use may enhance resilience. Still, human factors such as the startle effect (62) described later in the thesis, may compromise MI communication as previously described by this author (4), suggesting the use of technical adjuncts such as forced steering or patching of EMS radios in MI that will be described later in the thesis.

1.6 Research on major incident medical communication

The paramount role of communication in MI should mandate high quality and extensive research in the field. However, that is not the case. This may probably be due to the rare occurrence of MI in general and the challenges of differing definitions and varying terminology even between neighbouring countries and organizations. Therefore, MI

communication has only been sparsely reported in research and generally unquantified apart from a recent case report from this author (4). The literature predominantly consists of case reports and MI evaluations. Consequently, knowledge and research gaps are believed to exist and therefore, MI and disaster management relies on best practice and expert knowledge. The skills of the professionals have been obtained from extensive training, exercises and possibly dissemination of experience from real-time MI or disaster scenarios. Likewise, the transportation of skills acquired during normal operations contribute to MI management skills.

1.6.1 Communication research in general

Medical communication has been the subject of scientific research using various research methods, ranging from systematic scoping reviews (36) to qualitative research (37). Endpoints have not been used and focus has been inter-disciplinary communication competencies, acknowledging the need for communication skills in emergency medicine in a systematic scoping review (36). The need for structured communication skills training has been underlined as an essential skill along with core medical technical and non-technical skills (37). In line with theoretical communication models such as the Shannon-Weaver model described later, Brindley (38) underlines the need for prominent communication skills to establish shared situation awareness (60), described later, and a mental model.

1.6.2 Major incident and disaster medical communication research

The major challenge to MI and disaster research is related to their infrequent occurrence and the option of performing a randomized control trial in MI or disaster scenario, which traditionally was unfeasible or even unethical to carry out. Consequently, high quality research on MI and disaster epidemiology in general and communication specifically is sparse or even non-existing. In the preparations for the thesis, it has not been possible to identify scientific research on the specific topic apart from case reports describing communication difficulties and consensus papers. There is a need to establish unique MI and disaster definitions and terminology ahead of advanced research (39) initiatives other than case reports.

1.6.3 Need for standardized reporting of major incidents

Historically, an important source of MI and disaster epidemiology is the Swedish committee of disaster medicine (KAMEDO) (40), under the direction of Swedish National Board of Health and Welfare. Since 1963, observers have collected data and interviewed professionals involved in MI and disaster management in all parts of the world. In total, 63 KAMEDO reports are published and available from an open-access website.

KAMEDO reports are comprehensive but not systematically structured. The requirements for a scientific report in terms of ethics committee approval, account of missing data, conflicts of interests etc., are not formally addressed and therefore, KAMEDO reports cannot be categorized as scientific work. Nevertheless, they provide valuable information for researchers in MI and disasters (41).

The development of majorincidentreporting.net portal was the ambitious efforts derived from a thesis by Fattah (42), seeking to develop a consensus-based template for reporting of MI. The reporting follows the same structure and addresses all relevant aspects of a MI or disaster. The collaboration has published ten scientific articles (43) and the portal features ten published reports from all parts of the world (44).

However, funding, technical issues and complex legislation on patient confidentiality have challenged MI reporting on the portal. Concerns of whether society preparedness becomes vulnerable when exposing weaknesses in MI management using the portal have also reduced reporting.

Other articles describe templates for post-event medical reporting of essential variables (45) to improve data collection and the ability to make comparisons between various mass-gatherings, comparable to and with the risk of developing into a MI, such as the disaster at Roskilde Festival in Denmark (46), the Love Parade in Duisburg (88) and similar incidents.

1.7 Description of communication in major incidents and disasters

The modes of MI communication may range from verbal exchange of information to sophisticated digital platforms, depending on the geo-political and socio-economic settings

of the MI. Developing countries may be faced with the very simple challenge of access to a reliable, well-functioning communication system or sufficient number of devices. In the other end of the spectrum are high-income countries' EMS organizations that are government funded and utilize encrypted high fidelity and reliability radio systems such as the Terrestrial Trunked Radio (TETRA) (47) standard that most Scandinavian and European police and emergency authorities utilize in MI management.

Communication in MI relies on both human and technological input, interpretation, processing and output of data essential for MI management.

1.7.1 Definition of communication

The definition of communication is difficult. To share information or be in relation with someone do not suffice a definition that should encompass transfer of information and is mirrored by the fact that communication is both an academic discipline and a universal phenomenon. Since this thesis focuses primarily on radio communication in MI, the following will use Claude Shannon and Warren Weaver model of communication (48).

1.7.2 Communication models

The Shannon Weaver (48) model sees communication as a continuum of steps of communication elements such as formation, composition, encoding, transmission and reception of message (See table 5).

Table 5 – Shannon Weaver model of communication.

STEP		ELEMENTS
1.	Formation of communicative motivation	Information source
2.	Message composition	Information source
3.	Message encoding	Information source
4.	Transmission of message	Transmitter
5.	Noise interruption of message quality	Noise source
6.	Reception of encoded message	Receiver
7.	Decoding of message	Destination
8.	Interpretation of message	Destination

The steps are overlapping and influenced by multiple factors, e.g., cultural background, anticipatory expectations and predefined conceptions. Although expanded and amended over time, the Shannon Weaver communication model operates with a simple theory, stating that information is sent from an emitter/sender/encoder to a destination/receiver/encoder (See Table 5). Other researchers (49) have challenged and expanded the model, e.g., the Sender - Message – Channel – Receiver model (See table 6).

Table 6 – Sender – Message – Channel - Receiver model of communication

SENDER	MESSAGE	CHANNEL	RECEIVER
Comm. Skills	Content	Hearing	Comm. Skills
Attitude	Treatment	Seeing	Attitude
Knowledge	Structure	Tasting	Knowledge
Social system	Codes	Feeling	Social system
Culture			Culture

Among theories that are more recent is the Transactional model of communication by Barnlund (50) that states that the sender and receivers are not fixed positions and change roles simultaneously during exchange of information, i.e., exactly what happens during a radio communication.

1.8 Modes of communication

Worldwide, several modes of communication are available for authorities and organizations involved in sudden-onset MI management. In the majority of developed countries, such systems are coordinated at government level, based on legislation and state funding. The dissemination and tradition of non-government and voluntary organizations may be independent of those systems, depending on socio-economic factors and legislation.

1.8.1 TETRA radio communication

The background for the TETRA (47) radio network was a need for interdisciplinary communication between preparedness services and police, across units and potentially borders. The TETRA network was introduced more than twenty years ago and is in some respects outdated in terms of bandwidth, interface design and user-friendliness.

TETRA is comparable to e.g., the GSM (Global system for mobile communications) standard for mobile phones that allows communication irrespective of label and manufacturer. The European Telecommunications Standardizations Institute (ETSI) developed TETRA along with GSM, UMTS (Universal Mobile Telecommunications System), GPRS (General Packet Radio Service) and DMR (Digital Mobile Radio) standards. The system utilizes unique infrastructure for excellent coverage.

1.8.2 VHF communication

Very High Frequency (VHF) (51) is a widespread system, which utilizes the radio frequency electromagnetic waves from 30 to 300 Megahertz (MHz). The VHF system is a network of radio base stations and repeater sites throughout an area. Communication is possible through mainly line-of-sight propagation. VHF is in use for two-way land; marine and aircraft mobile radio systems, such as walkie-talkies, ships and aviation communication devices. Worldwide, frequencies are divided into subparts, dedicated for special use, e.g., marine, aviation and amateur radio utilization.

1.8.3 UHF communication

Ultra-High Frequency (UHF) (52) is a system for on-site radio communications. The UHF system provides local radio coverage at incident sites utilizing UHF mobile radios, fitted to vehicles and handheld radios. The 300 to 3 000 MHz radio waves provide the foundation for the UHF system that is more dependent of the line-of-sight propagation and limited by less reflection. For land-based mobile radio systems and two-way radios used for voice communication for commercial, industrial, public safety, and military purposes, the UHF spectrum is in use worldwide.

1.8.4 Computer Aided Dispatch communication

Modern EMS and several authorities involved in MI management including police, fire & rescue services and some military units, such as maritime Search & Rescue (SAR) and Urban SAR units use Computer Aided Dispatch (CAD) (53) systems. CAD is a method of dispatching personnel, vehicles or other units to an incident assisted by sophisticated computer programs.

CAD systems comprise modules providing multi-level services inside a dispatch centre involved in public safety. CAD services include the dispatching of incoming calls, status of units and their tracking. CAD systems provide interfaces for dispatchers, field personnel and other parties to operate and use radio and telephone systems. CAD is used for messaging to the dispatched units via a mobile data terminal and for the storing and retrieval of essential information on the task dispatched.

CAD operates on consoles in the dispatch or communication centre, e.g., Emergency Medical Communication Centre (EMCC) in an EMS system. The console is the interface between the dispatcher and the units managed by the authority. CAD combines multiple sources of information such as automated vehicle location and geographic information for optimized service by dispatching the closest units to an incident location as fast as possible.

Different brand CAD systems support data exchange in an international standard with the purpose to ease interdisciplinary cooperation between authorities in both everyday life and sudden-onset MI.

1.8.5 Digital platforms communication

Sophisticated devices such as the prehospital patient journal are in use for MI communication in Denmark and other countries. An electronic casualty clearing station is featured for the EMS units involved in a MI. The system allows for injury and triage level registration of the patients at the scene of a MI. This feature enables both pre- and in-hospital services to have an overview of the patients arriving to a trauma centre from a MI. It also features a chat function for direct communication from the incident site to the receiving hospital or vice versa.

1.8.6 Satellite phone communication

Satellite phones are a type of mobile phone that allows for connection to telephone networks or other phones via radio through orbiting satellites (54). Since its use is not limited to cell-tower covered areas, its use is unrestricted on the Earth's surface. There are two types of sat phones: one type operating on low-orbiting satellites, i.e., 400-700 miles above earth surface and those on high geostationary orbit satellites, 22 236 miles above earth surface.

The advantage of satellite phones for use in MI and disasters is obvious, since standard cell phone networks are operating close to maximum capacity on a daily basis. Subsequently, satellite phones are not prone to breakdown because of network overload, which is the case for mobile phones in an emergency. Similarly, e.g., natural disasters or the deliberate harmful action of terrorists cannot damage the satellite infrastructure.

Table 7 – Selected communication devices.

Type of communication device	Propagation	Users
Terrestrial Trunked Radio – TETRA	Digital infrastructure	Preparedness, police, EMS, fire & rescue, SAR, USAR, military
Very High Frequency – VHF	30-300 MHz Line of sight	EMS, EMCC, aviation, marine
Ultra High Frequency – UHF	300 – 3 000 MHz Line of sight	Commercial, industrial, public safety personal radio services, Citizen Band
Computer Aided Dispatch – CAD	Digital infrastructure	EMCC, police, fire & rescue, SAR, USAR
Digital platforms – PPJ Denmark	Digital infrastructure	EMS, hospitals
Satellite phones	Satellite	EMS, military, police, fire & rescue

EMS: Emergency Medical Service; SAR: Search & Rescue; USAR; Urban SAR; EMCC: Emergency Medical Communication Centre; PPJ: Prehospital Patient Journal

1.9 Communication adjuncts

1.9.1 Radiotelephony procedure

Radiotelephony procedure (55) comprises the different techniques for clarification, simplification and standardization of human communications over two-way radios. Armed forces, civil aviation, police, fire & rescue and EMS dispatch systems utilize the concepts' international regulations, official procedures, technical standards, and commonly understood conventions. It serves to ensure efficient, reliable, and inter-operable communication in radio transmission.

Voice procedures (56) are aimed at optimizing speech transmission. Therefore, radio messages should be "pre-planned, brief and straightforward". In order not to confuse the

recipient, messages should follow a clear and logic construction. Speech technique encompasses the use of rhythm, speed, volume and pitch of the voicing in purveying communication over radio that also includes microphone technique as an essential factor when transmitting communication in a radio.

1.9.2 Radio discipline

Radio discipline (57) is paramount when occupying a shared circuit with several colleagues eager to purvey information. Established procedures and conventions should be followed and trained on a regular basis. Rules of thumb such as “Accuracy, Brevity, Clarity”; the five W’s, i.e. “Who, What, Why, When, Where” and similar rules are important to remember.

1.9.3 International radiotelephony spelling alphabet

The NATO phonetic or spelling alphabet (58) is a special alphabet applied in radio communication to avoid confusion. The spelling of parts of a message containing letters and numbers aims to reduce the potential of mistakes, because some letters and numbers sound quite similar, especially if static, ambient noise or interference occurs in the dialogue.

1.9.4 Voice calling procedure

The voice calling procedure (59) is a systematic method of establishing radio communication according to standardized procedures that are common in maritime, aeronautical, military and civil telecommunications. It specifies how to initiate, continue and terminate radio communication to avoid mistakes, interruptions and mistakes. When trained and maintained properly, the procedure is simple and easy to follow.

1.9.5 Forced steering of radios in major incident communication

Communication systems such as the TETRA utilizes temporary inter-disciplinary talk groups as part of pre-defined MI communication grid. It has been demonstrated (4) that it is difficult in stressful situations such as MI to operate TETRA radios to the correct inter-disciplinary talk group and thus preventing the communication between authorities involved in MI management and to disseminate high-stakes decisions to EMS personnel.

It is possible to utilize forced steering or patching of the radios from EMCC. A simple PC based grid system enables EMCC operators to patch all units in a MI or disaster to the right inter-disciplinary talk group. That is the case in MI and disaster management in e.g., Norway and other countries. It potentially increases mental bandwidth in EMS personnel and may aid in focusing on the primary task in MI management.

1.9.6 Headset microphones

Headset microphones are available in conjunction with most communication devices described earlier. The simple reduction of ambient noise in chaotic incidents or simply to reduce wind noise (4) may be an important adjunct to increase perception of information.

Table 8 – Selected communication adjuncts

Type of communication adjunct	Characteristics
Radiotelephony procedure	Clarification, simplification, standardization of communication
Radio discipline	Accuracy, brevity, clarity in communication
International spelling alphabet	NATO phonetic spelling alphabet to reduce mistakes
Voice calling procedure	Initiation, continuation, termination of radio communication
Forced steering of radios	Centrally directed steering of radios in major incident communication
Headset microphones	Reduction of ambient noise

1.10 Human factors in MI communication

1.10.1 Situation awareness

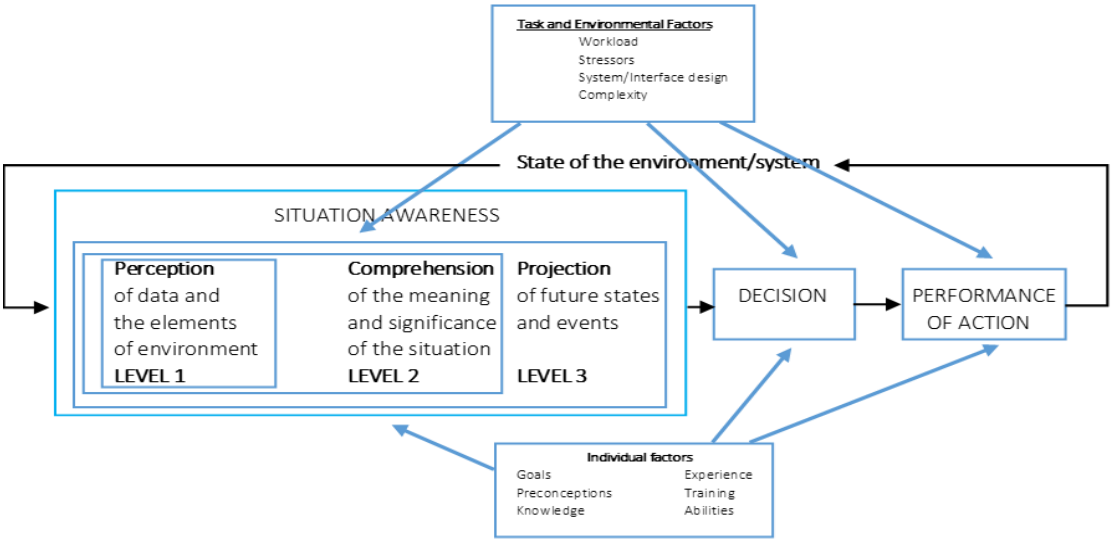
For high-stakes decision making in MI and disaster response to be successful, situation awareness (SA) is paramount. Endsley (60), defines SA as “the perception of environmental elements and events with respect to time or space, the comprehension of their meaning, and the projection of their future status”. The Endsley model of SA defines three levels: 1. Perception of data and the elements of the environment; 2. Comprehension of the meaning and significance of the situation and finally 3. Projection of future states and events. When the three levels are processed, a decision and performance of action is possible.

Both SA, decision and action performance are influenced by task/environmental factors such as stress, workload, complexity and importantly, system/interface design. Individual factors such as knowledge, training, experience, preconceptions and expectations from surroundings are also influential on SA. The model is dynamic and constantly repeated as the situation develops and new input is perceived, comprehended and projected into a future status.

1.10.2 Interface design interpretation

The system/interface design of e.g., communication devices is a crucial factor in the SA model. An unintuitive interface design may keep the user from achieving or even losing SA, especially in combination with complexity, workload and the stress that are inherent in MI management. A Danish investigation (61) into the use of TETRA radios among emergency authorities found that the competence in use of the radios was restricted among EMS and EMCC personnel. An unintuitive interface design of the TETRA radios in combination with insufficient initial training as described by Holm (35) were most likely causes according to the report.

Figure 2 - Endsley's model of situation awareness.



1.10.3 Startle effect

The aviation industry recognizes the startle effect as a deleterious factor in aircraft accidents. The brainstem derived human reflex to sudden stimuli such as loud noise or unexpected cognitive input may be applied to occupational settings including aviation (62) and emergency medicine. The effects of fear derived from threat may compromise cognition significantly. The result may be poor performance in the unexpected critical incident or event.

In Danish and Norwegian helicopter EMS (HEMS), the aeromedical crew resource management a.k.a. ACRM concept incorporates the startle effect as a significant entity in aviation industry-derived mandatory training. HEMS physicians are often medical incident commanders in MI and disasters (2) due to high level of formal training (4) in and exposure to MI and as an important part of MI and crisis management plans. Therefore, the startle effect is a relevant factor in MI and disaster management that should be disseminated into and addressed in EMS systems other than HEMS for future improvement, for resilience and to mitigate consequences.

1.10.4 Option paralysis

Option paralysis (63) refers to the psychological effect that occurs, when an individual is incapable to decide between several choices and ends up without a decision. The effects of choice overload may be option paralysis, a well-described psychological phenomenon. In psychology, the “less is more” concept stems from option paralysis and choice overload theories. This may also be the solution for mitigation when transferred to the EMS arena.

1.10.5 Stress

Stress is an inherent human factor in EMS professionals’ work, which may compromise their ability to carry out tasks and cope with complex situations. Stress is defined as a psychological load, often accompanied by physical symptoms or reactions. Short-term stress may be beneficial, whereas prolonged stress may cause serious illness. The symptoms of stress include anxiety, increased tension and irritation. Stress may lead to sadness and mental

depression. The causes of stress are numerous and include psychological trauma or prolonged emotional or work-related load.

1.10.6 Fatigue

Fatigue encompasses the physiological and psychological effects of sleep deprivation as the result of prolonged mental or physical activity. Fatigue compromises optimal cognitive skills performance and physical performance as well. The effects of somnolence and decreased attention may be dangerous in every aspect, especially when operating complex devices such as radios. Fatigue mitigation includes sleep registration, fatigue risk management or national legislation, such as flight time regulations in HEMS operations and rest time regulation in EMS and some but not all ambulance services when applicable.

Table 9 – Selected human factors in major incident communication

Type of human factor	Characteristics
Situation awareness	Perception, comprehension, projection, decision, performance
Interface design interpretation	Intuitive, important for situation awareness
Startle effect	Compromised cognition; poor performance in critical events
Option paralysis	Incapable to make decision between several choices
Stress	Psychological load; physical symptoms; emotional/behavioural symptoms
Fatigue	Compromised cognitive skills, somnolence, decreased attention

1.11 Overall aims of the thesis

1.11.1 Thesis focus

This thesis focuses on literature describing communication in the immediate medical management of sudden-onset MI. Consequently, the purpose is to identify, extract data from and do quality appraisal of existing relevant literature on the subject. The overall aim is to create an overview of previous and current MI and disaster communication.

1.11.2 Thesis objective

The objective is to aid in creating robust and resilient systems of communication in sudden-onset MI and disaster management based on the study findings. EMS and preparedness leaders will be able to benefit from the conclusions of the scoping review and possibly implement recommendations for daily practice and future research in this important field for future MI management enhancement. The findings will be available for EMS professionals through publication of the study findings in relevant peer-reviewed scientific journals and at meetings and conferences.

1.11.3 Thesis limitations

The nature of the scoping review and the single reviewer format encompass inherent biases that potentially may limit the generalizability and transferability. The study will address validity in the quality appraisal of internal and external validity whereas reliability is ensured through pre-search protocol registration in relevant portals and prompt registration of protocol amendments.

1.12 Research question

The main research question for this scoping review is:

What are the patterns and challenges in communication during the immediate management of sudden-onset major incidents?

2. Methods

2.1 Rationale for choice of research method

In the process of selecting the research method for the thesis, several considerations were discussed with thesis supervisor, programme supervisors and fellow students in the master's programme during sessions presenting the students' projects. The research question had been formulated ahead of these discussions, i.e., to explore the patterns and challenges in sudden-onset MI communication. Subsequently, different theoretical approaches were investigated and discussed between student and supervisor.

2.1.1 Registry study

A registry study (64) is an observational study in which a drug, a device or procedure under evaluation is prescribed to patients, used on patients or performed in an operational setting. Afterwards, pre-defined as per protocol outcome data are collected. The main difference to e.g., clinical studies is the fact that registry studies are observational whereas clinical studies are investigational, i.e., exploring the effects of the drug, device or procedure under investigation based on a protocol and laboratory tests ahead.

The application of a registry study did not seem feasible, primarily due to the nature of MI and the expected dissemination into indexed and non-indexed literature. MIs are spectacular in terms of public attention, however extremely small in volume. It was speculative whether operational MI data would have disseminated into registries that were accessible and within the scope of the master's thesis. Consequently, it was decided between the author and the supervisor that a registry study would not be able to answer the research question in a meaningful way.

2.1.2 Prospective observational study

A prospective observational (65) study is defined as an observational study that is most often longitudinal in its nature. It serves to investigate the consequential outcomes of interest after the study has commenced. The creation of a study protocol and analysis plan precedes study initiation, most likely mandating permissions from EMS administrators and an ethics

committee since prospective observational studies usually involve selecting a specific cohort of subjects and observing them over a long period.

Factors such as possible questionnaire fatigue in EMS personnel and the complexity and rare occurrence of sudden-onset MI soon discouraged the feasibility of a prospective observational study in the current thesis. The scope of the thesis and the research question suggested that it would be hard or impossible to carry out by way of that research method.

2.1.3 Feasibility study

A feasibility study (66) assesses the practicality of an intended project or a new procedure. Feasibility studies analyse viability and practicality of a procedure to establish the likelihood of success for e.g., the implementation of a new procedure, guideline or device.

For sudden-onset MI communication, it is evident that communication relies on sophisticated devices, comprehensive manuals and guidelines. It was soon decided that it was beyond the scope of the thesis to introduce a new communication guideline or device; and that the possible ability to answer the research question was very limited by way of a feasibility study.

2.1.4 Meta-analysis

Existing knowledge of sparse sudden-onset MI epidemiology restricted to mainly case reports obviated the option of performing a meta-analysis of the included literature. Meta-analysis (67) is the statistical process of analysing and combining results from several similar studies, e.g. randomized controlled trials or systematic reviews. The scientific demands for the conduct of meta-analyses are high in terms of the quality of the included literature. A priori assumptions and experience from similar scientific activities on the predominance of e.g., case reports in MI epidemiology excluded the option of conducting a meta-analysis.

2.1.5 Delphi study

A Delphi study comprises the conduct of structured group sessions with e.g., experts in a specific field. The purpose is to answer a specific research question through consensus among the participants, developing as the Delphi study unfolds in sequential rounds.

Participants have the opportunity to change their opinion during the rounds, influenced by the anonymized opinions of their co-participants.

This research method would definitely have been feasible for the master's thesis. However, the conduct of such a Delphi study was beyond the scope of the thesis, given e.g., lacking MI and disaster definitions, lack of common nomenclature and an ambition to firstly define the field scientifically and secondly describe the patterns and challenges in MI and disaster communication. Nevertheless, a Delphi study would ensure expert opinion for the development of consensus guidelines and structure in MI and disaster management.

2.1.6 Non-indexed literature and grey literature

The term non-indexed literature (68) simply states that a publication has not been indexed in a registry such as MEDLINE, Scopus or similar. Strongly debated, non-indexed literature is considered by the scientific community to be of lower scientific quality as compared to indexed. Non-indexed literature is generally not peer-reviewed, affirming the scientific inferiority.

Some non-indexed literature is referred to as grey literature, i.e., any document that did not go through a peer review for publication. Examples of grey literature include government documents and reports; discussion forums; blog posts; conference papers and interviews.

2.1.7 Scoping review

Literature on MI epidemiology is heterogeneous and sparse (69) and often, the lessons learned in MI management and communication, are the results of government hearings, commissions and e.g., transportation safety board reports. Therefore, the theoretical approach to identify literature depicting communication patterns and challenges in MI was anchored in an ambition to include existing indexed and non-indexed literature from other sources that may include the findings from multiple study designs and methods if any. A scoping review (70) seemed like the best possible research method available within the scope of the master’s thesis and was decided upon.

To be able to critically appraise and interpret the results of the search, it was important to do a very broad search to quantify and qualify the discussion and provide useful conclusions and recommendations for future MI management in general and communication specifically.

2.2 Scoping vs. systematic review

The thesis aimed to systematically identify, extract data from and critically appraise the quality of existing indexed and non-indexed literature on communication in the immediate management of sudden-onset MI. Even so, to provide an overview of indexed and non-indexed literature on the topic with no limitation with regard to type of study design. The deliberate application of a scoping review method (71) is with the purpose of including non-indexed literature mentioned earlier. The nature of the thesis limits the number of reviewers to one, obviating the option of a systematic review and s systematic scoping review that requires at least two reviewers.

2.2.1 The role of scoping reviews

Scoping reviews are conducted when one wants to investigate key concepts within a field of interest; to clarify working conditions or simply to grasp or encompass the subject matter, as opposed to e.g., systematic reviews investigating the effects of an intervention from a set of predefined outcome variables (72). Scoping reviews may be the precursor to a systematic review; identify research or knowledge gaps; identify the different types of available evidence in the field of interest; examine how research is – or is not – conducted in the field and, most prominent to the current thesis, identify the key concepts and definitions available in the field (73).

2.2.2 Precursor of a systematic review

The scoping review's role as a precursor of a systematic review is prominent when identifying the available evidence prior to the conduct of a systematic review (74). For the possible identification of emerging or lacking evidence, the scoping review may prove useful (75). For the identification of patterns in sources of evidence, and in the mapping, reporting or discussion of these characteristics, a scoping review is considered a relevant choice.

2.2.3 Quality appraisal in scoping reviews

Because of the overview focus of scoping reviews, quality appraisal by means of assessment of methodological limitations or risk of bias of the evidence is generally not applicable (76). However, it can be performed if the nature of the review mandates that in its aim, and that is the case for this scoping review to enhance validity. The implications for practice and the recommendations for future research will be based on the findings of the scoping review in this thesis with the very important distinction that evidence-based clinical guidelines and recommendations must stem from a systematic review. This scoping review is a precursor of that future systematic review.

The scoping review may be useful in the development of e.g., policy maps by identifying evidence from sources other than scientific articles, i.e., policy documents, non-published conference papers, dissertations and reports. Therefore, one advantage of scoping reviews to evidence-based healthcare and practice lies in the examination of a broader area to identify knowledge and research gaps (77), which is an important aspect of this thesis.

2.3 Research design

The research design applied for this master thesis was a scoping review to provide overview of relevant literature and published materials on communication in sudden onset MI.

2.3.1 Guidelines and protocols applied

The review question, outcomes, inclusion and exclusion criteria and methods of analysis were predefined, and the protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO), with registration no. CRD42021289203 (78) and Open Science Framework (OSF) with registration no. 10.17605/OSF.IO/MBT7V (79) ahead of any database search. Amendments to the protocols were registered. Furthermore, the project was registered (80) at NSD - Norwegian Centre for Research Data. No registration number is available, but a unique ID code in URL is available from the author on reasonable request.

The review adhered to the PRISMA-ScR extension for scoping reviews guideline (81, 82).

PROSPERO does not accept scoping reviews; thus, the registration of the current review was in the format of a systematic review for future conduct of this to avoid self-plagiarism concerns and because of the current scoping review's role as a precursor of a systematic review.

2.3.2 Non-indexed literature search

The review aimed to collect information that fitted pre-specified eligibility criteria to assess the specific review question. When planning the review protocol, the mnemonic "PCC; Population, Concept, Context" was used as the basis upon which sources were to be considered for inclusion in the scoping review. The PCC model applied in the non-indexed literature search was defined as: In EMS professionals (Population) does the use of communication devices adhere to guideline, if applicable, and does that influence mortality and morbidity (Concept) in sudden-onset MI (Context).

2.3.2.1 Population/types of participants

Personnel from authorities involved in MI management, e.g., EMS professionals, prehospital physicians, rescue workers, police, military, voluntary organizations.

2.3.2.2 Concept

The scoping review protocol focused on the use of communication devices in management of sudden-onset MI. If guidelines were available and/or applicable, guideline adherence was evaluated as well. The actual and potential consequences of communication breakdown for MI management, patient outcome and resource availability were evaluated.

2.3.2.3 Context

The registered scoping review protocol defined sudden-onset major incidents as the context for the search.

Table 10 – Population, Concept. Context question

PCC Population – Concept - Context	
Population	Personnel from authorities involved in MI management
Concept	Use of communication in major incidents; guideline adherence
Context	Sudden-onset major incidents involving EMS

2.3.3 Scientific database search

The review aimed to collect information that fitted pre-specified eligibility criteria to assess the specific research question. When planning the scoping review of scientific databases, the mnemonic "PICO"- Population, Intervention, Comparison, Outcome, was used to structure the research question and inclusion of studies. The PICO model applied in the scientific database search was defined as: In EMS professionals involved in sudden-onset MI (population), does the use of communicative devices (intervention), adhere to guideline, if applicable (comparator), and does that influence mortality and morbidity (outcome).

2.3.3.1 Population

EMS personnel involved in the immediate management of sudden-onset major incidents.

2.3.3.2 Intervention

The intervention in question was the use of communication in major incidents.

2.3.3.3 Comparison

Adherence to guideline if applicable was comparator.

2.3.3.4 Outcome

Outcome was the description of communication in major incidents in the included literature.

2.3.4 Dual formats in literature search

It was decided to apply both the PCC format and the PICO format in the literature search. That was based on several reasons, including the intention of performing a broad search; the difference between the two formats (71-75), i.e., they derive from the Joanna Briggs Institute

guidelines and the PRISMA-ScR guidelines, respectively. The PICO format includes an intervention whereas the PCC format includes concept. The latter relates better to searches within non-indexed literature, which do not necessarily follow a common structure, derived from guidelines and protocols.

Furthermore, the two formats applied in the scoping review do overlap and are believed to ensure a broad search with the purpose to find the best possible indexed and non-indexed literature to answer the research question at hand. One could label it a mixed methods study if both quantitative and qualitative methods were applied. However, that is not completely the case in a scoping review.

Table 11 – Population, Intervention, Comparison, Outcome question

PICO Population- Intervention – Comparison – Outcome	
Population	All sudden-onset major incidents involving EMS
Intervention	Use of communication in major incidents
Comparison	Guideline adherence yes/no if applicable
Outcome	Description of communication in major incidents

2.4 Search strategy

The search strategy for scientific databases was developed by the author who is the subject specialists and was peer-reviewed by a research librarian. The following databases were searched: Cochrane Library, Embase, Medline, Scopus, SveMed+ and Web of Science up until January 6, 2022 (Scopus was last searched on January 10, 2022). The search strategy was developed in Embase and Medline, validated using known references and translated to the additional databases.

The author developed the non-indexed literature search strategy with the assistance of a librarian. The following databases and websites were searched: Web of Science; Embase; Scopus; Google Scholar; http://www.ndltd.org; https://www.dart-europe.org/basic-search.php; http://www.opengrey.eu/; https://www-base-search-net.ezproxy.uis.no/; https://oatd.org/. The search was performed 16-22 March 2022.

2.5 Eligibility criteria

The current review included all indexed and non-indexed published manuscripts that focus on communication in MI in a broader perspective.

2.6 Study population and available data sources

All literature stating that the incident described was defined as or considered in a system to be a major incident or disaster was included in the scoping review. The use of a specific definition was obviated to avoid the possible exclusion studies that might be relevant to answer the research question.

The study population was EMS personnel involved in the direct management of a MI, irrespective of their actual role or position, thus not restricted to e.g., physicians or medical incident managers.

The term sudden-onset was applied at the discretion of the author, depicting the unexpected and unprepared onset of a MI or disaster that would require the mobilization of extraordinary EMS resources to counteract the actual or imminent threats to people, animals and society-critical infrastructure from the consequences of the MI in question.

2.7 Source of evidence screening and selection

Results from the conducted search were collected and combined in the Endnote20® software (Alfasoft AB, Gothenburg, Sweden) (83) and duplicate studies were eliminated using the Covidence® (Veritas Health Innovation, Melbourne, Australia) software (84). For the identification of potentially eligible studies and papers, this author screened titles and abstracts carefully. For eligible studies, full text retrieval and review was performed. Articles and studies were included at the author's discretion since this was a scoping review.

2.8 Data sampling

In the review, Endnote bibliographic database was used to systematically search all the titles and abstracts. The chosen studies were carefully read by this author for data sampling and quality appraisal. A data sampling template was developed with the inspiration from similar studies (1,136)

The data sampling template included thirty items of interest that were supposed to answer the research question. They were divided into four subheadings that included MI demography; communication; incident characteristics and finally incident response.

For demography, the checklist was expected to provide information on affected area; affected population; accessibility to incident site(s) and finally other relevant pre-incident data.

For communication, information on communication type (e.g., radio, sat phone etc.); type of communication device (e.g., TETRA radio); communication mode (e.g., verbal, written, text etc.) and other relevant information.

The incident characteristics subheading comprised time, date and place; description of the incident and the damage it caused; the number of deceased; the number of injured; the total number of victims involved; scene access; distance to hospitals; and finally, other incident characteristics.

Incident response included information on how and if the MI was declared; a timeline for the medical response; patient logistics if applicable; the number of communication devices in use for the MI management; the type of communication breakdown; attempts to rectify communication breakdown; alternate communication system; alternate non-technical communication system; background communication education; scene safety; communication breakdown consequences and finally other incident response data.

Accordingly, and as per protocol, a quality appraisal template tool was developed. Twelve items to assess internal and external validity were in use.

For internal validity, the items included the following five questions: Is the author a person directly involved in the MI medical response; Does the literature provide reference to where the data was obtained; Does the literature provide reference to how the data was obtained; Do the authors declare no conflict of interest; and finally: Has an ethics committee approved the reporting?

To evaluate external validity of the included literature, the following seven items of interest were in use: Does the literature describe the local emergency medical services structure; Is the MI clearly described; Are the medical resources used in the MI response clearly described; Are missing data accounted for; Are other limitations discussed; and finally: Is the study design clearly described?

2.8.1 Author/year

For every source included, the first author and year of publication was noted.

2.8.2 Objective/s

The objective of the paper was documented.

2.8.3 Participants

Demographic details and defining characteristics of participants were noted.

2.8.4 Concept

Interventions and phenomena of interest, including communication guideline adherence if available and/or applicable were reported.

2.8.5 Context

Details of context including geographic location, type of MI and relevant data were recorded.

2.9 Analysis and presentation of results

2.9.1 Data compilation

The data extracted from the included papers were compiled in diagrams intended to display the findings in a tabular format to enhance reader-friendliness. Simultaneously, a narrative interpretation of the findings in the included literature was performed as well.

2.9.2 Level of evidence

Level of evidence (LOE) was decided by means of the evidence evaluation worksheet by the International Liaison Committee on Resuscitation (ILCOR) for therapeutic interventions (85) with adaptation from a review article on levels of evidence (86).

2.10 Data synthesis

Due to the lack of outcome variables per se, this author performed a textual narrative analysis of the findings from each of the included studies and structured a synthesis based on the characteristics of the studies on the types of MI and communications challenges they described.

2.10.1 Deviations from protocol in search strategy

In Scopus, the entry term "tele communication" was excluded due to a large number of irrelevant results. The non-indexed literature databases search yielded a huge number of very diverse and heterogeneous papers in terms of quality and ability to answer the review question. The amendment was promptly registered in PROSPERO and Open Science Framework for protocol adherence. For both registrations, status is ONGOING based on specific plans to produce a scientific paper based on the present narrative review

2.10.2 Analysis of identified literature

This author scanned identified literature for titles and abstracts and excluded literature non-compliant with inclusion criteria. When in doubt, full text was obtained for unclear or uncertain articles.

Data analysis was conducted due to the registered protocol using PCC and PICO methodology in adherence with PRISMA (87) and PRISMA-ScR (82) guidelines. In the scoping review, Participants/population encompassed all EMS personnel communicating in a MI.

Intervention, concept, context, comparators and outcomes as per protocol were extracted using the data sampling instrument.

From each of the included articles and papers, the 30 data items were sampled in accordance with the pre-registered protocol. The data comprised four categories, which included demography; communication; incident characteristics and incident response.
Following data sampling, quality appraisal was performed in accordance with protocol, using the pre-registered twelve-item checklist to evaluate internal and external validity of the included literature.

2.10.3 Deviations from protocol in quality appraisal
None

2.11 Data variables

Not applicable.

2.12 Statistics

Not applicable. Percentages were calculated from quantities of total.

2.13 Ethical and legal considerations

According to Norwegian legislation and University of Stavanger requirements, a data management plan was registered at Norwegian Centre for Research Data (NSD). Registration number is not available despite consultation. However, a unique ID in URL code is available upon reasonable request from the author.

3. Results

3.1 Summary of results

3.1.1 Identification of studies from main database search

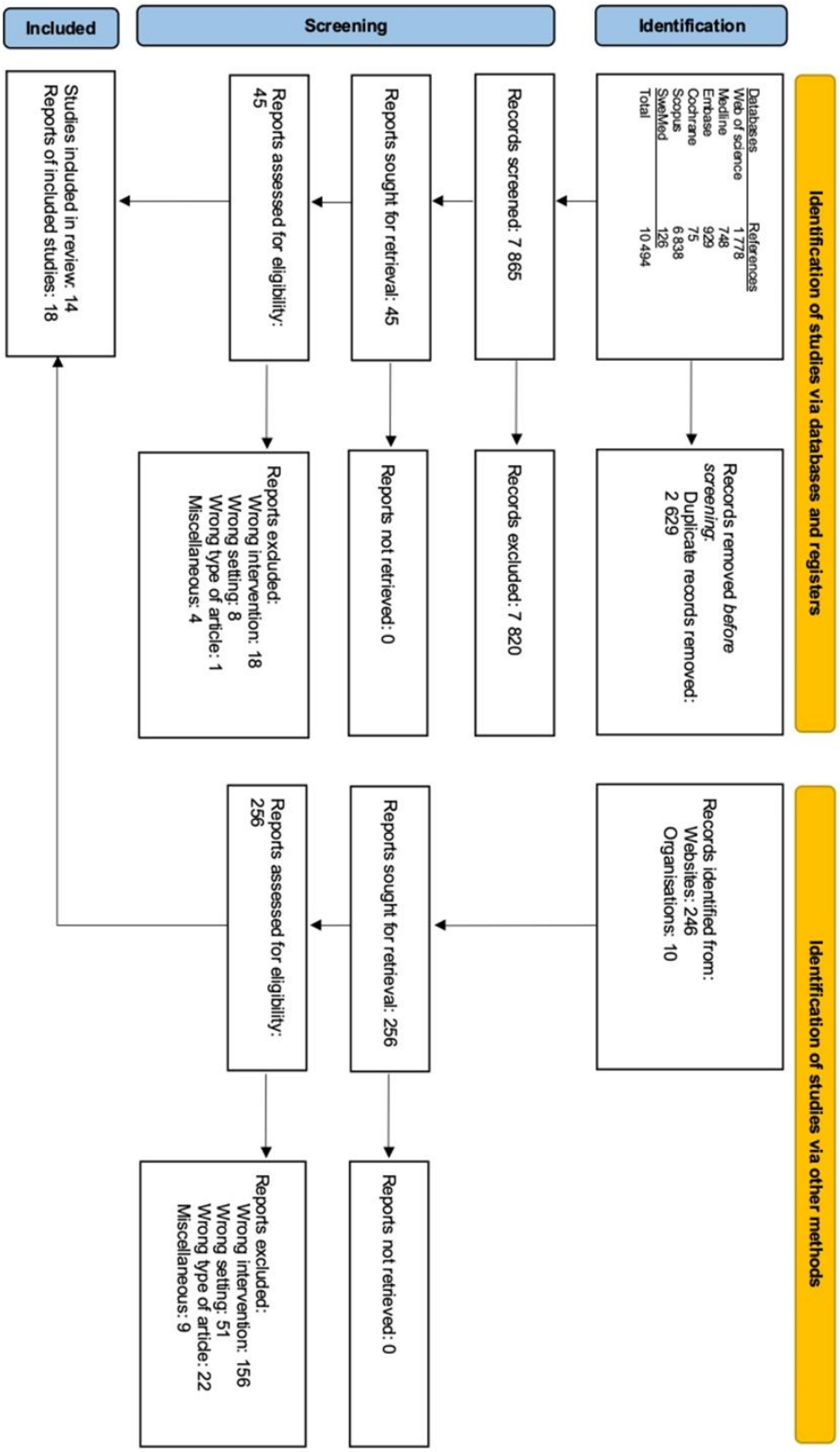
In accordance with deviations from protocol, the main database search identified previous research fitting the eligibility criteria and provided an overview of published literature. In total, 10 494 articles, papers and studies were imported from six databases. The removal of duplicates (2 629) produced 7 865 studies, whose titles and abstracts were screened. This process rendered 45 full-text articles and papers that were assessed for eligibility. Thirty-one articles were excluded and fourteen that met the inclusion criteria were included in the scoping review. Selection process and reasons for exclusion are listed in the PRISMA flow diagram (Figure 3). Detailed description of the search strategies for each database can be found in Appendices 8.5.1 thru 8.5.6.

3.1.2 Identification of studies from non-indexed literature search

The non-indexed literature search identified 256 published articles of which 238 were excluded after screening based on title and, when available, abstract. Eighteen articles and papers were included after full-text review.

Thus, the scoping review comprised 32 included articles and papers (2, 4, 88-117) from different sources. Accordingly, the PRISMA flow diagram (Figure 3) describes the selection process.

Figure 3. PRISMA 2000 Flow diagram depicting the different scoping review stages.



3.2 Quality of included studies

The scoping review included 32 papers including both indexed and non-indexed literature. The review comprised 25 case reports, three mixed methods publications, two questionnaires, one consensus paper and one non-systematic literature review.

Consequently, scientific quality was generally low as case reports findings might not be generalizable and do not establish a cause–effect relationship. This may lead to the risk of over-interpretation. As for the questionnaires, the consensus papers and the non-systematic literature review.

From the predefined twelve-item checklist, a quality appraisal of the included articles and papers was performed. The purpose was to evaluate internal and external validity. In total, the included papers contained data on (231/384) 60.2 % of the predefined items for quality appraisal.

Items of interest registered in study protocol on internal validity included the following:

1. Is the author a person directly involved in the MI medical response?

In twelve papers (37.5%), the author was directly involved in the MI medical response.

2. Does the literature provide reference to where the data was obtained?

The included papers provided information of where data were obtained in 27 papers (84.4%).

3. Does the literature provide reference to how the data was obtained?

Twenty-six papers (81.3%) referred how data was obtained.

4. Do the authors declare no conflicts of interest?

In eighteen papers, the authors declared no conflict of interests (56.3%)

5. Has an ethics committee approved the reporting?

Ethical approval was described in just six papers (18.8%).

Items of interest registered in study protocol on external validity included the following:

1. Does the literature describe the local emergency medical services structure?

In 24 papers (75%), the local EMS structure was described.

2. Is the major incident clearly described?

The incident was clearly described in 26 (81.3%) of the papers.

3. Are the medical resources used in the major incident response clearly described?

Twenty-five papers describe the medical resources used.

4. Does the literature describe the type, means and capacity of communication?

Type, means and capacity of communication was accounted for in 68.8% (22 papers).

5. Are missing data accounted for?

Ten papers (31.3%) accounted for missing data.

6. Are other limitations discussed?

Other limitations are discussed in five papers (15.6%).

7. Is the study design clearly described?

Thirty papers clearly explained the study design.

Findings from quality appraisal are presented in tabular format in Figure 4. Items for quality appraisal are presented in Appendix 8.3.

Figure 4. Quality appraisal instrument

Figure 4. Quality appraisal instrument

	INTERNAL VALIDITY					EXTERNAL VALIDITY						
	Is the author a person directly involved in the major incident medical response?	Does the literature provide reference to where the data were obtained?	Does the literature provide reference to how the data were obtained?	Do the authors declare no conflicts of interest?	Has an ethics committee approved the reporting?	Does the literature describe the local emergency medical services (EMS) structure?	Is the major incident clearly described?	Are the medical resources used in the major incident response clearly described?	Does the literature report the type, means and capacity of communication?	Are missing data accounted for?	Are other limitations discussed?	Is the study design clearly explained?
Ackermann et al 2011	?	Y	Y	Y	?	N	Y	Y	N	N	Y	Y
Björnstig et al 2011	N	N	N	Y	N	Y	Y	Y	Y	N	N	Y
Brismar et al 1990	N	Y	Y	Y	N	Y	Y	Y	N	N	N	Y
Brändström et al 2006	N	Y	Y	N	N	Y	Y	Y	Y	N	N	Y
Brändström et al 2007	N	Y	Y	N	N	Y	Y	Y	Y	N	N	Y
Buerk et al 1982	?	N	N	N	?	Y	Y	Y	N	N	N	Y
Butts et al 2007	N	Y	Y	N	N	N	N	N	Y	N	N	Y
Englund et al 2012	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y
Gomez et al 2007	?	Y	Y	N	?	Y	Y	Y	Y	N	N	Y
Hansen et al 2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hardy 2013	Y	Y	Y	Y	?	Y	Y	Y	Y	N	N	Y
Hardy et al 2015	Y	Y	Y	Y	?	Y	Y	Y	N	N	N	Y
Hedelin et al	N	Y	Y	Y	?	Y	Y	Y	Y	N	N	Y
Heltne 2012	Y	Y	Y	Y	?	Y	Y	Y	Y	Y	N	Y
Hu et al 2014	N	Y	Y	?	?	N	N	N	Y	N	N	Y
Huang et al 2012	Y	Y	N	?	?	N	N	N	Y	N	N	N
Hägnevik et al 1996	N	Y	Y	?	?	Y	Y	Y	Y	N	N	Y
Iselius 2004	N	Y	Y	?	?	Y	Y	Y	Y	N	N	Y
Iversen 2019	Y	Y	Y	Y	?	Y	Y	Y	Y	Y	N	Y
Jama 2007	Y	Y	Y	Y	?	Y	Y	Y	Y	Y	N	Y
Kapuca et al 2006	N	N	N	N	N	N	N	N	Y	N	N	N
Kulling et al 1993	N	Y	Y	?	?	Y	Y	Y	N	N	N	Y
Kulling et al 1997	N	N	N	?	?	Y	Y	Y	N	N	N	Y
Lavery et al 2005	?	N	N	Y	?	N	Y	N	N	N	N	Y
Palttale et al 2012	N	Y	Y	N	?	N	N	N	N	N	N	Y
Picazo et al 2010	Y	Y	Y	Y	?	Y	Y	Y	Y	Y	N	Y
Rehn 2000	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
Rimstad et al 2015	?	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Román-Morales 2015	Y	Y	Y	Y	?	Y	Y	Y	Y	Y	N	Y
Sollid 2011	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sollid et al 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Yamamura et al 2014	?	Y	Y	?	?	N	N	N	N	N	N	Y

MI: major incident; Y: yes; N: no; ?: unclear

3.3 Main results

3.3.1 Demography

Items of interest registered in study protocol on demography:

1. Information on affected area?

Basic information on the affected area was provided in 28 papers (87.5%).

2. Information on affected population?

Twenty-seven papers (84.4%) provided information on the affected population.

3. Information on accessibility?

Information on accessibility was provided in 27 papers (84.4%)

4. Other relevant pre-incident data?

Twenty-seven papers (84.4%) described other relevant pre-incident data.

3.3.2 Communication

Items of interest registered in study protocol on communication:

1. Information on communication type?

Information on communication type was provided in 25 papers (78.1%).

2. Type of communication device?

The type of communication device was described in 25 papers (78.1%).

3. Communication mode?

Communication mode information was available in 21 papers (65.6%)

4. Other relevant communication characteristics?

Twenty papers (62.5%) provided other relevant communication characteristics.

3.3.3 Incident characteristics

Items of interest registered in study protocol on incident characteristics:

1. Time, date and place of incident?

In 29 papers (90.6%), time, date and place of incident was described.

2. Description of incident and damage it caused?

In 27 papers (84.4%), description of the incident and the damage it caused was available.

3. Number of dead?

The number of dead was provided in 26 papers (81.3%).

4. Number of injured?

The number of injured was available in 26 papers (81.3%).

5. Total number of victims involved?

Twenty-six papers (81.3%) provided total number of victims involved.

6. Scene access?

In 25 papers (78.1%), scene access was described.

7. Distance to hospitals?

Distance to hospitals was described in 22 papers (68.8%).

8. Other incident characteristics?

In 27 papers (84.4%), other incident characteristics were included.

3.3.4 Incident response

Items of interest registered in study protocol on incident response:

1. Information on how MI was declared?

Twenty-two papers (68.8%) provided information on the MI was declared.

2. Timeline for the medical response?

A timeline for the incident was provided in 24 papers (75%).

3. Who participated?

In 24 papers (75%) it was described who participated.

4. What tasks were performed?

Twenty-five papers (78.1%) described what tasks were performed.

5. Patient logistics?

In 25 papers (78.1%), patient logistics were provided.

6. Number of communication devices?

Information on the number of communication devices that was available in just two papers (6.3%).

7. Type of coms breakdown?

The type of breakdown was described in 23 papers (71.9%).

8. Attempts to rectify communication breakdown?

In 21 papers (65.6%), attempts to rectify communication was described.

9. Alternate communication systems?

Alternate communication systems were described in fourteen papers (43.8%).

10. Alternate non-technical communication systems?

In five papers (15.6%), alternate non-technical communication systems were described.

11. Background communication education?

Background education in the use of communication devices could be obtained from just two papers (6.3%).

12. Scene safety?

In 23 papers (71.9%), scene safety was described.

13. Communication breakdown consequences?

Consequences of breakdown were described in 25 papers (78.1%).

14. Other relevant incident response data?

Twenty-seven papers (84.4%) provided other relevant incident response data.

Items for data sampling are presented in tabular format in Appendix 8.4. Findings from data sampling are presented in tabular format in Figures 5 and 6.

3.4 Findings from included literature

3.4.1. Narrative interpretation of the characteristics from the included articles with communication focus and selected operational details.

A case report by Ackermann (88) described the events of the Love Parade in Duisburg, Germany in 2010, killing 21 and injuring more than 500 people as the result of very limited access, lacking contingency plans for escape routes and failing inter-authority coordination causing panic among the estimated 200 000 to 1 400 000 spectators. Communication issues were breakdown due to system overload and compromised command & control as the result of that.

Björnstig (89) described six buss crashes in Sweden, killing thirty people and injuring 355. A pattern of communication breakdown for unspecified reasons resulted in lost command & control and failing inter-authority cooperation. Pattern analysis and recommendations for future MI management with communication focus are provided.

In a KAMEDO report by Brismar (90), the tragic events at the 1988 air-show at the United States Air Force Base Rammstein in Germany were described, killing 70 and injuring 346 persons as the result of an airplane crash. Communication breakdown, unclear distinctions between military and civil jurisdiction and lacking cooperation because of that were the most important findings in the case report. The mid-air collision of three aircraft from the Italian Air Force display team Frecca Tricolore caused a crash in front of 300 000 spectators and subsequent explosions and fire caused the severe incident.

Brändström (91) described the 2002 Bali terrorist attacks in Indonesia, killing 202 and injuring more than 3 000 victims in a case report. Communication breakdown was the predominant issue, resulting in lost command & control, complicated by lacking pre-incident EMS coordination.

Brändström (92) was also the author of a KAMEDO report on the 2004 Madrid, Spain terrorist train bombing, also described by Gomez (96) in case reports. Communication breakdown resulting in lost command & control and lacking hospital coordination were the main findings in the incident, killing 193 and injuring approximately 2 050. Al-Qaeda terrorist placed ten bombs in four commuter trains near the main Atocha Central Station in the busy morning hours that simultaneously blew off within minutes. The attacks caused a massive MI response involving multiple EMS systems and several trauma centres in Madrid. In the aftermath, there were speculations of the involvement of ETA, the armed Basque nationalist and separatist terrorist organization and conspiracy theories claiming a self-inflicted attack for political reasons, similar to those concerning the September 11th, 2001 attacks on the United States. However, investigations found that compromised cooperation between and within police branches and intelligence led to the attack, as the perpetrators were under surveillance already from 2001 by secret services. In Spain, the incident is referred to as “11M”.

Buerk (93) described the 1980 Las Vegas, USA, MGM Grand Hotel fire. Major findings were communication breakdown due to system overload and incompatibility that compromised information flow, caused panic and the coordination of e.g., HEMS and hospital resources.

The September 11th, 2001 New York, USA, World Trade Centre events were described by Butts (94) in a mixed methods study and Kapucu (107) in a consensus paper. The prompt communication breakdown due to system overload was one important finding, yet also the alternate pathways to rectify command & control in the devastating event, killing 2 995 and injuring 2 680, were important findings. Two hi-jacked commercial aircraft were deliberately flown into the two towers of the World Trade Centre by the terrorists, causing the massive buildings to collapse afterwards.

The simultaneous attacks on the Pentagon in Washington, D.C. and a fourth hi-jacked plane that crashed in Pennsylvania and was believed to be targeted at the Capitol in Washington, D.C., prompted the declaration of a national state of emergency, including the closure of American airspace to all commercial traffic. The al-Qaeda driven massive terrorist attack on multiple American structures is probably the most spectacular and dramatic incident in post-World War II history with massive implications for the world society, aviation industry and world-wide anti-terror legislation.

Four papers by Englund (95), Rimstad (114) and Sollid (2, 116) all depicted the 2011 Oslo/Utøya, Norway, lone terrorist attacks, killing 76 people and injuring 159. The main communication issues were breakdown due to system overload, inter-authority communication system incompatibility and lacking MI communication guidelines. The perpetrator's use of a secondary incident site and the subsequent chaos and lack of resources to manage both incidents simultaneously were described in detail by the authors of the reports.

First, a car bomb detonated in the Government Quarter in downtown, Oslo, killing eight and injuring more than 200 people. Two hours later, the perpetrator attacked the summer camp on the island of Utøya, organized by the youth wing of then ruling Norwegian Labour party. Disguised as a police officer, the perpetrator opened fire at the young people on the island of Utøya, killing 67 and injuring at least 32. The events of the 22nd of July 2011 were the worst since World War 2. The perpetrator was later sentenced to 21 years in so-called preventative detention in prison.

One case report by Hansen (4) described a train accident in Nyborg, Denmark in 2019. Non-intuitive guidelines for selected structures in Denmark, lack of initial training and weather phenomena such as hurricane and flooding compromised sufficient communication were highlighted. Eight people were killed and fifteen injured in the accident where a high-speed train collided with a trailer falling from a passing train. This was the only included paper to quantify MI communication in detail with affiliation times and shifts to temporary inter-authority communication channels. The focus was on the fact that the responsible authority in a previous report had already described insufficient communication abilities in Danish EMS.

Hardy described a complex road traffic incident in Sheppey, Kent, United Kingdom in 2013 in two included papers (97, 98), injuring 69 people. Both intra- and inter-authority communication was lacking due to insufficient training and experience in MI management. Furthermore, communication breakdown due to both system overload/capacity and human factors. Communication breakdown is the main problem mentioned in the report. Subsequently, MI protocols and training have been enhanced.

The 1999 train crash near Paddington Station in London, United Kingdom, that killed 31 and injured 417, was reported by Hedelin (99) in a KAMEDO report. Command & control was compromised as the result of insufficient pre-incident preparedness plans. Resources were ample and actually in excess of needs. By demand, several communication systems were in use as alternates to breakdown due to system overload, such as landline phones, mobile phones and radios. A need for computer systems for registration and identification of victims involved was observed. The report mentions the possible use of personal identification number like the one e.g., Sweden and Denmark utilize, to overcome that obstacle.

Heltne (100) provided a case report on fire in a tunnel in Gudvanga, Norway in 2013, injuring 66 people. Main findings were communication breakdown as the result of insufficient radio coverage inside the tunnel and inter-authority coordination issues. The complexity caused by two incident sites in neighbouring counties inflicted jurisdiction confusion and compromised intra- and inter-authority communication substantively.

A literature review by Hu (101) on lessons learned from September 11th, 2001 in the United States in light of the then recent Boston Marathon bombings and a mixed methods study by Huang (102) on a natural disaster in China in 2012 provided reflections and recommendations for future disaster management with communication focus. Operational details were not provided in those papers; however, they do represent important contributions for future MI and disaster management enhancement.

Hägnevik (103) covered the 1993 terrorist bomb attack on World Trade Centre, New York, USA, that killed six people and injured more than thousand. Lost command & control and the resulting inadequate inter-authority coordination were predominant findings. This was the first official terrorist attack on American soil by assumed Islamic extremists, trained in al-Qaeda training camp in Afghanistan. The World Trade Centre suffered substantive structural damage.

Iselius (104) provided a detailed KAMEDO report on the 1998 Eschede, Germany train accident, killing 101 and injuring 88 persons. The communication breakdown had actual consequences for patient management and outcome. The accident was the result of the derailing of a high-speed train at 200 km/h, crashing into a bridge that collapsed on two of the coaches. It was the result of a fatigue fracture in a wheelset of the high-speed train that prompted a change of design in the aftermath. The accident remains the worst rail disaster in Germany and the worst high-speed rail disaster in the world to date.

The 2011 buss rollover in Skaidi, Norway, that injured 22 people, was described in detail by Iversen (105), finding concerns on pre-incident communication setup and the use of several independent communication systems. This resulted in resource issues echoing EMCC reluctance to call in extra units and personnel, probably due to lacking shared situation awareness, caused by insufficient communication from incident site.

A school shooter in Jokela, Finland, killed eight and injured fourteen in 2007. The case report by Jama (106) found communication breakdown as the result of TETRA network difficulties. The beneficial effectiveness of Finnish TEMS concept was highlighted in the report. Jokela was the second school shooting in Finland after the 1989 Raumanmeri incident but was to be followed by the Kauhajoki School shooting in 2008.

The fire on board the ferry Scandinavian Star off Lysekil, Sweden, in 1990, killing 159 and injuring thirty, was reported by Kulling (108) who also reported on the devastating loss of the ferry Estonia (109) in the Baltic Sea between Finland, Sweden and Estonia in 1994, killing 852 and injuring 137. In both incidents, communication issues complicated cross-nation coordination and inflicted loss of command & control and information on the destination of the surviving victims.

The Scandinavian Star fire was the result of an arsonist that lit multiple fires on the ship en route from Oslo, Norway to Frederikshavn, Denmark. Blocked fire doors, insufficient initial fire drill training of the crew, lacking maintenance of essential fire equipment and an expedited inauguration of the ferry line were all contributors to the tragic incident.

The Estonia sank on its way from Tallinn, Estonia to Stockholm, Sweden. Causes are unclear at this point, since recent investigations as of September 2022 have demonstrated structural damage to the ship, suggesting a collision with a large object or as the result of an explosion. These findings contrast the initial conclusions of the Estonia commission that found that the loss of the bow visor due to rough sea and insufficient secure mechanism caused flooding of the car deck and the capsizing of Estonia. The shipwreck was pronounced an official tomb by the Swedish government to preserve the peace of the grave for the victims and to prevent divers from approaching the wreck for salvage hunting. The neighbouring nations sustained that decision.

In both events, lacking clarity of military and civilian authority in international waters and the significance of the flag nations of the involved vessels preceded difficulties in the management of these severe incidents. As of today, final decisions on legal responsibility and blame for the disasters are pending and several government commissions in Denmark, Norway, Finland, Sweden and Estonia have been established over the years. Documentary and feature films on the incidents underline the public interest in spectacular MI and disasters.

Lavery (110) reported on the Omagh, Northern Ireland, car bombing in 1998, killing 29 and injuring 336. Communication breakdown was the possible result of insufficient pre-incident communication setup. A branch of Irish Republican Army, Real IRA or New IRA took

responsibility of the incident. It was the deadliest single incident in the 30-year long Northern Ireland conflict between Catholic and Protestants.

Palttala (111) shared the results of a questionnaire on gaps in disaster and MI communication provided by international MI experts and non-governmental organizations. Emphasis was pointed towards the importance of communication in disaster and MI, both in regard to command & and control in disaster management and for public outreach in the immediate and long-term aftermath from natural disasters.

Picazo (112) disclosed the operational details from a prison fire in Santiago, Chile, killing 81 and injuring 21. The findings mirrored the need for preparedness plans to mitigate communication breakdown and loss of lives to the consequences of that. Furthermore, insufficient pre-incident EMS setup, prison crowding and the nature of the incident itself contributed to the unnecessary loss of several lives.

The train accident in Åsta, Norway, in 2000 caused 19 fatalities and 67 injured persons. The case report by Rehn (113) described the obvious need for high-fidelity communication systems such as the TETRA network to enhance inter- and intra-authority communication. The report found concerns about unclear pre-incident MI management guidelines and expressed the need for a national inter-disciplinary system for MI management. This was later established.

A gas explosion in a hospital in Mexico City, Mexico is described by Román-Morales (115). The incident injured 71 persons including 27 neonates. The explosion caused fire, discharge of infectious materials and radiation from equipment. For communication, breakdown was seen as the result of a pre-incident setup that included two separate emergency communication systems.

Finally, the results of a questionnaire on the repercussions of the 2011 Earthquake in Sendai, Japan, killing 19 747 and injuring 6 242, was presented by Yamamura (117), echoing the importance of reliable communication in MI management in an uncompensated disaster. The 9.1 Richter scale underwater earthquake caused an up to 40 meters tsunami and was

the most powerful ever recorded in Japan and a national state of emergency was declared by the state of Japan.

The compensated natural disaster caused an uncompensated industrial disaster, as the Fukushima Daiichi nuclear power station experienced the meltdown of three reactors and discharged radioactive water because of flooding of cooling systems. Hundreds of thousands of people had to be evacuated from the vicinity of Fukushima. The losses aside of human lives, injury and agony was calculated at 34.5 billion USD. In the aftermath, United Nations initiated the Sendai Framework evolved, that was intended to guide agencies to pre-emptive counteract natural and man-made disasters as opposed to mitigate the effects of those.

4.5 Data compilation

To provide information to support the inclusion of each source in the scoping review, all evidence details, characteristics and results from the extraction instrument applied were recorded in tabular format. The details of the included sources are summarized in Figures 5 and 6 and appendices 8.1 and 8.2.

4.6 Data sampling

Overall, 667/960 (69.5 %) of the 30-item checklist were answered by the included articles and papers in the scoping review. Information that proved hard to obtain from the available literature included the number of communication devices that was available in just two (6.3%) papers (4,105) and the background education in the use of communication devices that could be obtained from just two papers (6.3%). Similarly, information on the attempts to rectify communication breakdown was available in 14 papers (43.8%).

Items for data sampling are presented in Appendix 8.4.

Figure 5. Data sampling instrument

Figure 5. Data sampling instrument

	DEMOGRAPHY				COMMUNICATION				INCIDENT CHARACTERISTICS							
	Basic info affected area	Basic info on affected population	Accessibility in the region	Other relevant pre-incident data	Coms type	Type of coms device	Coms mode – in everyday ops and in MI	Other relevant coms characteristics	Time, date and place	Description of incident and damage it caused	Number of dead	Number of injured	Total number of victims involved	Scene access	Distance to hospitals	Other incident characteristics
Ackermann et al 2011	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	N	Y
Björnstig et al 2011	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
Brismar et al 1990	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Brändström et al 2006	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Brändström et al 2007	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Buerk et al 1982	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	N	Y
Butts et al 2007	Y	N	N	N	Y	Y	N	N	Y	N	N	N	N	N	N	N
Englund et al 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Gomez et al 2007	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hansen et al 2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hardy 2013	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hardy et al 2015	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hedelin et al 2006	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Helktne 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hu et al 2014	Y	Y	Y	Y	Y	N	Y	N	N	N	N	N	N	N	N	N
Huang et al 2012	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	Y
Hägnevik et al 1996	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Iselius 2004	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Iversen 2019	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Jama 2007	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Kapucu et al 2006	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	Y	N	N	N
Kulling et al 1993	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Kulling et al 1997	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Lavery et al 2005	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Palttala et al 2012	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Picazo et al 2010	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Rehn 2000	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Rimstad et al 2015	Y	Y	Y	Y	N	N	N	N	Y	Y	N	N	N	N	N	Y
Román-Morales 2015	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sollid 2011	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sollid et al 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Yamamura et al 2014	N	N	N	N	Y	Y	N	Y	Y	N	N	N	N	N	N	N

Coms: communication; MI: major incidents; Y: yes; N: no; ?: unclear

Figure 6. Data sampling instrument

Figure 6. Data sampling instrument (continued)

	INCIDENT RESPONSE													
	Information on how was the MI declared	The timeline for the medical response	Who participated	What tasks were performed	Patient logistics	Number of coms devise	Type of coms breakdown	Attempts to rectify coms breakdown	Fall-back/alternate coms system	Fall-back/alternate non-technical coms system	Background coms education	Scene safety	Cons breakdown consequences	Other incident response data
Ackermann et al 2011	Y	Y	N	Y	Y	N	N	N	N	N	N	Y	N	Y
Björnstig et al 2011	N	N	Y	Y	Y	N	Y	Y	Y	N	Y	Y	N	Y
Brismar et al 1990	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y
Brändström et al 2006	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y
Brändström et al 2007	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y
Buerk et al 1982	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y
Butts et al 2007	N	N	N	N	N	N	Y	Y	Y	N	N	N	Y	N
Englund et al 2012	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y
Gomez et al 2007	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y
Hansen et al 2021	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Hardy 2013	Y	Y	Y	Y	Y	N	Y	Y	N	N	N	Y	Y	Y
Hardy et al 2015	Y	Y	Y	Y	Y	N	Y	Y	N	N	N	Y	Y	Y
Hedelin et al 2005	Y	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	Y	Y
Heltne 2012	Y	Y	Y	Y	Y	N	Y	N	N	N	N	Y	Y	Y
Hu et al 2014	N	N	N	N	N	N	Y	Y	N	N	N	N	Y	N
Huang et al 2012	N	N	N	N	N	N	Y	Y	Y	N	N	N	Y	Y
Hägnevik et al 1996	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y
Iselius 2004	Y	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	Y	Y
Iversen 2019	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y
Jama 2007	Y	Y	Y	Y	Y	N	Y	Y	N	N	N	Y	Y	Y
Kapuca et al 2006	N	N	N	N	N	N	Y	Y	Y	N	N	N	Y	N
Kulling et al 1993	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y
Kulling et al 1997	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y	Y
Lavery et al2005	N	Y	N	N	Y	N	Y	Y	N	N	N	N	Y	Y
Palttale et al 2012	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Picazo et al 2010	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y
Rehn 2000	Y	Y	Y	Y	Y	N	Y	N	N	N	N	Y	Y	Y
Rimstad et al 2015	N	N	Y	Y	N	N	N	N	N	N	N	Y	N	Y
Román-Morales 2015	Y	Y	Y	Y	Y	N	Y	Y	N	N	N	Y	Y	Y
Sollid 2011	Y	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	N	Y
Sollid et al 2012	Y	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	Y	Y
Yamamura et al 2014	N	N	N	N	N	N	N	N	N	N	N	N	N	N

Coms: communication; MI: major incident; Y: yes; N: no; ?:: unclear

4. Discussion

4.1 Summary of findings

This thesis focused on communication within EMS and between authorities during management of sudden-onset major incidents. The attention was directed to the pivotal importance of adequate communication to maintain command & control in MI management. With the scoping review, the thesis aimed to identify and describe published scientific literature and nin-indexed literature to describe patterns and challenges in MI and disaster management.

The included papers were of varying quality and low level of evidence. The vast majority were case reports, which rank low in the hierarchy of research (118). However, the ability to provide answers to the review question was generally good and provides a foundation to identify knowledge and research gaps on the subject matter for future research efforts.

It has become evident that resource portals such as KAMEDO (40, 41) and majorincidentreporting.net (42-44) provide valuable and extremely useful information to improve future MI and disaster management, whereas scientific literature as such is sparse, heterogeneous and of low scientific quality in terms of level of evidence.

The lack of high-quality observational studies that describe epidemiology and generate hypotheses hinders conclusions that can be used by policy makers to develop guidelines for MI and disaster management other than those based on best practice or expert knowledge.

4.1.1 Major incident and disaster characteristics

The heterogeneous nature of MI and disasters are mirrored in the descriptions that range from compensated MI with ample resources to sheer chaos, endangering the survival and outcome of the victims.

Therefore, the included literature ranges from relatively simple MI related to road traffic incidents (89,97-98,105) to uncompensated natural disasters (117) and complex terrorist attacks (2,91-92,94-96,103,107,114,116-117) killing thousands of people. The included

incidents are distributed all over the world excluding Africa, which is incidental and unintended.

The EM-DAT database (23, 24) provides full insight to the demographic and geographical distribution of MI and disasters. It is established that natural disasters kill approximately 45 000 people each year. This number has decreased significantly as the result of better standards of living; infrastructure and enhanced response systems, even in World Bank defined (22) low-income countries.

The share of the Gross Domestic Product (GDP) inflicted by natural disaster relief costs is described by Pielke et al. (119) and apart from peaks, the number is decreasing but still accounts for 0.15-0.5 of global GDP. However, if we look at individual countries, huge variations from 0.05 to 5% are seen (120). Vulnerable nations including Afghanistan, Cameroun, Kenya and Samoa are substantively affected by devastating natural disasters such as earthquake, flooding and hurricanes.

Public attention to MI and disasters is traditionally massive. Spectacular incidents such as The September 11th, 2001 attacks (94, 107) on the United States have produced several feature films, thousands of articles and reports. On a smaller scale, the Great Belt train accident (4) yielded 861 articles in Danish media. Yet, the type and location of MI or disaster defines the degree of news coverage, described by Eisensee (121) who studied mass media influence on natural disaster response in United States.

Eisensee et al found that severity or the number of killed in the disaster is less important than how spectacular the media considers the incident. In numbers, they found that for one person killed by a volcano, 38 920 must die from famine to achieve the same probability of news coverage. Similarly, they found that 45 times as many people must die in a disaster in Africa to achieve the same media attention as one in Europe.

The United Nations Human Development Report (122) establishes that in nations where a large percentage of the population still lives in extreme poverty (22), or receive a low Human Development Index (123), citizens are significantly more vulnerable to suffer from the effects

of MI and natural disasters. It is stated in the report (122) that general development, poverty relief, and enhanced resilience to natural disasters will be key to reducing death to disasters.

4.1.2 The importance of communication

Valuable information of the communication setup in daily practice and in MI and disaster scenarios is provided in the majority of the included literature, with varying degrees of detail. The general impression is that communication challenges in MI and disasters are described as problematic but remain generally unquantified in the included papers. The efforts to overcome communication shortcomings and breakdown mirrors the action-principle (32) described earlier and the stamina, resilience and conscientiousness in EMS professionals.

Nevertheless, the scoping review has described some degree of communication breakdown in 72 % of the incidents. Factors other than the rare occurrence of MI and disaster must play a role. EMS personnel may be challenged by MI guidelines (8, 31, 32) that are significantly different than in daily operations. Despite micro training, tabletop and full-scale MI exercises, the review has demonstrated substantive communication challenges.

As described by Holm (35), the initial training in operating communication devices is under prioritized to medical skills and the Danish CFB report (61) confirms some degree of lacking skills in EMS professionals. The significant difference between everyday operations and rare, complex MI may be one of several factors that may lead to communication challenges or breakdown. The Startle effect (62) and the general term “human factors” have been described earlier but that is hardly the full explanation.

In a paper by Hart (124), sociocultural background played a major role in attitudes toward encoding communication. The national and cultural origin influences the so-called rhetorical sensitivity, described by Ting-Toomey (125). Japanese, French and United States respondents preferred substantively different styles of communication to encode messages in the best possible manner.

In Scandinavian EMS, two- or three tiered systems (4, 126) are predominant, i.e. personnel with background ranging from ambulance workers to prehospital physicians. The

prerequisite background education is inherently varying, giving rise to different attitudes towards acquisition of new skills.

In EMS systems (126) using physician-manned units such as mobile emergency care units and HEMS, the physician is the highest medical resource and the natural leader. Leadership – followership dynamics have been described extensively (127, 128). In daily operations, teamwork is presumably straightforward, whereas in MI and disaster scenarios, stress, fatigue, work overload and other human factors may lead to misbehaviour (129) from both parties in their interaction. The probability of human error (130) is substantively increased, supported by the findings in this review.

Measures to mitigate teamwork challenges are widespread in the aviation industry (131) and in the medical field (132, 133). For Scandinavian and most European HEMS systems, the industry-derived mandatory annual courses in Aeromedical Crew Resource Management (ACRM) utilizes the European HEMS and Air Ambulance Committee (EHAC) (134) standard for education and training.

A literature review by Thompson et al. (135) describes the crucial role of HEMS teams in MI management, also found by Johnsen (136). Both papers find that the HEMS team is expected to assume medical command of MI management. This may be due to incident location, expedited response inherent in rotor-wing aircraft, medical seniority or as the result of a prerequisite role in MI management, mirrored in MI management documents such as in Danish REFIL (8) and similar Finnish (30) and Norwegian (31) guidelines.

4.1.3 Challenges in major incident communication

The scoping review has demonstrated knowledge and research gaps in the included material, calling for systematic scientific research in the field, since the majority of the included papers describe communication breakdown with consequences for patient survival and outcome and for society's expedited return to a normal state.

Comprehensive guidelines (8, 30, 31) clearly describe MI communication. Guidelines serve to establish and maintain command & control and therefore, it follows that when communication is compromised or break down, command & control may be at risk at

personal; team; and management level. Measures to mitigate lost command & control are simple in everyday operations; however, in MI, complexity and the breakdown of essential systems may tamper those attempts.

Communication with authorities and units other than those involved in MI management may include receiving hospitals, emergency management agencies, and voluntary organizations. Guidelines for that do exist, however in-depth knowledge of their operation and responsibilities is key.

There may be risks involved in MI management and the concept of operating in chaos may compromise MI communication. The Pre-Hospital Trauma Life Support (PHTLS®) (137) concept that is utilized in several EMS systems describe scene safety (138, 139) in detail. In short, a scene is not safe for EMS personnel until it has been declared so by Police and Fire & Rescue services. In that concept it is inherent, that patient treatment cannot be performed in that part of the incident scene due to the risk of injury to personnel.

Patients will have to be evacuated from the unsafe zone for treatment other than first aid measures and for triage. Naturally, patient survival and outcome may be substantively tampered by that concept and efforts to stop both the killing and the dying from e.g., terrorist attacks are implemented in most EMS services.

The TEMS (26-28) concept in a Scandinavian context has been mentioned earlier and the effects (140) and experiences (141) described as well, suggesting that both TEMS and Tactical Emergency Casualty Care (TECC) (142, 143) are important concepts in the post-9/11 era.

4.1.4 Consequences of lacking communication in major incidents

The consequences of breakdown of communication are described in detail in (25) 78% of the included papers. The complexity of MI and disaster response is mirrored in the difficulty to describe the direct consequence on patient outcome of communication breakdown. In less complex incidents with ideal incident scene build-up, communication breakdown may not influence command and control and patient management (4), whereas multi-national marine incidents (108, 109) are characterized by some degree of chaos and loss of command & control.

In the Scandinavian countries, every health professional is obliged by legislation (144) that defines the responsibilities of authorities, e.g., state, regions, municipalities, personnel etc. The legislation adheres to the Declaration of Human Rights (145, 146), e.g., right to life, care, private life and equality including medical care. The majority of nations in the world have signed the declaration.

In some of the included literature (2, 4, 91, 94-95, 107, 114, 116-117), the declaration of a state of emergency (147) is described. When a fundamental threat to a nation is imminent, a government has the power to declare a state of emergency in response to the extraordinary situation. Normal government functions, legislation, and selected human rights are suspended with the declaration. Government agencies are authorized to execute preparedness plans and restrictions on economic, political and civil activity may be implemented.

There are two essential components in a state of emergency legislation. Firstly, the legal framework, that encompasses the legislative and constitutional foundations. Secondly, the operational framework that describes the organizational structures and strategies to mitigate the effects of the state of emergency.

States declaring a state of emergency are obliged by international treaties such as European Convention of Human Rights and Fundamental Freedoms (148) and the International Covenant on Civil and Political Rights (149) to observe important aspects such as temporality, proportionality and legality. Certain human rights can never be limited, including right to life, humane treatment and the integrity of the legal system.

4.1.5 Consequences of lacking initial training in the use of communication devices

Holm (35) has described the effects of lacking initial training in the use of communication devices among Danish prehospital physicians. A shocking 38 % did not receive any initial training at all, whereas 29 % rated their own skills as advanced or expert level. Thirty-one percent of the responders did not feel capable to handle communication in a MI sufficiently.

The seemingly deliberate choice from EMS managers to prioritize core medical skills over communication skills may be hard to comprehend. The findings of this review underline the

need to emphasize basic training before entering service in EMS and implement ongoing training or line checks in the ability to use communication devices proficiently.

Simulation in the use radio communication has not been utilized (150) whereas simulation in e.g., prehospital trauma care (151) and ultrasound (152, 153) are widely implemented with significantly improved performance after completing training. In the study by Holm (35), it is recommended to implement simulation to improve communication skills.

In a case report by this author (4), it was found that almost half of Danish prehospital physicians do not have the formal education in MI management. It comprises a three-week intensive course with several tabletop and full-scale exercises and an exam. The use of communication devices such as TETRA radio and digital platforms is trained extensively throughout the course and lessons in the basics of operating the devices are included.

Danish prehospital physicians that have not received formal training as the result of bottleneck and financial issues receive a very basic introduction to communication devices. It is likely that their skills in operating communication devices are less comprehensive, compared to those with formal training, giving rise to insufficient usage of the options as described in a report (61).

Radio operations in daily life and MI and disasters scenarios should optimally be the same but in another magnitude. That is unlikely in terms of increased complexity in MI, stress, fatigue and other human factors such as the Startle effect (62) described earlier. The Endsley's Model of Situation Awareness (60) explains that the sequence of Perception – Comprehension – Projection is necessary for decisions and performance of actions to happen. The effects of both task/environmental and individual factors are enhanced in MI scenarios. Consequently, the mental workload is significantly increased.

4.1.6. Data sampling

The items of interest used in data sampling were created to the discretion of this author, based on personal assumptions on relevance to describe MI and disaster communication and inspiration from similar studies (1, 154) on MI and disaster management. In future research on the subject to allow for data analyses, items of interest to describe MI communication

should be uniformly defined for scientific use, as described in studies on the Utstein template (155, 156).

The implementation of the Utstein template is evaluated in a paper by Otto et al. (157), finding that the concept has become well established with a prolonged and far-reaching impact. Especially in research on resuscitation, pre-hospital and disaster medicine but also evolved to influence new disciplines such as veterinary, stroke and space medicine. The Utstein Formula for Survival in Resuscitation (158) is one major achievement of the concept that hypothesizes that medical science, efficiency of education and implementation will improve survival from cardiac arrest.

The impact on EMS is seen in the Utstein involvement in The Global Resuscitation Alliance (159), a global effort to promote best practices and implement emergency management systems to improve survival after cardiac arrest. Therefore, the application of the Utstein template is one way to scientifically qualify and solidify future research in MI communication.

4.1.7 Low volume – worse outcome phenomenon

Despite immense public and societal attention (4, 121) MI are rare occurrences. In a study by Johnsen et al. (154), just 0.16% of HEMS missions in Norway were MI. The subsequent lack of experience and routine is an inherent risk in MI management and communication challenges, or breakdown is most likely to be the result of the very few MI that EMS personnel encounter.

The “High volume – better outcome” phenomenon has been described in a systematic review (160) and despite limited quality of available evidence; volume-based managerial policies by themselves could result in better outcomes. However, only a few studies describe the underlying circumstances echoing a positive volume-outcome association.

The opposite “Low volume – worse outcome” has been described as well (161) by Tracy et al, concluding that significant volume-outcomes relationship exists with the recommendation of minimum annual volume requirements. Northup et al challenge these findings in a paper (162) that cannot justify the volume – outcomes relationship. Transferability to MI management and communication challenges may seem speculative.

However, the relationship would be obvious but has not been investigated. The findings of this scoping review indicate that a relationship does exist, since MI communication breakdown is frequent.

4.1.8 Intra-authority communication

EMS setup in daily life may differ substantively between socio-economic arenas and is described in detail in 78 % of the included literature. The transition from daily life into MI scenarios requires the addition of extraordinary resources as per MI definition (5) utilized in this review.

In MI and disaster, communication pathways are intuitively substantively more complex than in daily life, as several authorities are involved on different levels (163) (Also see figure 1). For intra-authority communication in MI to be successful, unambiguous, intuitive and transparent communication grids are essential and they are provided in every EMS (8, 30, 31). Basic knowledge of the grid, frequent micro training and regular exercises in the communication is essential to command & control in MI and disaster management.

In most European systems, the prehospital physician is appointed the leader of the medical team (135). However, leadership skills in physicians may be varying and not necessarily the result of a formal education (4). In a systematic review by Sadowski (164) it was found that leadership curricula in graduate medical education was mediocre in quality; mostly based on mentorship and coaching and limited in its effectiveness.

When physician do educate themselves in leadership, Frich et al demonstrated in a systematic review (165) that leadership development programs are associated with increased self-assessed knowledge and expertise. Focus is on individual outcome rather than on system level. Therefore, the effects of educated leadership performance remain less quantified.

The EMS arena may be a hostile environment (166) as opposed to the safer hospital surroundings. Mostly, transportation related incidents and assault in the EMS are predominant, as for female personnel to be more prone to injury (167). Brutalization and

burnout (168, 169) in EMS are becoming major problems and a harsh tone among EMS professionals is not believed to contribute positively to intra-authority communication.

4.1.9 Inter-authority communication

Communication is one of the key foundations of inter-authority cooperation (170). However, several obstacles could compromise inter-authority communication, including different wordings; the widespread use of abbreviations; different nomenclature between authorities and finally different priorities in respective sectors.

Especially the use of abbreviations may be a challenge in inter-authority communication and lead to mistakes, described by Holper (171). In the paper, the authors found that more than thirty percent of all abbreviations used in a general medical unit were ambiguous. Coghlan et al. (172) found the same pattern in the use of abbreviations in hospital discharge summaries, leading to potentially compromised patient care.

MI managers from different sectors have the same objective, but different angles and priorities may hinder common tactical progression in the management. However, in complex arenas such as MI, organizations tend to develop both formal and informal relationships in the shared efforts, described by Kapucu (173). Grounded in network and complexity theories, the concept of interdependency between authorities in extreme situations is described. Interdependency may positively influence organizations in their adaptation to very dynamic arenas such as MI, for a better outcome.

The need for a common language between MI parties involved is pivotal. The mutual education for incident commanders in Denmark described by this author (4) is of major importance. MI and disaster exercises may be extremely useful and paramount in the training of MI resilience and is described in another section.

4.1.10 Major incident exercises

Findings from large-scale exercises do exist (174, 175) or public availability. In a paper by Porthouse (176) on MI exercises in United Kingdom, the importance of train the team-based

approach and efficient communication in addition to effective command & control is described.

MI preparation may come in several formats, from a simple review of established plans over tabletop exercises to full-scale, high fidelity scenario training. In Linköping, Sweden, Katastrofmedicinsk Centrum provides training facilities for both full-scale and tabletop training in MI incident management. Communication focus is mirrored in the academic production (177, 178) from the unit as for the development of the Emergo Train System®, described in a paper by Nilsson (179).

The Emergo Train System® consists of a patient database with specific casualties, together with specific staff and other types of resources such as vehicles, HEMS, SAR etc. involved in MI. The system is ideal to adapt local pre- and in-hospital setup into the system for realistic exercise purposes. The victim bank encompasses specific injury categories and each victim has specific medical needs within a certain period that must be met.

In Denmark, a national full-scale exercise (180) comprising all authorities involved in MI management is held every second year. The KRISØV or National Crisis Exercise is a spectacular event requiring months of planning and multiple locations. The scenarios have included cyber-attack, nuclear accident, terrorist attack and chemical accident. The participating authorities evaluate every exercise and publish a full report (181) with key lessons.

4.1.11 Major incident case reports

The vast majority of included literature in the scoping review are case reports, limited by their retrospective, non-blinded, and nonrandomized trial design. By itself, that constitutes a source of biases that affects study outcome (182). Therefore, findings provided by case reports might not be generalizable and could not be useful to establish a cause–effect relationship, with a consequent high risk of over-interpretation.

In a study by Krusenvik (183), the advantages and disadvantages are addressed. Case reports may provide in-depth relevant data, since they originate from reality and may promote an understanding of complex real-life situations. Findings are context-sensitive and may

enhance new theories and add strength to previous research findings. The disadvantages are their limited generalizability and rigor. In conclusion, the study finds that, like all research methods, case studies as a scientific method have both advantages and disadvantages.

Crowe et al. (184) found that the case studies are suitable for the detailed, real-life context description of e.g., critical events and interventions. Therefore, case studies should be considered when no available experimental design is appropriate to answer the research question.

MI and disaster resource portals such as KAMEDO (40, 41) and majorincidentreporting.net (42-44) provide valuable operational and background information and several of the included articles stem from those portals.

KAMEDO reports are comprehensive in volume and detail and produced by experts who have not been part of the incident management team. However, their structure is varying and do not strictly follow a general format. This limits comparison to some degree. On the other hand, the publications from majorincidentreporting.net all use the same structure, are easily approached and can be compared for the sharing of experience and expertise by colleagues in the same field of interest.

Similar forums do exist, such as Society for Disaster Medicine and Public Health (185), National Centre for Disaster Medicine and Public Health (186); both providing peer-reviewed publications and research.

4.1.12 Stress and fatigue in major incident communication

Stress and fatigue described earlier, are important human factors that may influence MI communication. A recent study by Maleczek (187) underline the stressful environment of the EMS arena. In otherwise healthy Austrian EMS physicians, ECG abnormalities were present in 70% of the included individuals during strenuous shifts and particularly during alarms at night. Therefore, stress impact is an important contributor to compromised performance.

Stress levels may vary between individuals and remedies such as the National Aeronautics and Space Administration Task Load Index (NASA-TLX) (188) and cognitive appraisal (189,

190) may be tools to quantify stress levels among EMS professionals. EMS management should endorse the recognition of stress as an important barrier to proficient communication.

Fatigue may also play a role in troubleshooting MI communication challenges. Research confirms that in e.g., Canadian paramedics, 55% reported that were fatigued at work, and the study by Donnelly et al. (191) found a solid association between fatigue and safety outcomes. The respondents reported a significant overrepresentation of injuries, safety compromising behaviours and errors or adverse outcome due to fatigue.

Efforts to mitigate the effects of fatigue in EMS are described by Patterson (192), suggesting evidence-based guidelines for fatigue risk management. In a series of systematic reviews, the deleterious effects of fatigue on EMS professionals are described, stressing the need for fatigue management. Barger et al. (193) describe the beneficial effects of fatigue training on safety and health outcomes among EMS workers. Similar findings on the effect of scheduled napping were seen in a systematic review (194).

HEMS systems are exposed to fatigue in the same manner as ground-based units. However, flight and duty time rules (195) limit the magnitude of fatigue experienced as aviation. Ground-based units are under the rules and regulations of e.g., the European Union (196), yet the rules in EMS differ between countries and how the EMS is organized.

4.1.13 Future communication devices

Although new systems are emerging, the TETRA radio is the currently the most widespread means of communication. However, concerns in terms of restricted bandwidth and the limited options of streaming e.g., drone footage from an incident site, indicate the need for future communication devices. Similarly, the interface design of TETRA radios is of concern to some authors (4) and may have contributed to communication challenges in the past.

Kapucu (197) has addressed the design, capabilities and important aspects such as encryption in an attempt to describe the needs of EMS personnel for reliable and easy to use future communication systems. Emerging new technology (198) at low cost enables the

development of a multi-function device to ensure sufficient communication and support the dissemination of high-stakes decisions in both everyday life and in MI management.

Danish police is currently testing a new multi-function communication device (199) on the Faroe Islands. It combines the user-friendly interface design of a regular smartphone with assets such as large bandwidth, a large screen, multiple options for inter-authority information sharing, using its own, encrypted mobile net, inaccessible to foreign intruders, as described in an interview with this author (200).

5.1.14 Triangulation of research in major incident communication

The results from the scoping review elicited research gaps. To counteract that, the combination of different research methods may be one way of creating research to provide a foundation for e.g., consensus guidelines. Methodological triangulation (201, 202) involves the combination of qualitative and quantitative methods in one study. Methodological triangulation applies different methods in the efforts to answer the same research question.

Data triangulation (203) describes the process where several data sources are applied, combining e.g., data collection in time, space or populations to enhance generalizability. Similarly, investigator and theory triangulation use the combination of multiple investigators and theories respectively to mitigate e.g., observer bias and see a research question from different angles to avoid blind spots.

Triangulation of research methods should provide a more complete picture of a current research problem. Furthermore, bias is reduced when relying on several data sources, methodologies and investigators. Finally, research validity and credibility may be enhanced when combining complementary methods to compensate for their individual limitations. On the other hand, triangulation of research methods is very time-consuming and thus costly. Similarly, the combination of different data sources, methods and investigators may prove to be inconsistent or contradictory but can lead to a different approach.

4.2 Strengths and limitations

4.2.1 General strengths and limitations

Items for data extraction and quality appraisal were selected by this author for their assumed relevance and ability to answer the review question. These items may not be complete or represent a reference standard, since no such standard exists. Similarly, it may represent a potential weakness that only articles in English and Scandinavian languages were included, since MI occur worldwide and predominantly in World Bank defined developing countries as the result of natural disasters. This represents a language limitation. Scientific articles without abstracts were not included which may have failed to identify relevant studies. The single reviewer format of this scoping review may also have contributed to that.

The use of a priori protocol registered ahead of any searches contributed to an unbiased search for all relevant literature relevant to answer the review question. The very few protocol deviations even so. The research processes are clearly described and documented; therefore, reliability is high and other researchers would be able to conduct the same study.

The unintended inclusion of multiple reports on the same spectacular incidents is indicative of a potential skewness and selection bias.

The overrepresentation of case reports in the included articles and papers represents an inherent bias since case reports are limited by their retrospective, non-blinded, and non-randomized trial design. Therefore, the findings are neither generalizable nor useful in establishing a cause-effect relationship, thus there is a risk of over-interpretation.

However, some, but not all, learning points from case reports may be generalizable to similar EMS systems and geo-political arenas. A standardized way of reporting MI such as the one used in majorincidentreporting.net would produce more data on MI management and response for future enhancement.

On the other hand, case reports may contribute to an almost complete picture of the operational descriptions of MI communication, which is beneficial for future MI management and the development of guidelines for communication, reporting and inter-disciplinary cooperation in MI management.

Level of evidence as per ILCOR (86) was very low, LOE D5, i.e., “studies not directly related to the specific patient/population (e.g., different patient/population, animal models,

mechanical models, etc.)", confirming the inability to provide the foundation for evidence-based guidelines for MI and disaster response.

The use of adjuncts such as PRISMA (87) PRISMA-ScR (82) guidelines is essential to promote and enhance scientific transparency in systematic and scoping reviews.

4.2.2 Reliability and validity

The replicability of research results for other researchers refers to reliability (204) of a scientific study, whereas validity (205) refers to accuracy. Internal validity is the ability of included indexed and non-indexed literature to measure the intended items of interest, whereas external validity refers to generalizability to other geo-political and socio-economic arenas. In theory, inter-rater reliability (206,207) and test-retest reliability mean that other researchers would be able to reproduce the same results.

The quality appraisal of the scoping was conducted as per pre-registered protocols (78, 79), aimed at depicting the internal and external validity. In general, the scientific quality of the included papers was mediocre, based on lacking ethics committee approval and declaration of interest conflicts. Likewise, internal validity was low since several of the items in question were unaccounted for. The same goes for external validity, however with better ability to answer the questions available for that.

This thesis provided pre-registered protocols, enabling researchers to conduct s similar study and for reliability enhancement. Protocol amendments were registered promptly. However, for PROSPERO (78), COVID pandemic related issues inflicted that the protocol and subsequent ammendments were simply registered and not peer-reviewed up until October 4th, 2022.

For the included indexed and non-indexed literature, none had protocols as such, since the vast majority was case reports. Detailed information on the study design was however available in 30/32 papers, whereas missing data accountability and limitations discussion were lacking in general, reducing external validity of the included literature.

Inter-rater reliability (206, 207) and test-retest reliability were not applicable in the scoping review. Content validity (208) goes to establish the relevance of the measured data, in this case items of interest. To this author's best knowledge, no previous studies have addressed MI communication in in the same manner and therefore, an established common dataset has no tradition. Consequently, content validity of the measured data could not be assessed.

4.2.3 Scoping review strengths and limitations

The benefits of available guidelines for scoping reviews such as PRISMA-ScR (82) and Joanna Briggs Institute (71-74) are obvious. The application of structure and evidence-based methods for the conduct of searches following proper registration at recognized platforms support scientific reliability and validity and first and foremost, transparency and objectivity. The scoping review adhered to the registered protocols in every possible manner.

The conduct of a scoping review requires formulation of data sets or items of interest. The lacking uniform, agreed-upon definition of MI[1] to some degree hindered the formation of unambiguous items.

The single-reviewer format produced uncertainty towards missing important sources of information or including papers of limited relevance to answer the review question. This may be a substantive bias. The lacking option of sharing doubts and insecurity with a co-reviewer was somewhat frustrating, compromising the ambition to be in line with methodological guidelines. Finally, the heterogeneity of the material assessed for inclusion in the review represents an inherent bias, i.e., the low level of evidence and lack of structure in the included material in itself represents bias.

4.3 Challenges in the thesis

4.3.1 Attempts to create guidelines

Attempts to create consensus guidelines in lack of scientific evidence often include the formation of expert groups within a small field of medicine. Their efforts are often and to this author possibly unfairly referred to as the GOBSAT (209) phenomenon, i.e., Good Old Boys Sat Around the Table, discussed in a thesis by Bolle (210). The condescending acronym

suggests that the approach is unscientific and that another group could have come up with other conclusions. On the other hand, these considerations may be fair and the risk of creating echo chambers is imminent, when relying on the same colleagues and experts in the field. They may have a tendency to attend the same conferences and courses and be the initiators of the same projects and are invited to participate in expert panels such as Delphi rounds by their expert colleagues.

The Delphi techniques (211, 212) serves to answer a research question through consensus among subject experts. This scientific method uses the reflections among experts, who are able to nuance and reconsider their opinion based on the input from anonymized co-participants. The Delphi technique has been suggested for the development of reporting guidelines (213) but unfortunately not been widespread (214) or that purpose. The technique has also been criticized for low reliability (215, 216) and it is recommended to carefully use available guidelines (217) and as far as possible seek to ensure high response rates when conducting Delphi technique research to enhance validity.

4.3.2 Dissemination of findings

The dissemination finding from a scientific study includes publication in indexed academic journal articles, in books or in published theses. If not published, the findings will remain non-indexed literature, discussed earlier. Most scientific and academic journals are peer-review (218, 219) based, i.e., an editorial refereeing to ensure quality for publication. Peer-review also serves to mitigate plagiarism and most of all, to reject low-quality work. Consequently, high-profile journals have rejection rates (220) up to 90-95% of submitted articles.

It is widely accepted, that peer-reviewed journals are superior in academic merit to so-called secondary sources such as review journals, books and compilations. Tertiary sources include encyclopaedias. For knowledge to disseminate, publication in peer-reviewed, acknowledged journals is key.

At the other end of that spectrum are predatory journals (221, 222) that promise editorial and publishing services, that are not provided and with the sole purpose of fiscal profit at the expense of scientific quality. Academically inexperienced researchers, eager to publish their

work or intrigued by a potential job position to publish, may be lured by predatory journals, putting their future careers at risk. Initiatives to identify and eliminate predator publishers to mitigate the threats to evidence-based research are described by Van Nuland (223).

Case report overrepresentation was found in this scoping review, reflecting the lack of high-quality research on the specific matter of MI and disaster communication. Until recent years, the conduct of randomized controlled trials in the pre-hospital field has been very limited, restricted be tradition, ethical considerations and feasibility.

However, large-scale, multi-centre, randomized controlled trials such as TRAUMOX2 (224) in Denmark, Germany and The Netherlands and REBOARREST (225) in Norway, Denmark and Italy are being conducted currently; the latter based on a pilot study (226) showing promising results and the feasibility of a complex research project in the prehospital arena. Therefore, the conduct of similar studies in the field of MI and disaster medicine is no longer unrealistic and should be endorsed despite the rare occurrence of such incidents.

5. Conclusions

5.1 Conclusions

This scoping literature review aimed to search, identify, describe and critically appraise current scientific and non-indexed literature describing communication in sudden-onset major incident management. The efforts of the scoping review were to some degree hindered by heterogeneous reporting of relevant data and lack of a quantified description of communication challenges in the management of major incidents and disasters. The patterns of communication in major incidents are frequent breakdown for mainly unspecified reasons and the challenges are predominantly inter-authority communication issues affecting command & control.

5.2 Implications of the findings for research

The findings of this scoping review illicit the need for further research in the topic to improve future MI communication and to provide EMS organizations and personnel with human and technological skills that can support command & control in MI. This scoping review has demonstrated severe gaps in knowledge and research on MI communication. Therefore, the conduct of a systematic review on the topic is essential to obtain peer-reviewed scientific knowledge. This scoping review is intended to be the precursor (73) of a systematic review. The current findings in the review of lacking types of available evidence in the field support that ambition.

The need for standardized MI and disaster reporting using templates preapproved by local ethics committees and in line with local national legislation should be endorsed or even mandatory for rapid dissemination of actual or potential issues relevant for MI and disaster management and response. The template should include detailed communication characteristics for comparison and future improvement.

5.3 Implications of the findings for practice

The included material discloses that communication challenges or breakdown is predominant in MI and represent threats to firstly command & control and secondly patient

survival and outcome. There is a need for easy-to-use and reliable communication devices and unambiguous guidelines for communication. Forehand training in the use of communication devices should be highly prioritized at the same level as medical skills and efforts to enhance resilience and mitigate option paralysis are pivotal.

5.4 Future research perspectives

The agreement on a uniformly accepted nomenclature and common definitions of major incidents and disasters are essential. The use of common entities in the description of major incidents will enhance evaluation and dissemination of lessons learned in major incident management locally and internationally.

This thesis found that the predominant research design was case reports with weak methodology and low levels of evidence, suggesting that until hypotheses are generated for future research, systematic reporting should be endorsed or mandated by EMS management. Reporting resources such as majorincidentreporting.net and similar portals should enjoy the support and endorsement from management and authorities, perhaps using public outreach in forums such as EUPHOREA (227) and MIMMS (9).

The future might call for an international multicentre, prospective observational study on major incident communication with focus on command & control and intra- and inter disciplinary communication. Endpoints should include communication guideline adherence and efforts to mitigate communication challenges and the possible consequences for patient survival and outcome.

Similarly, feasibility or simulation studies of new communication methods and implementation of guidelines could provide knowledge on future MI communication progression. This scoping review has demonstrated research and knowledge gaps that would benefit from a deeper understanding and dissemination of experience from e.g., studies performed during large-scale or tabletop exercises. Likewise, the possible transportability of military experiences would be beneficial; however, confidentiality and secrecy issues might hinder that.

A Delphi technique study among MI experts to explore important aspects and items for communication based on experience would provide important knowledge for future MI preparedness plans and guidelines. A follow-up feasibility study would clarify the impact on MI management in exercises and real-time incidents.

In conclusion, the importance of communication in sudden-onset MI and disasters must be enhanced and mirrored in guidelines by way of combined qualitative and quantitative research methods.

5.5 Conflicts, funding and acknowledgements

5.5.1 Conflicts of interest

None declared.

5.5.2 Funding

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7. Tables and figures

7.1 List of tables

7.2 Table of figures

8. Appendices

8.1 Overview of included literature

Study designs and description of communication in sudden-onset major incidents.

Paper	Method	Description of communication
1. Ackermann et al. 2011	Case report	Injury focus; preparedness plans; hospital capacity
2. Björnstig et al. 2011	Case report	Command & Control; cooperation; coms breakdown
3. Brismar et al. 1990	Case report	Command & Control, MI declaration, coms breakdown
4. Brändström et al. 2006	Case report	Command & control; coms breakdown; Medevac
5. Brändström et al. 2007	Case report	Command & control; coms breakdown, triage
6. Buerk et al. 1982	Case report	Scene description; information flow; triage; HEMS
7. Butts et al. 2007	Mixed methods	Coms breakdown; alternate pathways,
8. Englund et al. 2012	Case report	Command & control; inter-authority communication, Intra-authority communication
9. Gomez et al. 2007 (Same MI as Brändström et al. 2007)	Case report	Command & control; coms breakdown
10. Hansen et al. 2021	Case report	Coms grid adherence; affiliation times; pre-incident coms education; coms breakdown consequences
11. Hardy 2013	Case report	Intra-authority communication issues, inter-authority communication issues
12. Hardy et al. 2015 (Same MI as Hardy 2013)	Case report	Intra- authority communication issues.
13. Hedelin et al. 2006	Case report	Command & control; pre-incident preparedness
14. Heltne 2013	Case report	Coms breakdown; coms coverage; coms limits
15. Hu et al. 2014	Literature review	Inter-authority and cross-sector coordination
16. Huang et al. 2012	Mixed methods	Disaster response focus; coms breakdown
17. Hägnevik et al. 1996	Case report	Command & control; inter-authority communication
18. Iselius 2004	Case report	Command & control; coms breakdown consequences
19. Iversen 2019	Case report	Command & control; pre-incident coms setup
20. Jama 2007	Case report	Inter-authority coms; command & control
21. Kapucu et al. 2006 (Same MI as Butts et al.)	Consensus paper	Inter-authority communication; coms breakdown.
22. Kulling et al. 1993	Case report	Command & control; cross-nation coordination
23. Kulling et al. 1997	Case report	Cross-nation coordination; alternate coms
24. Lavery et al. 2005	Case report	Intra-authority communication; pre-incident issues. Coms breakdown
25. Palttala et al. 2012	Questionnaire	Coms challenges; coms training and experience
26. Picazo et al. 2010	Case report	Command & control; pre-incident preparedness.
27. Rehn 2000	Case report	Command & control; coms breakdown; triage
28. Rimstad et al. 2015 (Same MI as Englund et al.)	Mixed methods	Situation assessment; information sharing; knowledge and experience; decision making focus
29. Román-Morales 2015	Case report	Command & control; inter-authority issues; coms breakdown; funding of coms
30. Sollid 2011 (Same MI as Englund et al.)	Case report	Command & control; inter-authority communication. intra-authority communication; coms breakdown
31. Sollid et al 2012 (Same MI as Englund et al.)	Case report	Command & control; inter-authority communication. intra-authority communication, coms breakdown
32. Yamamura et al 2014	Questionnaire	Intra-authority communication, coms focus

Coms: communication; MI: Major incident; HEMS: Helicopter emergency medical service; Medevac: medical evacuation

8.2 Overview of major incident characteristics from included literature

Major incident characteristics from included literature.

Paper	Location	Dead/Injured	Type of MI/disaster
1. Ackermann et al. 2011	GER	21/500+	Mass gathering at music festival
2. Björnstig et al. 2011	SWE	30/355	Buss crashes
3. Brismar et al. 1990	GER	70/346	Air show plane crash
4. Brändström et al. 2006	RI	202/300+	Terrorist bomb attacks at bars/discos
5. Brändström et al. 2007	ESP	193/2 050	Terrorist train bomb attacks
6. Buerk et al. 1982	USA	85/613	Hotel fire
7. Butts et al. 2007	USA	2 995/2 680	2001 9/11 World Trade Center terrorist attack
8. Englund et al. 2012	NOR	76/159	Oslo/Utøya terrorist attacks
9. Gomez et al. 2007	ESP	193/2 050	Terrorist train bomb attacks
(Same MI as Brändström et al. 2007)			
10. Hansen et al. 2021	DEN	8/15	Train collision on bridge
11. Hardy 2013	UK	0/69	Road traffic accident on bridge
12. Hardy et al. 2015	UK	0/69	Road traffic accident on bridge
(Same MI as Hardy 2013)			
13. Hedelin et al. 2006	UK	31/417	Train accident
14. Heltne 2013	NOR	0/66	Truck and tunnel fire
15. Hu et al. 2014	USA	N/A	N/A
16. Huang et al. 2012	CN	N/A	N/A
17. Hägnevik et al. 1996	USA	6/1 000+	1993 World Trade Center terrorist attack
18. Iselius 2004	GER	101/88	Train accident
19. Iversen 2019	NOR	0/22	Buss rollover
20. Jama 2007	FIN	8/14	School shooting
21. Kapucu et al. 2006	USA	2 995/2 680	2001 9/11 World Trade Center terrorist attack
(Same MI as Butts et al.)			
22. Kulling et al. 1993	SWE/DEN	159/30	Scandinavian Star ferry fire
23. Kulling et al. 1997	FIN/SWE/EST	852/137	Estonia ferry shipwreck
24. Lavery et al. 2005	NIR	29/336	Terrorist bomb attack
25. Palttala et al. 2012	N/A	N/A	N/A
26. Picazo et al. 2010	CHI	81/20	Prison fire
27. Rehn 2000	NOR	19/67	Train collision
28. Rimstad et al. 2015	NOR	N/A	Oslo/Utøya terrorist attacks
(Same MI as Englund et al.)			
29. Román-Morales 2015	MEX	0/71	Gas explosion at neonate hospital
30. Sollid 2011	NOR	68/61	Utøya terrorist attacks
(Same MI as Englund et al.)			
31. Sollid et al. 2012	NOR	76/159	Oslo/Utøya terrorist attacks
32. Yamamura et al. 2014[117]	JPN	19 747/6 242	Earthquake East Japan

MI: Major incident; N/A: not applicable; 9/11: September 11th; GER: Germany, SWE: Sweden; RI: Indonesia; ESP: Spain; USA: United States of America; NOR: Norway; DEN: Denmark; UK: United Kingdom; CN: China; FIN: Finland; EST: Estonia; NIR: Northern Ireland; CHI: Chile; MEX: Mexico; JPN: Japan; 9/11: September 11th.

8.3 Quality appraisal items

Quality appraisal items
Do the included papers answer the following questions?
Internal validity
Is the author a person directly involved in the major incident medical response?
Does the literature provide reference to where the data were obtained?
Does the literature provide reference to how the data were obtained?
Do the authors declare no conflicts of interest?
Has an ethics committee approved the reporting?
External validity
Does the literature describe the local emergency medical services structure?
Is the major incident clearly described?
Are the medical resources used in the major incident response clearly described?
Does the literature report the type, means and capacity of communication?
Are missing data accounted for?
Are other limitations discussed?
Is the study design clearly explained?

8.4 Data sampling items

Data sampling items
Do the included papers answer the following questions?
Demography
Basic information on affected area
Basic information on affected population
Accessibility in the region
Other relevant pre-incident data
Communication
Communication type
Type of communication device
Communication mode – in everyday operations and in major incident
Other relevant communication characteristics
Incident characteristics
Time, date and place
Description of incident and damage it caused
Number of dead
Number of injured
Total number of victims involved
Scene access
Distance to hospitals
Other incident characteristics
Incident response
Information on how the major incidentI was declared
The timeline for the medical response
Who participated?
What tasks were performed?
Patient logistics
Number of coms devise
Type of communication breakdown
Attempts to rectify comunication breakdown
Fall-back/alternate communication system
Fall-back/alternate non-technical communication system
Background communication education
Scene safety
Communication breakdown consequences
Other incident response data

8.5 Search strategy

Appendix 8.5.1

Web of Science (Clarivate Analytics) - Web of Science Core Collection

Searched 6.1.2022

Search no.	Search	Result
1	((communicat* NEAR/2 system*) OR coms OR (communication NEAR/2 breakdown*) OR (radio NEAR/2 communicat*) OR (radios NEAR/2 communicat*) OR "Emergency medical service communication system*" OR "ems communication system*" OR (tetra NEAR/4 communicat*) OR ("terrestrial trunked radio*" NEAR/4 communicat*) OR (("multi disciplinary" OR multidisciplinary OR "cross disciplinary" OR "inter disciplinary" OR interdisciplinary) NEAR/2 communication*)) (Topic) 7:36 PM	125,031
2	TS=(rescue NEAR/2 work*)	1,426
3	TS=((emergen*) NEAR/1 ("health care" or healthcare or medical) NEAR/1 (service* or dispatch))	12,594
4	TS=((accident*) NEAR/1 (emergen* or squad*) NEAR/1 (service*))	224
5	TS=(((mass* or major or multiple or complex) NEAR/2 (electric* or "high voltage") NEAR/2 (accident*)))	9
6	TS=((structure* or building* or bridge*) NEAR/2 (collapse*))	6,838
7	TS=((aviation* or airline* or aeroplane* or aircraft*) NEAR/2 (accident* or crash* or collision* or trauma* or injur*))	2,604
8	TS=(((mass* or major or multiple or complex) NEAR/2 (traffic or road*) NEAR/2 (accident* or crash* or collision* or trauma* or injur*)))	490
9	TS=(terror* or bioterror* or bio-terror*)	54,205
10	TS=((disaster* or calamit* or fatalit* or catastroph* or poly-trauma* or polytrauma* or multi-trauma* or multitrauma*))	215,967
11	(mass* or major or multiple or complex) NEAR/2 (incident* or emergen* or casualt* or accident* or trauma* or injur* or destruction or explosion*) (Topic)	55,924
12	#2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11	336,321
13	#12 AND #1	1,650
14	TS=(((mass* or major or multiple or complex) NEAR/4 (incident* or accident* or disaster* or trauma* or casualt* or emergenc*) NEAR/4 (communicat*)))	
15	**#14 OR #13**	**1,778**

Appendix 8.5.2

Ovid MEDLINE(R) ALL 1946 to January 05, 2022

Searched 6.1.2022.

Search no.	Search	Result
1	Radio/	2206
2	Emergency Medical Service Communication Systems/ and (radio or radios).ab,ti.	92
3	((Communicat* adj3 system*) or COMS or (Communication adj3 breakdown*) or ((Radio or radios) adj3 communicat*) or Emergency medical service communication system* or ems communication system* or (tetra adj5 communicat*) or (terrestrial trunked radio* adj5 communicat*) or ((multi disciplinary or multidisciplinary or cross disciplinary or inter disciplinary or interdisciplinary) adj3 communication*)).ab,ti.	15007
4	1 or 2 or 3	17132
5	Disasters/	20159
6	Disaster Medicine/	898
7	Disaster Planning/	15082
8	Mass Casualty Incidents/	2333
9	Accidents/	19928
10	Accident Prevention/	9250
11	Accidents, Aviation/	2731
12	Accidents, Traffic/	46023
13	Explosions/	4159
14	Structure Collapse/	139
15	Rescue Work/	2220
16	Emergency Medical Services/	45967
17	Emergency Medical Dispatch/	163
18	exp Terrorism/	13299
19	((mass* or major or multiple or complex) adj3 (incident* or emergen* or casualt* or accident* or trauma* or injur* or destruction or explosion*)).ti,ab.	49376
20	(disaster* or calamit* or fatalit* or catastroph* or poly-trauma* or polytrauma* or multi-trauma* or multitrauma*).ti,ab.	95116
21	(terror* or bioterror* or bio-terror*).ti,ab.	12485
22	((aviation* or airline* or aeroplane* or aircraft*) adj3 (accident* or crash* or collision* or trauma* or injur*)).ti,ab.	1035
23	((mass* or major or multiple or complex) adj3 (traffic or road*) adj3 (accident* or crash* or collision* or trauma* or injur*)).ti,ab.	261
24	((structure* or building* or bridge*) adj3 collapse*).ti,ab.	1053
25	((mass* or major or multiple or complex) adj3 (electric* or "high voltage") adj3 accident*).ti,ab.	1
26	(accident* adj2 (emergen* or squad*) adj2 service*).ti,ab.	226
27	(emergen* adj2 (health care or healthcare or medical) adj2 (service* or dispatch)).ti,ab.	10497
28	(rescue adj3 work*).ti,ab.	579
29	5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28	282551
30	4 and 29	688
31	((mass* or major or multiple or complex) adj5 (incident* or accident* or disaster* or trauma* or casualt* or emergenc*) adj5 communicat*).ab,ti.	71
32	**30 or 31**	**748**

Appendix 8.5.3

Embase Classic+Embase 1947 to 2022 January 05

Searched 6.1.2022.

Search no.	Search	Result
1	radio/	821
2	((Communicat* adj3 system*) or COMS or (Communication adj3 breakdown*) or ((Radio or radios) adj3 communicat*) or Emergency medical service communication system* or ems communication system* or (tetra adj5 communicat*) or (terrestrial trunked radio* adj5 communicat*) or ((multi disciplinary or multidisciplinary or cross disciplinary or inter disciplinary or interdisciplinary) adj3 communication*)).ab,ti.	18345
3	1 or 2	19078
4	disaster/	19078
5	mass disaster/	2984
6	exp disaster planning/	13498
7	disaster medicine/	1497
8	accident/	42343
9	accident prevention/	18186
10	aircraft accident/	3011
11	destruction/	8614
12	electric accident/	648
13	explosion/	6232
14	structure collapse/	266
15	traffic accident/	69677
16	rescue work/	1122
17	emergency health service/	110530
18	emergency medical dispatch/	268
19	exp terrorism/	9881
20	((mass* or major or multiple or complex) adj3 (incident* or emergen* or casualt* or accident* or trauma* or injur* or destruction or explosion*)).ti,ab.	66681
21	(disaster* or calamit* or fatalit* or catastroph* or poly-trauma* or polytrauma* or multi-trauma* or multitrauma*).ti,ab.	121466
22	(terror* or bioterror* or bio-terror*).ti,ab.	14719
23	((aviation* or airline* or aeroplane* or aircraft*) adj3 (accident* or crash* or collision* or trauma* or injur*)).ti,ab.	1318
24	((mass* or major or multiple or complex) adj3 (traffic or road*) adj3 (accident* or crash* or collision* or trauma* or injur*)).ti,ab.	340
25	((structure* or building* or bridge*) adj3 collapse*).ti,ab.	1103
26	((mass* or major or multiple or complex) adj3 (electric* or "high voltage") adj3 accident*).ti,ab.	3
27	accident* adj2 (emergen* or squad*) adj2 service*).ti,ab.	263
28	(emergen* adj2 (health care or healthcare or medical) adj2 (service* or dispatch)).ti,ab.	14260
29	(rescue adj3 work*).ti,ab.	763
30	4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29	439194
31	3 and 30	860
32	((mass* or major or multiple or complex) adj5 (incident* or accident* or disaster* or trauma* or casualt* or emergenc*) adj5 communicat*).ab,ti.	86
33	**31 or 32**	**929**

Appendix 8.5.4

Cochrane Library (Wiley)

Searched 6.1.2022.

Search no.	Search	Result
1	MeSH descriptor: [Radio] this term only	28
2	MeSH descriptor: [Emergency Medical Service Communication Systems] this term only	53
3	((radio OR radios)):ti,ab,kw	2889
4	#2 AND #3	0
5	((Communicat* NEAR/2 system*) or COMS or (Communication NEAR/2 breakdown*) or ((Radio or radios) NEAR/2 communicat*) or "Emergency medical service communication system*" or "ems communication system*" or (tetra NEAR/4 communicat*) or ("terrestrial trunked radio*" NEAR/4 communicat*) or (("multi disciplinary" or multidisciplinary or "cross disciplinary" or "inter disciplinary" or interdisciplinary) NEAR/2 communication*)):ti,ab,kw	851
6	#1 OR #4 OR #5	878
7	MeSH descriptor: [Disasters] this term only	82
8	MeSH descriptor: [Disaster Medicine] this term only	4
9	MeSH descriptor: [Disaster Planning] this term only	34
10	MeSH descriptor: [Mass Casualty Incidents] this term only	24
11	MeSH descriptor: [Accidents] this term only	47
12	MeSH descriptor: [Accident Prevention] this term only	134
13	MeSH descriptor: [Accidents, Aviation] this term only	13
14	MeSH descriptor: [Accidents, Traffic] this term only	444
15	MeSH descriptor: [Explosions] explode all trees	4
16	MeSH descriptor: [Structure Collapse] this term only	0
17	MeSH descriptor: [Rescue Work] this term only	21
18	MeSH descriptor: [Emergency Medical Services] this term only	1077
19	MeSH descriptor: [Emergency Medical Dispatch] explode all trees	6
20	MeSH descriptor: [Terrorism] explode all trees	75
21	((mass* or major or multiple or complex) NEAR/3 (incident* or emergen* or casualt* or accident* or trauma* or injur* or destruction or explosion*)):ti,ab,kw	4691
22	(disaster* or calamit* or fatalit* or catastroph* or poly-trauma* or polytrauma* or multi-trauma* or multitrauma*):ti,ab,kw	6241
23	(terror* or bioterror* or bio-terror*):ti,ab,kw	259
24	(((mass* or major or multiple or complex) NEAR/3 (traffic or road*) NEAR/3 (accident* or crash* or collision* or trauma* or injur*))):ti,ab,kw	16
25	((aviation* or airline* or aeroplane* or aircraft*) NEAR/3 (accident* or crash* or collision* or trauma* or injur*)):ti,ab,kw	24
26	((structure* or building* or bridge*) NEAR/3 collapse*):ti,ab,kw	6
27	(((mass* or major or multiple or complex) NEAR/3 (electric* or "high voltage") NEAR/3 (accident*))):ti,ab,kw	0
28	((accident* NEAR/2 (emergen* or squad*) NEAR/2 service*)):ti,ab,kw	7
29	((emergen* NEAR/2 ("health care" or healthcare or medical) NEAR/2 (service* or dispatch))):ti,ab,kw	1627
30	(rescue NEAR/3 work*):ti,ab,kw	40
31	#7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15 or #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30	13095

32	#6 AND #31	69
33	(((mass* or major or multiple or complex) NEAR/5 (incident* or accident* or disaster* or trauma* or casualt* or emergenc*) NEAR/5 communicat*)):ti,ab,kw	6
34	**#32 OR #33**	**75**

Appendix 8.5.5

Scopus (Elsevier).

Searched 10.1.2022.

Search no.	Search	Result
1	TITLE-ABS-KEY ((communicat* W/2 system*) OR coms OR (communication W/2 breakdown*) OR ((radio OR radios) W/2 communicat*) OR "Emergency medical service communication system*" OR "ems communication system*" OR (tetra W/4 communicat*) OR ("terrestrial trunked radio*" W/4 communicat*) OR (("multi disciplinary" OR multidisciplinary OR "cross disciplinary" OR "inter disciplinary" OR interdisciplinary) W/2 communication*))	413,511
2	(TITLE-ABS-KEY ((mass* OR major OR multiple OR complex) W/2 (incident* OR emergen* OR casualt* OR accident* OR trauma* OR injur* OR destruction OR explosion*)))	92,661
3	(TITLE-ABS-KEY ((disaster* OR calamit* OR fatalit* OR catastroph* OR poly-trauma* OR polytrauma* OR multi-trauma* OR multitrauma*)))	447,530
4	(TITLE-ABS-KEY (terror* OR bioterror* OR bio-terror*))	80,960
5	(TITLE-ABS-KEY (((mass* OR major OR multiple OR complex) W/2 (traffic OR road*) W/2 (accident* OR crash* OR collision* OR trauma* OR injur*))))	1,131
6	(TITLE-ABS-KEY ((aviation* OR airline* OR aeroplane* OR aircraft*) W/2 (accident* OR crash* OR collision* OR trauma* OR injur*)))	13,624
7	(TITLE-ABS-KEY ((structure* OR building* OR bridge*) W/2 (collapse*)))	11,195
8	(TITLE-ABS-KEY (((mass* OR major OR multiple OR complex) W/2 (electric* OR "high voltage") W/2 (accident*))))	10
9	(TITLE-ABS-KEY ((accident*) W/1 (emergen* OR squad*) W/1 (service*)))	279
10	(TITLE-ABS-KEY ((emergen*) W/1 ("health care" OR healthcare OR medical) W/1 (service* OR dispatch)))	51,602
11	(TITLE-ABS-KEY (rescue W/2 work*))	3,951
12	#2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 ((TITLE-ABS-KEY ((mass* OR major OR multiple OR complex) W/2 (incident* OR emergen* OR casualt* OR accident* OR trauma* OR injur* OR destruction OR explosion*)))) OR ((TITLE-ABS-KEY ((disaster* OR calamit* OR fatalit* OR catastroph* OR poly-trauma* OR polytrauma* OR multi-trauma* OR multitrauma*)))) OR ((TITLE-ABS-KEY (terror* OR bioterror* OR bio-terror*))) OR ((TITLE-ABS-KEY (((mass* OR major OR multiple OR complex) W/2 (traffic OR road*) W/2 (accident* OR crash* OR collision* OR trauma* OR injur*))))) OR ((TITLE-ABS-KEY ((aviation* OR airline* OR aeroplane* OR aircraft*) W/2 (accident* OR crash* OR collision* OR trauma* OR injur*)))) OR ((TITLE-ABS-KEY ((structure* OR building* OR bridge*) W/2 (collapse*)))) OR ((TITLE-ABS-KEY (((mass* OR major OR multiple OR complex) W/2 (electric* OR "high voltage") W/2 (accident*))))) OR ((TITLE-ABS-KEY ((accident*) W/1 (emergen* OR squad*) W/1 (service*)))) OR ((TITLE-ABS-KEY ((emergen*) W/1 (	662,276

	"health care" OR healthcare OR medical) W/1 (service* OR dispatch)))) OR ((TITLE-ABS-KEY (rescue W/2 work*)))	
13	#1 AND #12	6,689
14	TITLE-ABS-KEY(((mass* or major or multiple or complex) W/4 (incident* or accident* or disaster* or trauma* or casualt* or emergenc*) W/4 (communicat*)))	197
15	**#13 OR #14**	**6,838**

Appendix 8.5.6

SveMed+ (Karolinska Institutet)

Searched 6.1.2022.

Note: Update of Svemed with new material ended on 1 January 2020.

Search no.	Search	Result
1	noexp:"Radio"	29
2	noexp:"Emergency Medical Service Communication Systems"	47
3	radio OR radios	68
4	#2 AND #3	4
5	"communication system"	71
6	"communication breakdown"	0
7	"radio communication"	1
8	"ems communication system"	47
9	tetra	0
10	"Multidisciplinary communication"	822
11	"Multi-disciplinary communication"	0
12	"cross disciplinary communication"	822
13	"interdisciplinary communication"	822
15	"inter-disciplinary communication"	0
16	"terrestrial trunked radio"	0
17	#1 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16	920
18	noexp:"disaster"	0
19	noexp:"disaster planning"	204
20	noexp:"Disaster Medicine"	14
21	noexp:"Mass Casualty Incidents"	42
22	noexp:"Accidents"	325
23	noexp:"Accidents, Aviation"	10
24	noexp:"Accidents, Traffic"	510
25	noexp:"Explosions"	45
26	noexp:"structure collapse"	0
27	exp:"Terrorism"	118
28	noexp:"Accident Prevention"	151
29	noexp:"Emergency Medical Services"	1065
30	noexp:"emergency medical dispatch"	0
31	noexp:"Rescue Work"	57
32	disaster*	371
33	calamit*	0
34	fatalit*	16
35	catastroph*	37
36	polytrauma*	3
37	poly-trauma*	0

38	multitrauma*	110
39	multi-trauma*	0
40	major incident*	7
41	mass casualt*	42
42	accident*	1583
43	trauma*	2162
44	emergenc*	3041
45	destruction	35
46	explosion*	67
47	injur*	4311
48	terror*	84
49	bioterror*	40
50	bio-terror*	0
51	collapse*	30
52	rescue work*	62
53	#18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31	2229
54	#32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39 OR #40 OR #41OR #42	2042
55	#43 OR #44 OR #45 OR #46 OR #47 OR #48 OR #49 OR #50 OR #51 OR #52	7981
56	#53 OR #54 OR #55	9039
57	**#17 AND #56**	**126**