Table 2. Included studies

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| **Study** | **Study type and** study design | **Population**  **and setting** | **Aim** | **Summary of main findings** | **Quality Rating**  **(MMAT)** |
| Al-Damouk &  Bleetman, (2005) [UK] | **Mixed method.** Quantitative survey, qualitative observations and debriefing in two simulated chemical and blast incidents. | 192 hospitals  32 ambulance trusts for surveys. Two EDs involved in simulations. | To assess the impact of Department of Health initiative on acute hospital and ambulance Trusts to equip and manage chemically contaminated victims. | Practical difficulties exist with PPE suits. | 3  (75%) |
| Alexander et al., (2005)  [Canada] | **Quantitative.** Observational Study. | 18 emergency doctors | To evaluate interactive web-based disaster planning curriculum with real time disaster exercise. | Scenarios were enjoyable, realistic and relevant. | 3  (75%) |
| Allegra, et al., (2001) [USA] | **Quantitative**. Retrospective analysis of ED visits for Concern for Exposure (CE) of anthrax. | 15 EDs over a 4 month period from  1 month before 9-11 to 2 months after October 11 | Identify and characterise ED visits by patients concerned with exposure to e anthrax in 2001. | An increase in CE visits occurred during the 1 month period after October 11 2001. | 2  (50%) |
| Anathallee et al., (2007) [UK] | **Quantitative.**  Descriptive telephone survey. | 261 hospitals with ED. Duty sister/charge nurse/duty shift leaders. | To assess current facilities and procedures in UK EDs for the management of potential biological incidents. | EDs in the UK are not prepared for emerging biological threats. | 4  (100%) |
| Ashkenazi et al., (2006) [Israel] | **Quantitative.**  Descriptive retrospective analysis of patient records. | 104 victims from explosive MCIs. | To assess the precision of triage in MCIs. | Primary triage, even when carried out by experienced trauma Doctors, can be unreliable in a MCI. | 4  (100%) |
| Becker & Middleton, (2008) [USA] | **Qualitative.** Exploratory focus group study. | 77 ED nurses and doctors | To understand the perceptions, concerns, information needs, preferred information sources, and views of existing guidance and information related to radiological terrorism. | Hospitals and EDs are not sufficiently prepared for a terrorist event involving radioactive materials. | 3  (75%) |
| Bloch et al., (2007)a [Israel] | **Quantitative.**  Descriptive. Disastrous Incidents Systematic Analysis Through-Components, Interactions, Results. (DISAST-CIR) | 131 victims taken to nearby hospitals following an explosion. | Identify lessons learned from the medical response to a terrorist explosion. | Distribution of casualties from the scene plays a vital role in the management of a MCI. | 4  (100%) |
| Bloch et al., (2007)b [Israel] | **Quantitative.** Descriptive study. | 64 patients presented to ED. | To describe the characteristics and lessons learned from a terrorist explosion. | After an explosion, a large number of mildly injured victims experiencing stress are to be expected, without a direct relation to the attack. | 4  (100%) |
| Braun et al., (2004) [USA] | **Quantitative.** Descriptive survey. | 223 hospitals pre and post 9-11.  Staff most familiar with the hospital’s emergency management plan. | To evaluate the effectiveness of the links between accredited hospitals and other key entities in responding to a bioterrorism event. | Before 9-11 few hospitals addressed bioterrorism in their emergency management plans. By 2002 majority of responding hospitals had a bioterrorism response plan. | 4  (100%) |
| Brinker et al., (2008) [UK] | **Quantitative.** Descriptive survey. | 28 emergency medicine registrars.  47 anaesthetic registrars. | Evaluate PPE knowledge amongst emergency doctors and anaesthetists. | Greatest awareness surrounding SARS. Fair knowledge was found about anthrax, plague Ebola and smallpox.  Knowledge about PPE was limited.  Knowledge about personal protection measures for biological agents was acceptable and limited for chemical agents. | 3  (75%) |
| Candiotti et al., (2005) [USA] | **Qualitative.** Descriptive survey. | 90 anaesthetic accreditation programmes. | To determine level of clinical management training provided to doctors for patients exposed to WMDs (Chemical, Biological, and Nuclear events) | The majority of anaesthetic residency programmes in the USA provided little or no training to management of WMD events. | 4  (100%) |
| Castle et al., (2010)a [UK] | **Quantitative.** Randomised Control Trial. | 81 participants:  Emergency nurses, nurse lecturers, paramedics, paramedic lecturers, and paramedic students. | To evaluate the impact of the CBRN-PPE on drawing up of drugs from glass ampoules, plastic ampoules, or pre-filled syringes. | NHS CBRN PPE has a negative effect on the drawing up of drugs especially from glass ampoules. | 4  (100%) |
| Castle et al., (2010)b [UK] | **Mixed methods**. Quantitative and qualitative. Clinicians secured ET tube and were then interviewed. | 75 clinicians: Anaesthetics consultants, registrars, ED doctors, pre-hospital doctors, paramedics and resuscitation officers. | Assess the impact of CBRN-PPE on the ability to secure an ETT with either the Thomas tube holder or cotton tape tied in a knot. | Thomas tube holder is easier and faster to apply when wearing CBRN-PPE in comparison to cotton tied in a knot. | 2  (50%) |
| Castle et al., (2010) c, [UK]. | **Qualitative.** Interviews. | 25 participants who were anaesthetists and paramedics. | To evaluate which IADs (Intermediate Airway Device) should be used by professionals in PPE during CBRNe events. | Heavy bias towards using Laryngeal Mask Airway and I-gel. | 2  (50%) |
| Claret et al., (2016) [France] | **Quantitative.** Prospective randomised crossover study. | 41 ED doctors. | To evaluate the performance of orotracheal intubation with the Miller laryngoscope compared to the Airtraq laryngoscope wearing CBRN-PPE type III, on infant manikins. | Orotracheal intubation success rate with the Airtraq laryngoscope was higher than with the Miller laryngoscope. | 4  (100%) |
| Cohen et al., (2013) [UK] | **Qualitative.**  Semi-structured interview using virtual scenarios. | 23 Pre- hospital and hospital clinicians. | Determine feasibility of virtual world environments for training. | Content validity of low cost virtual worlds for incident simulation has been established. | 3  (75%) |
| Cone & Cummings (2006) [USA] | **Quantitative.** Descriptive survey. | 1,704 hospital workers who were nurses, physicians, physician assistants/ nurse practitioners and other clinical staff. | To asses hospital employees attitudes and needs regarding work commitments during disasters. | Greater willingness to work after natural disasters than after manmade disasters. | 4  (100%) |
| Considine & Mitchell, (2009) [Australia] | **Quantitative** Disaster preparedness survey. | 64 ED nurses. | Explore issues related to disaster preparedness of emergency nurses. | Most nurses were willing to participate in CBR incidents. Willingness decreased with unknown chemical or biological agent. | 3  (75%) |
| De Ceballos et al., (2005) [Spain] | **Mixed methods.** Descriptive case study. | 312 victims following 10 commuter train explosions. | Review in hospital triage. Patterns of injuries’, and care of the victims. | There was an over-triage to the closest hospital. | 4  (100%) |
| Djalali et al., (2016)  [Italy] | **Qualitative.** Modified 3 step Delphi method. | 15 experts. | To determine competencies required by hospital staff when responding to CBRN emergencies. | Identified a set of core competencies and specific knowledge and skills required by medical staff to respond to CBRN emergencies. | 2  (50%) |
| Duong, (2009) [Australia] | **Mixed method.** Exploratory survey. | Senior nurses working within 8 EDs. | Examine emergency nurse’s knowledge and understanding of disaster response in healthcare settings. | Nurses perceived themselves to have a decreased level of disaster preparedness. | 4  (100%) |
| Durukan et al., (2009) [Turkey] | **Qualitative.** Descriptive case study. | 41 patients admitted to the ED with diagnosis of endosulfan poisoning. | Describe characteristics of patients with acute endosulfan mass poisoning | Healthcare professionals should understand the hazards associated with pesticide use. As well as the diagnosis and treatment of such presentations. | 4  (100%) |
| Einav et al., (2006) [Israel] | **Quantitative.** Descriptive study of patient records. | 325 victims from 32 events. | To suggest guidelines for hospital organisation during terror related MCIs. | High staffing demands for ED, operating theatres, and Intensive Care Units overlap. | 4  (100%) |
| Flaishon et al., (2004) [Israel] | **Quantitative.** Cross-over study. | 15 Anaesthetists. | To ascertain whether surgical attire or anti-chemical protective gear makes a difference in controlling the patient’s airway. Compared endotracheal tube with laryngeal mask airway. | Laryngeal mask airway  insertion is faster than tracheal intubation when wearing protective gear. | 2  (50%) |
| George et al., (2002) [UK] | **Quantitative.** Descriptive audit. | 261 EDs in Scotland, Wales and Northern Ireland. | Audit the facilities for chemical decontamination. Specifically for cyanide poisoning. | Only a minority of departments were satisfactorily equipped to deal with a serious chemical incident. | 3  (75%) |
| Goh, Tiah & Lim, (2007) [Singapore] | **Qualitative.** Retrospective Descriptive case study | 22 patients who were victim to a smoke inhalation incident. | Description of the triage criteria that were modified and adopted for a unique MCI. | Modified triage criteria with selective use of fibre optic examinations, chest radiography and arterial blood gas analysis are useful in smoke inhalation MCIs. | 3  (75%) |
| Jasper et al., (2005)  [USA] | **Mixed Methods.** Quantitative descriptive and observation of a multi-hospital large scale exercise. | 11 hospitals. | Exercise was deigned to determine the level of preparedness of hospitals to respond to a radiological terrorism event. To additionally promote long term learning for staff at participating hospitals. | Hospitals are well prepared for a terrorism event that involves a radiological dispersion device. However there is difficulty in maintaining readiness for events that are rare or never encountered. | 3  (75%) |
| Kaji & Lewis (2006) [US] | **Quantitative.** Descriptive. Cross- sectional telephone survey which was followed by an onsite survey. | 45 designated 9-1-1 receiving hospitals. | To characterise disaster preparedness among a cohort of hospitals focusing on practice variation, plan characteristics, and surge capacity. | Disaster preparedness and surge capacity are limited by a failure to fully integrate interagency training and planning. | 2  (50%) |
| Klima et al., (2011) [USA] | **Mixed Methods:** Descriptive statistics. Simulation of an MCI involving a chemical spill. | 16 hospitals. | To evaluate the results of a multidisciplinary and multi-organisation Full Scale Regional Exercise (FSRE). | Communication remains a significant gap in the mass casualty scenario. FSREs should be routinely performed to prepare for catastrophic events. | 2  (50%) |
| Kollek & Cwinn (2011) [Canada] | **Quantitative.** Survey. | 34 ED chiefs or physicians designated to complete the survey. | To use the Hospital Emergency Readiness Overview (HERO) to assess the readiness of the EDs in Canada at organisational and administrative levels. | Gaps in Canadian healthcare facility readiness for disasters, specifically one involving contaminated patients. There is a lack of standardised assessment of healthcare facilities and CBRN readiness is lacking. | 3  (75%) |
| Kollek, (2003)  [Canada] | **Quantitative.** Cross sectional online survey. | 53 ED chiefs. | To review the risks and characteristics of CBRN events and to assess the preparedness of Canada EDs to respond. | Canadian EDs and by inference Canadian hospitals are unprepared for a CBRN event. | 3  (75%) |
| Kotora, (2015) [USA] | **Quantitative**.  Retrospective observational online survey. | 191 doctors, mid-level providers and nurses employed in the ED. | Evaluated the CBRNe preparedness of doctors,  nurses and midlevel providers in an urban tertiary care ED. | Emergency care providers are inadequately prepared to manage CBRNe incidents. A valid and precise instrument capable of ensuring preparedness needs to be developed. | 2  (50%) |
| Lee & Franc., (2015) [Canada] | **Quantitative.** Prospective observational cohort study. Simulation study. | 21 emergency medicine resident physicians and 2 triage nurses.  . | To examine the impact of a two-step ED triage model using Simple Triage And Rapid Treatment (START) for pre-triage. Followed by triage with the Canadian Triage and Acuity Scale (CTAS), on patient flow during a virtual MCI simulation exercise. | Experienced triage nurses were able to apply the CTAS effectively during simulation exercise. A 2 step ED triage model using START and the CTAS had similar patient flow and triage accuracy when compared to START alone. | 4  (100%) |
| LeRoy Heinrichs et al., (2010) [USA] | **Mixed method. Quantitative** Descriptive questionnaires, observation on Virtual Emergency Department (VED) ii for chemical and radiological events. Followed by focus groups. | 10 Doctors  12 Nurses | Determine whether VED ii, is an effective clinical environment for training ED clinicians. | A virtual environment is an effective method of training for CBRNe events. | 3 (75%) |
| Malik et al., (2006) [Pakistan] | **Quantitative.** Descriptive case study. | 161 victims. | To determine the effectiveness of hospital management, triage system, hospital staff response, medical resources availability and surgical management of a mass casualty incident. | Mass  Casualty management in a terrorist attack requires prompt hospital response, appropriate triage, efficient surgical approach, and dedicated post-operative care. | 3  (75%) |
| Martz et al., (2011) [USA] | **Qualitative.** Descriptive study based on scenario drills. | -FBI  -Army 415th brigade  -Wisconsin national guard  -Wisconsin department of health services  -US coast guard  Fire department.  -Sheriff’s department.  -Police department.  3 hospitals. | To review the “Red dragon drill” largest multi-agency Radioactive Dispersal Device scenario. | Communication is not timely or reliable.  Staff turnover rates can significantly impact knowledge base.  Decontamination conducted by first responders must be verified. | 3  (75%) |
| Masterson et al., (2009) [USA] | **Quantitative.** Descriptive survey. | 204 participants from 8 hospitals. ED doctors nurses, and support staff. | To examine willingness to respond to various MCIs. | Staff members were more willing to work additional hours for victims of an aeroplane crash than for a radioactive bomb or a biological agent. | 3  (75%) |
| Mitchell. et al., (2012) [Northern Ireland] | **Quantitative.** Competency questionnaire, cross sectional survey and clinical audit. | 50 staff: in 3 EDs consisting of a mixture of skilled nurses. | Identify areas where ED nurses may need training and support to improve their response to a CBRNe incident. | Key areas identified for training:  - Waste management  - Triage  - Chain of command  - Awareness of the range of PPE and appropriate use  -Decontamination | 4  (100%) |
| Niska. et al., (2005) [USA] | **Quantitative.** Descriptive survey. | 294 Hospitals with 24 hour ED or outpatient department supervised by a doctor. | To provide a descriptive summary of the responses from which national estimates of preparedness can be generated for overall US hospitals. | Almost all hospitals have plans for responding to national disasters (97.3%). Most have plans for responding to chemical (85.5%), biological (84.8%), nuclear or radiological (77.2%) and explosive incidents (76.9%). | 2  (50%) |
| O’ Sullivan, et al., (2008) [Canada] | **Quantitative.** Survey. | 1,543 ED and ITU nurses. | To test 3 hypotheses:  1. Nurses will have higher preparedness for infectious diseases and natural disasters than CBRN events. 2. Perception of preparedness will vary according to previous outbreak experience. 3. Personal preparedness will be related to institutional preparedness. | Nurses felt least prepared to respond to a CBRN event.  Nurses with previous outbreak experience felt more prepared. Nurses felt their institutions were underprepared to respond to a large scale disaster. | 3  (75%) |
| Oh et al., (2010) [Singapore] | **Descriptive.** Case review. | 11 victims exposed to pepper spray. | To describe the ED response to the event, the spectrum of patient presentation, and their respective treatments. | Effects of pepper spray are typically self-limiting. Secondary exposure within a crowded public area can result in multiple casualties. | 4  (100%) |
| Raiter et al., (2007) [Israel] | **Quantitative.** Descriptive. Disastrous Incidents Systematic Analysis Through-Components, Interactions, Results. (DISAST-CIR). | 91 victims. | To describe and draw lessons about the management, of victims at hospitals close to an explosion. | The rapid accumulation of Emergency Medical Services vehicles combined with effective primary triage between five hospitals enabled a rapid conclusion of the event. | 4  (100%) |
| Rassin et al., (2007) [Israel] | **Quantitative**. 41-item questionnaire. | 104 doctors and nurses working in, or responding to the ED. | To examine the preparedness level of ED staff to deal with Mass Casualty Events (MCEs) involving paediatric victims. | Preparedness levels for MCEs involving children were low. | 4  (100%) |
| Reddy et al., (2009) [USA] | **Qualitative**.Focus groups implementing a crisis scenario. | 21 Clinicians (EMS and ED). | Identify challenges in co-ordination. | Challenges identified:  Ineffectiveness of current ICTs and breakdowns in information flow. | 3 (75%) |
| Riba et al., (2002) [Israel] | **Qualitative.** Focus groups. | Approximately 45 ED, ITU, operating theatre, and imaging department nurses. | Investigate the perceptions, reactions and feelings of nurses who cared for victims of multi-casualty terrorism in the ED. | Four stages of personal and professional involvement from nurses.  1. Call up for duty.  2. Waiting for causalities to arrive.  3. Treating the victims.  4. Closure of the event. | 2  (50%) |
| Rodoplu et al., (2005) [Turkey] | **Quantitative.** Retrospective descriptive study. | 69 victims. | Estimate the impact of open air mass bombings on a hospital. | Three waves of injured survivors.  First wave: primary injured survivors with mostly minor injuries.  Second wave: overlapping wave made up of primary injured survivors with more serious injuries. Third wave: secondary injuries transferred to the ED from other hospitals. | 4  (100%) |
| Satterthwaite & Atkinson (2010) [Australia] | **Qualitative.** Descriptive case study. | 30 victims. | Analyse the impact of reverse triage, to create surge capacity for disaster victims. | Reverse triage resulted in no increase in clinical risk. | 2  (50%) |
| Schultz et al., (2012) [USA] | **Qualitative.** Modified Delphi technique. | 16 doctors, nurses, and emergency medicine technicians. | Determine the knowledge and skills needed to effectively recognise and treat acute injuries and illnesses resulting from disaster events. Additionally, to create comprehensive disaster core competencies. | A framework of 19 content categories and more than 90 performance objectives were developed for clinicians to address the requirements of an all hazards disaster response. | 2  (50%) |
| Schumacher et al., (2015) [UK] | **Quantitative.** Descriptive survey. | 98 specialist registrars. | To assess the knowledge of respiratory and skin protection requirements needed during a resuscitation scenario with Advanced Life Support. | Current knowledge regarding PPE for chemical warfare agents is very limited. | 3  (75%) |
| Shah et al., (2015) [Pakistan] | **Quantitative.** Retrospective descriptive review. | 200 victims. | To share the experiences of a tertiary care facility in a low middle income healthcare setting in dealing with trauma victims from an explosion. | In countries with no pre-hospital triage system, implementing a pre-existing disaster plan with pre-defined interdisciplinary responsibilities can streamline in-hospital management of casualties. | 4  (100%) |
| Tham (2004), [Singapore] | **Qualitative.** Descriptive Case study | 11,461 patients who were screened for Severe Acute Respiratory Syndrome (SARS). | Describe the interventions adopted by the ED and hospital to contain SARS. | Although SARS was not a bioterrorism event, the ED disaster response was applicable in the outbreaks management. | 3  (75%) |
| Timm & Reeves (2007) [USA] | **Qualitative.** Descriptive case study. | 53 paediatric patients and 3 adults. | To summarise hospital’s response, lessons learned, and general disaster planning recommendations in a MCI involving contaminated children. | Hospitals should include children in their disaster exercises.  Most victims of disasters will not be triaged, decontaminated or brought by EMS to the ED.  Decontamination of children involves special considerations. | 3  (75%) |
| Treat, et al., (2001) [USA] | **Qualitative.** Interviews. | 40 hospitals  17 ED medical directors and 13 ED nurse Managers | Assess the training needs of emergency personnel for Weapons of Mass Destruction (WMD) preparedness in hospitals. | Hospitals are not prepared for WMD events. Especially in areas such as mass decontamination, mass medical response, awareness, health communications, and security. | 4  (100%) |
| Umer et al., (2009), [Pakistan] | **Quantitative.** Descriptive case study. | 36 victims from bus incident  104 victims from explosion. | To describe the management and outcome injuries of the 2 explosions. To further reflect on the process of care in a developing country. | Vital to understand the patterns of injury and logistical problems that result. | 3  (75%) |
| Waage et al., (2013) [Norway] | **Quantitative**  Descriptive retrospective case study following shooting incident. | 35 victims from a shooting incident. | To describe the hospitals surge capacity and analyse the hospital major incident plan. | Deviation from the major incident plan was needed. Communication systems and the organisation of radiological (scanning) services were most vulnerable. | 4  (100%) |
| Wetter, et al., (2001)[USA] | **Quantitative**.  Cross-sectional questionnaire survey. | 186 hospitals. Most responses were from registered nurses (87%, n=162). | Examine hospital preparedness for incidents involving chemical or biological weapons. | EDs are generally not prepared to treat victims of chemical or biological terrorism. | 3  (75%) |
| Whetzel et al., (2013) [USA] | **Quantitative.** Descriptive survey. Literature review followed by descriptive survey. | 177 emergency nurses. | Assess nurse’s perception of their role in a disaster and their perceived susceptibility to a disaster. | Emergency nurses have not taken basic actions to prepare themselves for disasters either personally or professionally. | 2  (50%) |
| Williams, et al., (2007) [UK] | **Qualitative.** Semi-structured interviews. | 18 participants consisting of nurse managers, senior nurses, consultants, and emergency planners. | Assess the preparedness of hospitals for the management of a chemical incident. | Deficiencies in planning facilities, equipment, and training. | 3  (75%) |
| Wong et al., (2006) [UK] | **Quantitative.** Questionnaire survey. | 179 registrars. | Evaluate the preparedness of middle grade staff and hospitals for major incidents. | Preparedness for major incidents in the UK remains poor. | 3  (75%) |
| Zhu et al., (2007)  [USA] | **Qualitative.** Focus groups. | 21 EMS and ED teams. | Understand the challenges associated with decision making and examine ways to support and improve them. | A simulation of R-CAST-MED enabled efficient information management. | 2 (50%) |