

Human Factors in the Emergency Department CBRNe Response: How is Technology used?

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Abstract. A systematic literature review was conducted to explore the current understanding and practices of ED first receivers for CBRNe events and establish how technology is used in the ED CBRNe response for detection, decontamination, and diagnosis. 67 papers were included, with 5 specifically on co-ordination and communication technologies. The current use of technologies in the ED CBRNe response is not without limitations, for example, lack of reception for mobile phones, walkie-talkie dysfunction and overwhelming IT systems.

Keywords. Emergency Department, Human Factors, CBRNe, Technology.

1. Introduction

Chemical, Biological, Radiological, Nuclear and explosive (CBRNe) events relate to specific hazards that may be encountered during an incident in which hazardous materials are released deliberately (Calder and Bland, 2015). Previous incidents include the chemical sarin attacks in Tokyo, 1995 (Okumura et al., 1996), biological anthrax letters in 2001 (Koenig, 2013), and the use of radioactive Polonium-210 (Litvinenko) in 2006 (Day, 2006). CBRNe incidents are low frequency events of high impact, resulting in a variable, and often large, number of casualties presenting at Emergency Departments (EDs) with symptoms which exceed the scope of routine clinical practice. September 11, 2001 (9-11) marked a shift in thinking (Niska et al., 2005) when the role of hospitals, as first receivers in mass casualty incidents (MCI), took on a greater importance (Timm and Reeves, 2007); EDs were forced to examine and update their emergency disaster preparedness plans (Masterson et al., (2009). The ED, as a system, is now seen to be at the forefront of the CBRNe response and serves as the gateway to the most appropriate care of patients (Whetzel et al., 2013).

Challenges in the ED CBRNe response include detection, decontamination and diagnosis, for example detecting a contaminant on a self-referring patient at the ED triage or waiting area (Koenig, 2003). Decontamination is an area of ambiguity in the ED; it is defined as “*the reduction or removal of harmful substances from the body*” (Levitin et al., 2003, p.201). The diagnosis of CBRNe-related ailments is difficult due to the rarity of CBRNe, and physiological symptoms which mimic other diseases making it harder to diagnose CBRNe related ailments (McFee & Leikin, 2009). From a Human Factors and Ergonomics (HFE) perspective the ED can be described as a complex environment where simultaneous presentations and evaluations of patients with widely different characteristics can result in high levels of uncertainty, extreme time

constraints, lack of feedback regarding level of treatment success and an unpredictable need for risky medical procedures (Wears and Perry, 2002). The ED has been described as an inter-related socio-technical system with social, technical and external (regulations and litigation) factors (Perry et al., 2012).

This systematic review aimed to explore the current understanding and practices of ED first receivers for CBRNe events and establish how technology is used in the ED CBRNe response for detection, decontamination, and diagnosis.

2. Methods

A seven-stage framework was used from the PRISMA statement (<http://www.prisma-statement.org>) research question, eligibility, search, identification of relevant papers from title and abstract, selection and retrieval of papers, appraisal and synthesis.

The research questions were:

1. How is technology used in the ED CBRNe response to aid detection, decontamination and diagnosis?
2. How are HFE principles applicable in the ED CBRNe response?

The first set of keywords were tested as preliminary searches in the British Nursing Index (BNI) and Medline. Search strings were formed and adapted (Figure 1) and used in over 20 databases including ASSIA (NHS evidence), BNI (NHS evidence), Ergonomics Abstracts, Google Scholar, Health Management technology (EBSCO), Medline (Ovid SP), Scopus (Elsevier), Science Direct, Toxline, and the Web of Science (WOS).

1. (hospital OR emergency department OR ED OR accident and emergency dep* OR A&E OR self present OR self presen* OR walking wounded OR p3) AND (CBRN OR CBRNE OR mass casualty inciden* OR mass casualty event OR mass casua*) AND (detection OR decontamination OR diagnosis OR equipment OR technologies) NOT (teaching or training or education)
2. (hospital OR emergency department OR self present*) AND (CBRN OR CBRNE OR mass casual*) AND (detection OR decontamination OR diagnosis) AND (equipment OR technologies) NOT (training OR teaching OR education)
3. hospital OR emergency department OR ED OR accident and emergency dep* OR A&E OR self present OR self presen* OR walking wounded OR p3 OR patient* AND cbrn OR cbrne OR mass casualty inciden* OR mass casualty event OR mass casua* AND detection OR decontamination OR diagnosis AND equipment OR technologies OR tech* AND NOT teaching

Figure 1: String searches used for ASSIA, BNI, , Google Scholar, EBSCO, Medline, Scopus, Science Direct, Toxline and WOS

Relevant papers were reviewed by title and abstract screening with the adoption of the inclusion/exclusion criteria, which were specific in terms of environment, participants, situation and actions. The titles and abstracts of 1,874 papers were reviewed. Duplicates and irrelevant papers were discarded. Papers were considered irrelevant if they were clinical guidelines, suggestions, studies not based in the ED or not based on CBRNe incidents. Screening and eligibility stages both reduced the number of references and also added papers by identifying relevant reference lists from individual papers (Figure 2).

The Mixed Methods Appraisal Tool (MMAT; Pluye et al., 2009) was used to assess the methodological quality of the included papers (n=67). The MMAT has been validated across qualitative, quantitative and mixed methods empirical studies. It allocates a score from 0 to 100 (in quartiles) where the overall quality for a mixed methods score cannot exceed the quality of the weakest criteria components. Included papers were given methodological quality scores of 0-4 (0-100%), depending on how many of the criteria they met. A score of 0 indicated that no criteria were met, and a score of 4 (or 100%) indicated that all criteria were met. Papers that scored an MMAT score of 0 or 1 (0%-25%) were discarded as the methodological quality of the studies were deemed to be too poor for inclusion, bringing the number of studies to n=60. Included papers were coded in NVivo10 for thematic analysis based synthesis.

3. Results

The focus of this paper is how technologies are used in the ED CBRNe response and whether HFE principles are applicable in a CBRNe response. Studies were reviewed for the use of technologies to aid detection, decontamination, and diagnosis of CBRNe exposure. Literature was identified for decontamination but not for technologies for use in detection and diagnosis. It was found that the terms 'preparedness' and 'response' tended to refer to actions associated with a CBRNe response.

The included papers reflected the multi-faceted nature of the topic in terms of country, sample population and methodologies. The studies were conducted in USA (20), Canada (5), UK (12), Israel (8), Australia (3), Europe (Italy (1), Norway (1), Spain (1), Ireland (1), Turkey (2) and Asia (Singapore (3), Pakistan (3)). Six areas were identified to explore the current understanding and practices of first receivers: preparedness (n= 20), response (n= 29), problems of PPE (n= 9), decontamination (n= 9), knowledge, skills and experience (n= 18), and technologies (n=5). The methodological quality of the studies was relatively strong with 70% of the included studies rated as medium or strong (n=42).

The studies exploring the use of technologies in the CBRNe response will be described in more detail (Alexander et al., 2004; Cohen et al, 2012; LeRoy Heinrichs et al., 2010; Reddy et al., 2009); and Zhu et al., 2007). All papers scored 75% on the MMAT suggesting that the research was of an acceptable quality.

The rarity of CBRNe events means that technology tends to be implemented as a method of training first receivers (Alexander et al., 2004; Cohen et al., 2012; Leroy Heinrechs et al., 2010). Specifically, Alexander et al (2004) provided emergency doctors with an interactive internet based platform to formulate a disaster plan based on forum discussions during a real time full scale disaster exercise. This forum was reported to be a cost effective way of training doctors in managing CBRNe events leading to questions about whether traditional teaching methods could be replaced by a combination of internet based practice and real life simulations.

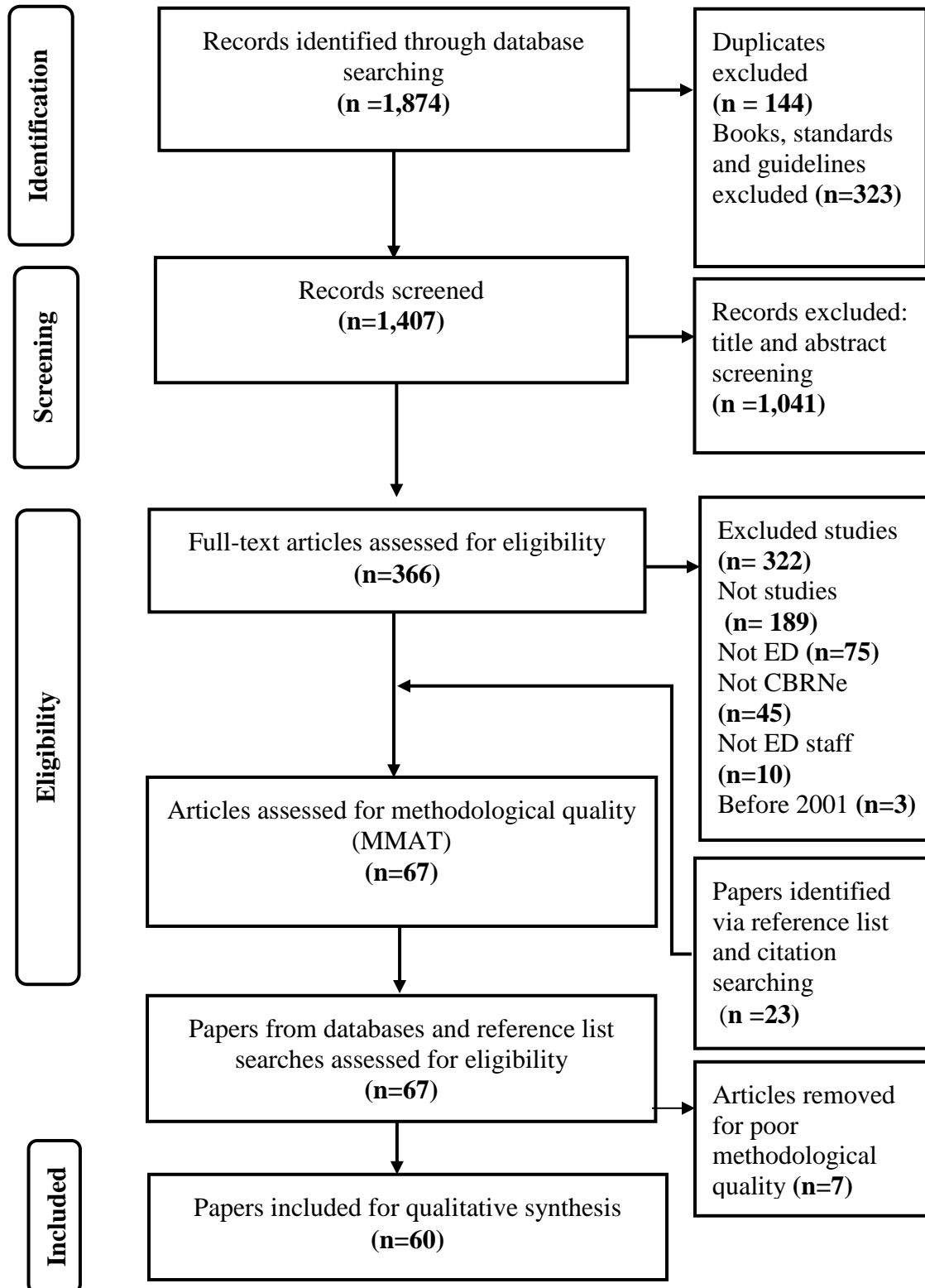


Figure 2: PRISMA flow chart of the literature search

First author, (year), Country	Study type	Population and setting	Aim	Study Design	Outcomes measured	Key Findings	Statistical outcomes	MMAT
Alexander, A., et al. (2004), Canada.	Observational Study,	18 e Emergency Doctors	Evaluate interactive web based disaster planning curriculum and real time full scale disaster exercise.	Used internet platform to review literature about disaster plan. Redesigned plan virtually.	Evaluation forms.	Scenarios were enjoyable, realistic and relevant.	N/A	3 (75%)
Cohen et al., (2012), UK.	Prospective cohort feasibility study.	23 Pre-hospital and hospital clinicians. Virtual scenarios.	Determine feasibility of virtual world environments for training.	Study conducted online via interactive 3D environments.	Feedback summary.	Content validity of low cost virtual worlds for incident simulation has been established.	95% of participants wanted to use virtual worlds for future training.	3 (75%)
LeRoy Heinrichs et al., (2010), USA.	Observational study	10 Doctors 12 Nurses	Determine whether the VED ii, is effective clinical environment for training ED clinicians.	Questionnaire.	Responses on Likert scale	A virtual environment is effective method of training.	Before training 18% were confident after the training 86% felt confident or very confident in managing CBRNe event.	3 (75%)
Reddy et al.,(2009), USA	Qualitative study.	21 Clinicians (EMS and ED)	Identify challenges in coordination.	7 focus groups: scenario based.	Information and communication needs ICT use Roles & responsibilities.	Challenges identified: Ineffectiveness of current ICTs and breakdowns in information flow.	N/A	3 (75%)
Zhu et al., (2007) USA	Qualitative Study	21 EMS and ED teams.	Understand challenges associated with decision making Examine ways to support and improve them.	Focus groups revealed main challenges in response is Information management.	Scenario based responses.	A simulation of R-CAST-MED Enabled efficient information management.	N/A	2 (50%)

Another way of increasing knowledge to improve ED clinicians response to CBRNe events is by simulating CBRNe incidents (Cohen et al., 2012) as a “*virtual world*” environment to train clinicians to obtain an overview for pre-hospital, command structure and in-hospital responses to CBRNe events. LeRoy Heinrichs et al., (2010) described the development and testing of the Virtual Emergency Department ii (VED) with virtual patients exposed to radiological and chemical events; they suggested that this method of training was very effective.

A key finding is the deficiency in communication technologies between ED and Emergency Medical Services (EMS) teams (Reddy et al., 2009). EMS and ED teams felt that current communication technologies such as mobile phones and walkie-talkies were unreliable and lost reception at certain locations or did not function properly when surrounded by materials such as concrete and steel. Also, there were concerns that computer systems were incapable of handling the vast amount of information exchanged in the management of a MCI. Clinicians believed information technology systems would be overwhelmed in such cases and reported that they would use paper-based systems as a more reliable means of storing information. A key objective of training is to enhance communication and co-ordination in CBRNe events (Alexander et al., 2004). A means of improving co-ordination and communication amongst EMS and ED teams was proposed by Zhu et al., (2007) as a computer based decision support system; (R-CAST-Med). They reported that the support system was received positively in CBRNe simulations based on collaboration between EMS and ED teams.

4. Discussion and Conclusion

This review has focused on the current understanding and practices of ED first receivers to CBRNe events. This review found that technologies to enhance co-ordination and communication are required as a means of timely and reliable information exchange to improve patient care in CBRNe events. Finally using technology for training first receivers is used to increase confidence and the ability to respond to CBRNe events. The current use of technologies in the ED CBRNe response is not without limitations, for example, lack of reception for mobile phones, walkie-talkie dysfunction and overwhelming databases.

The application of HFE principles, in particular a socio-technical systems approach would be interesting to consider the quality of care offered to patients within the context of the organisation and the management of CBRNe events, This review has explored current ED response, and implementation of technologies in the CBRNe response. It has highlighted two aspects which need to be further investigated. Firstly, the application of HFE principles to the complexity of the ED to enhance the understanding of the response systems for multifaceted CBRNe events. It is suggested that the SEIPS model (Carayon et al, 2006) is applicable in the ED CBRNe response. This can be used to describe the ED as a work system reliant on tools and technologies, with the CBRNe event as a process and quality patient care as an outcome. Secondly, a detailed exploration of detection, decontamination and diagnosis technologies to improve the CBRNe response and ultimately improve patient care.

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