Burn Disasters—An Audit of the Literature

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Abbreviations:
ADF = Australian Defence Force
CASEVAC = casualty evacuation
DMAT = Disaster Medical Assistance Team
DRK = German Red Cross
DRT = Disaster Response Team
EMS = emergency medical services
ENT = ears, nose, throat
GMUGH = Gregono Maranon University General Hospital
ICU = intensive care unit
IV = intravenous
LARMC = Landstuhl Army Regional Medical Centre
LAS = London Ambulance Service
MAS = medical aid station
MCI = mass-casualty incident
RDH = Royal Darwin Hospital
RIH = Rhode Island Hospital
SMT = Site Medical Team
SSD = silver sulfadiazine
TBSA = total body surface area
UNC = University of North Carolina
USAF = United States Air Force

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Abstract

All events that result in disasters are unique, and it is impossible to become fully prepared. However, through thorough planning and preparedness, it is possible to gain a better understanding of the typical injury patterns and problems that arise from a variety of hazards. Such events have the potential to claim many lives and overwhelm local medical resources. Burn disasters vary in scope of injury and procedures required, and are much more labor and resource intensive than non-burn disasters.

This review of the literature should help determine whether, despite each event having its own unique features, there still are common problems disaster responders face in the prehospital and hospital phases, what recommendations were made from these disasters, and whether these recommendations have been implemented into practice and the current disaster planning processes.

The objective of this review was to assess: (1) prehospital and hospital responses used during past burn disasters; (2) problems faced during those disaster responses; (3) recommendations made following those disasters; (4) whether these recommendations were integrated into practice; and (5) the key characteristics of burn disasters and how they differ from other disasters. This review is important to determine why, despite having disaster plans, things still go wrong.

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Introduction

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Objective

The objective of this review was to assess: (1) prehospital and hospital responses used during past burn disasters; (2) problems faced during those disaster responses; (3) recommendations made following those disasters; (4) whether these recommendations were integrated into practice; and (5) the key characteristics of burn disasters and how they differ from other disasters. This review is important to determine why, despite having disaster plans, things still go wrong.

The first part of this review includes a description of 37 individual burn disasters from the Cocoanut Grove fire in Boston in 1942 to the London bombings of 2005, using a standardized method. Then, the disasters are

Disaster (including death/injury total)	Burn Injuries	Non-Burn Injuries	Major Problem Areas
Cocoanut Grove - 491 deaths (>300 on-scene)	Burns between 1– >30% TBSA	Inhalation injuries prominent	Fire safety standards, scene access, triage, identification, and patient tracking
Texas City - 560 dead or missing - 3,000 with minor injuries	Mild-to-severe burns	Head injuries, lacerations, lung injury, abdominal injury, kidney and bladder injury, perforated eardrums, ocular injuries, amputations, fractures	On-site fire safety equipment, equipment shortage, overcrowding of disaster site, medical command
Los Alfaques Disaster - 102 deaths on-scene - 108 deaths in hospital	148 burned, including >122 with >50% TBSA full-thickness burns	Information not available	Patient transport, patient monitoring, triage, communication, medical command, ambulance and EMS dispatch, on-site medical aid, rural location, identification, media briefing
San Juanico LPG Plant Explosion - 550 deaths (300 on-scene) - >7,000 injured	625 people with severe thermal injuries	Information not available	Site and hospital access, communication, media interference, medical command, scene safety
Piper Alpha - 167 deaths - 62 injured	Burns typically of the face and hands	Shock, inhalation injury, hypothermia, wounds, and fractures	Scene access, fire safety equipment, communication, evacuation of patients
Bashkir Pipeline Disaster - 400 deaths - 800 injured	Of 800 injured, >97% suffered burns	Inhalation injuries	Evacuation of patients, scene access
Oklahoma City Bombing - 168 deaths - 592 injured	Burns (including thermal and chemical) made up 8% of injuries	Lacerations/abrasions, fractures/dislocations, head injuries, ocular injuries, perforated tympanic membranes, crush injuries	Scene safety, site access, communication
US Embassy Bombing, Nairobi - 253 deaths - 5,000 injured	Burns sustained, but exact numbers are not available	Information not available	Medical command, site coordination
9/11 Terrorist Attacks - 3,000 deaths (2,823 in New York, 189 at the Pentagon, and 44 in Pennsylvania) - >6,000 people treated for injuries	1/3 of hospitalizations in New York for severe burn injuries. 11 burn patients seen at the Pentagon	Cuts and lacerations, blisters, punctures, back pain, foreign bodies, fractures, crush injuries, infections/inflammation, inhalation injuries, respiratory complaints, eye and ear injuries, headaches, gastric/esophageal complaints, dental pain, and psychological stress	Scene safety issues, site access, communication, medical command, triage, patient evacuation, equipment supply, overcrowding of disaster scene
Bali Bombings - >200 deaths - 66 evacuated to Australia	Full-thickness burns prominent, including 40 patients with >10% TBSA burns	Shrapnel wounds, intra-abdominal injuries, limb swelling, peripheral ischemia, and several MRO infections	Communication, evacuation of patients, transport (local and long-distance), concurrent trauma, staff planning, patient monitoring, equipment, triage
Station Nightclub Fire, Rhode Island - 100 deaths (96 on-scene) - 215 injured	196 burn victims, with burns between <20% and >40% TBSA	Inhalation injuries	Inhalation injuries, fire safety standards, patient transport, communication
Terrorist bombings, Madrid - >200 deaths (177 immediate) - 1,500 injured	First- and second-degree burns	Tympanic membrane perforation, chest injuries, shrapnel wounds, fractures, eye lesions, head trauma, and abdominal injuries	Triage, overcrowding of hospital
Terrorist bombings, London - 56 deaths (52 on-scene) - >700 injured	Burn injuries, including inhalation injuries, were prominent	Blast injuies (perforated tympanic membranes, pneumothoraces, and perforated bowels), and traumatic amputations	Concurrent trauma, communication, scene safety and access

Table 1—Summary of scope of injuries, disaster response and major problems faced during some major burn disasters

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arranged into chronological order to determine whether the same problems continue to occur, and whether there is a trend in relation to the responses to the disaster.

Definitions
Generally, disasters are unforeseen, and immediate threats to public health involving "serious disruption to community life, which threatens or causes death or injury in that community, usually beyond day-to-day capacity of prescribed statutory authorities".[1]

Specifically, burn disasters have been defined as "an event resulting in mass burn casualties and severe loss of human lives and material from a known thermal agent".[2] A term that also is used is *thermal agent disaster*. This is defined as "a disaster causing severe losses of human lives and material goods as a result of massive heat production".[3] That is, it relates to the number of dead and injured, and the extent of damage to material goods. The term burn disaster relates more to the actual overall qualitative effect on living persons of an incident resulting from a thermal agent.

Methods

Review Design
A comprehensive review of the literature was performed using the online database *Medline* using the keywords: "disasters", "burns (including thermal injury)/disasters", "emergency treatment/burns/disaster planning", "burns/emergency treatment with first aid", "mass burn casualties", "terrorism/burns", "burns/bombs", and "terrorism/disaster planning" from 1966 through to September 2006. The search term "disasters", which was limited to English, yielded the best results. Approximately 220 relevant articles were identified, read, abstracted, and assessed using a standard format for: (1) death toll and scope of injury; (2) burn injuries that resulted; (3) injuries other than burns that resulted; (4) major problems experienced; and (5) the recommendations made.

Since currently, there are no standards for the classification of burn disasters, disasters included in this review were categorized based on their location and type of event (Table 1). These are listed in order of frequency of occurrence and include: (1) terrorist bombings; (2) nightclub, restaurant, and hotel fires; (3) industrial events; (4) transport accidents; (5) aircraft events; and (6) public events. Each event was analyzed chronologically in an effort to identify whether if the lessons learned from previous disasters actually had been heeded and incorporated into routine practice. Two independent raters cross-checked the process used for categorizing the disasters.

Inclusion Criteria
Articles were selected on the basis that they included prehospital and/or hospital responses to disasters that occurred since the 1942 Cocoanut Grove nightclub fire disaster, key characteristics of an effective disaster response and the common problems encountered during a disaster response.

Exclusion Criteria
Though similar in nature, terrorism-related events such as the New York World Trade Center bombing in 1993[4] were outside the scope of this review and excluded, including disasters due to natural hazards that resulted in no burn injuries. Other human-made events in which there were no survivors were excluded as they did not involve a major prehospital or hospital response. Also excluded were events resulting from bush fires spanning many days and war-related attacks, including attacks on military bases and military infrastructure. Finally, articles featuring burn disasters involving both burn injuries and survivors, but no information relating to the prehospital or hospital response, or the problems experienced during the response, were omitted on the basis that insufficient relevant information would be available.

Results

Since the Cocoanut Grove fire, there have been a vast number of major burn disasters and mass-casualty incidents (MCIs) involving burns from which several major recommendations have been made and key lessons (potentially) learned.

General Literature Findings and Trends
Currently, there is no uniform method to classify disasters in terms of injuries and casualty severity, i.e., there are no formal injury severity scales or APACHE scores that can be applied to a burn disaster. The walking wounded of one institution may be the higher triage level patients at another institution, depending on the number of casualties per staff member.[3]

Since 1942, planners have experienced similar problems, particularly in the area of communication, triage, and burn experience levels. However, some areas and solutions only have received special focus following recent major events; issues such as pre-arranged equipment and supply agreements, back-up communication, Disaster Medical Assistance Teams (DMATs),[5,6] the integration of burn centers into major trauma centers, and the indication that disasters can and do occur when least expected, started to be addressed following the 11 September 2001 terrorist attacks. While the worldwide attention generated by this particular attack has helped make people realize that something had to be done to prevent future disasters from occurring, or at least minimize the effects future events will have on people and infrastructure.

Casualty numbers and scope of injury, particularly the extent and depth of burn injuries, and the incidence of inhalation injury, generally are determined by factors such as the cause and location of the accident. For example, indoor fires may allow for a longer timeframe in which patients can be triaged to a specialist burn unit. Patients with the worst burn injuries, often combined with inhalation injuries, tend to die immediately.[7] Indoor fires often result in a higher incidence of inhalation injuries,[8] and thus, also tend to have a higher cumulative death rate and a greater proportion of on-scene deaths. Outdoor fires typically have low on-scene mortality rates and high hospital mortality rates, with many survivors having more extensive total body surface area (TBSA) burns. Casualties in outdoor fires often sustain burn injuries that are not immediately fatal, and are of exposed areas caused by radiant heat from the fire source.[8] Nearly all of the indoor fire mortality rates are due to immediate deaths at the scene. Industrial accidents, terrorist bombings, and aircraft crashes result in the frequent occurrence of combined burn and other

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trauma injuries, which can be problematic for triage officers and patient management. There are a number of key characteristics of a burn disaster that differ from other events. The number of people involved is always high, in terms of staff numbers and casualties, as can be seen in Table 1.

Burn injuries often are extensive with a high mortality rate and concurrent trauma is common, particularly with inhalation injuries.

Descriptions, Problems and Lessons Learned
Each of the disasters included is assigned into a category, and analyzed using a standard format: (1) injury and death toll; (2) burn injuries sustained; (3) injuries sustained other than burns; (4) disaster response; and (5) major problems experienced.

Terrorist Bombings

Tower of London Bombing, London, UK, 1974[9]
Injury/Death Toll—There was one death; 37 injured victims were transported to the hospital. Of which, 19 (51.4%) were admitted.
Burn Injuries—Ten patients suffered flash burns, along with concurrent, traumatic injuries. Two of these patients also suffered minor full-thickness burns due to burning clothing.
Non-Burn Injuries—Ten of those admitted had multiple, severe injuries, including a skull fracture, facial injuries, other fractures, abdominal injuries, lung injuries, injuries to skin, ocular injuries, and otologic injuries. Four patients presented with psychiatric symptoms.
Responses—Police officials created a clear route for ambulances to evacuate casualties to a definitive care facility rapidly. The first patients arrived at a hospital within 20 minutes of the blast.

Hospital casualty departments were prepared with prearranged emergency record cards, laboratory and radiology request forms, observation charts, and identification bracelets. Extra personnel, including nursing, medical, and ancillary staff were called in to assist with managing the extra influx of patients. One doctor was assigned to each patient, and responsible for documentation, assessment, and initiation of therapy. Each patient was reviewed further by consulting general and orthopedic surgeons. Anesthetists assisted with respiratory problems; a pathologist arranged blood products. Seven operating theaters were made available quickly. Based on their injuries, patients requiring surgery were assigned to an appropriate surgical team. Senior administrative staff handled public relations.
Major Problems—Medical personnel were faced with several patients who sustained multiple severe injuries not commonly seen during peacetime. Initial assessments frequently were problematic because many patients were deafened by the blast or did not speak fluent English.

Terrorist Explosion in Bologna, Italy, 1980[10]
Injury/Death Toll—There were 73 immediate deaths, and 11 deaths in the hospital. A total of 218 persons were wounded, of whom, 181 (85.2%) required admission to the hospital.
Burn Injuries—There were 28 burn patients; 14 had >20% TBSA mainly to the face, arms, and legs.
Non-Burn Injuries—Head injuries (skull fracture, brain contusion, and brain concussion), tympanic membrane perforation, ocular injuries, chest injuries (chest wall injuries, pneumothoraces, subcutaneous emphysema, and lung contusion), abdominal injuries, fractures of arms, legs or spine, superficial wounds, and lacerations were seen.
Responses—Within 30 minutes of the bombings, approximately 250 people assisted with rescue activities. Twenty ambulances were dispatched for transport of the wounded and dead. Travel time to the city hospitals was <10 minutes. No first aid was provided to casualties at the scene or during transportation. Nearly all of the casualties were transferred to one of five hospitals, with a total bed capacity of approximately 3,000 beds. Most of the live casualties arrived at and were admitted to the hospital within one-and-one-half hours. Ambulance crews controlled the dispersal of patients based on continual information regarding bed availability.
Major Problems—Despite large numbers of physicians and other personnel assisting on-scene, no form of medical leadership was present, and no special transport area was established for waiting casualties. At times, the disaster scene was overcrowded with medical personnel. This interfered with rescue work and patient identification.

Hipercor Terrorist Bombing, Spain, 1987[11]
Injury/Death Toll—There were 21 immediate deaths due to burns and asphyxia, and 45 persons were injured.
Burn Injuries—Twenty-four casualties were admitted to the local burn center.
Non-Burn Injuries—Information not available.
Responses—On-duty medical staff cared for the victims until off-duty burns and surgical staff arrived. Emergency department staff members were willing to help with triage and resuscitation, but had little experience in burn care. However, many nurses with burn care experience gathered at the burn unit.
Major Problems—Subsequent fires and explosions hindered scene access. Traffic congestion around the hospital resulted in the delayed arrival of extra staff. Some burns were treated with silver sulfadiazine (SSD) before wound depth and size was estimated. Time was wasted as the wounds had to be uncovered again. A lack of equipment (e.g., urine dosimeters) was noted.

Oklahoma City Bombing, Oklahoma City, US, 1995
Injury/Death Toll—There were 168 deaths, including 163 (97.0%) on-scene, three upon arrival to the hospital, and two following hospital admission. Injuries were sustained by 592 survivors, with 83 (14%) requiring hospital admission.[12]
Burn Injuries—Burns comprised 8% of injuries, and were more common in the fatally injured than in the survivors. Burns, including chemical burns also were sustained by rescue workers at the scene.[13]
Non-Burn Injuries—In total, 842 physical injuries were reported.[13] These consisted of: (1) lacerations, abrasions, and contusions (96%); (2) fractures/dislocations (46%); (3) head injuries (42%); and (4) eye injuries (28%). Perforated tympanic membranes also were present. Injuries sustained by 100 rescue workers included strains and sprains, lacerations and crush injuries, foreign bodies in the eyes, abrasions, corneal abrasions, foot injury, and avulsion fractures.[14]
Responses—The site was secured immediately by responding personnel to prevent any possible contamination of

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patients.[15] Following the blast, thousands of personnel, both medical and non-medical, and seven staffed ambulances rapidly attended the scene. Within the hour, 66 staffed ambulances were ready for deployment. Ambulances and other private vehicles transported 202 patients to the hospital closest to the scene.[16] However, a large proportion of responding personnel were not required, as the initial rush of patients quickly was replaced by fatalities.[12] Teams trained in critical incident stress management assisted in providing emotional support to staff.[13]

Major Problems—The suddenness and intensity of the explosion overwhelmed hospitals in Oklahoma City.[16,17] This also placed stress on the Disaster Mortuary Operational Response Teams.[18] The risk of further explosions meant that triage stations needed to be evacuated and relocated. Scene safety was impaired by the fragility of the building remains.[13] The subsequent collapse of the building following the explosions in a pancake-style manner resulted in the fatal crushing of potentially salvageable victims of the initial blast. Communication downfalls due to the overwhelming number of telephone calls made in the period shortly after the bombing severed connections between hospitals and emergency dispatch. Only three of the 15 hospitals involved in the disaster response had functional Hospital Emergency Administrative Radio systems, and many hospitals also had no back-up communications system.[12,17]

US Embassy Bombing in Nairobi, Kenya, 1998[19]

Injury/Death Toll—There were 253 deaths, with a further 5,000 people sustaining injuries.

Burn Injuries—Burns were sustained by many survivors, but exact numbers are not available.

Non-Burn Injuries—Information not available.

Responses—The police, army, fire brigade, and other emergency medical services (EMS) arrived rapidly on the scene. Many local passers-by stopped to help survivors, especially by rescuing people from the rubble and providing transportation to the hospital, with all available vehicles being used to transport the injured. Various rescue and medical teams from outside Kenya also provided assistance. Operation Recovery was established to provide counseling and advice to survivors and bereaved families.

Major Problems—There was little coordination of medical or rescue personnel on-scene.

Omagh Bombing, UK, 1998

Injury/Death Toll—There were 29 deaths, with 21 (72.4%) of these declared dead on-scene. An additional 336 people were injured; 129 (38.4%) required admission to the hospital.[20,21]

Burn Injuries—Eight persons with burn injuries were involved.

Non-Burn Injuries—Injuries seen included abdominal injuries (4), amputations (5), blast lung (1), burns (8), eye injuries (2), fractures (24), fractures and eye injury (3), head injury (1), soft tissue injury (10), and shrapnel wounds (72).[20]

Responses—The immediate response consisted of anyone who could help those around them, including off-duty soldiers and anyone with first aid experience. A triage system was formed whereby victims who appeared dead were left for dead, and conscious victims then, in a chaotic priority system, were transferred mainly to Tyrone County Hospital, which received a rapid influx of casualties. Buses, cars, and taxis were used to transport casualties to hospital.

Later in the response, paramedics and the army medical team arrived on-scene. A resident medical officer of the army medical team was the only doctor present on-scene and assessed the casualties retrieved by other rescue workers.

The senior sister at Tyrone County Hospital initiated the Major Incident Plan. Triage nurses attempted to categorize injuries and prioritize treatment. Senior medical staff assumed the responsibility for triage and commenced acute surgery. One consulting surgeon was present, but received assistance from a surgeon who traveled from Dungannon to the hospital (100 km) to assist. Major and minor treatment areas were established.

Once more staff arrived, patients were triaged at each hospital entrance by a doctor and nurse, and again triaged after receiving treatment. It was decided that patients would need to be evacuated to other units in Northern Ireland, as Tyrone County Hospital was overwhelmed. Military helicopters and ambulances from all Western stations in Northern Ireland were used to evacuate patients.[20]

Major Problems—Most patients suffered multiple severe traumatic and blast-related injuries, which impaired patient survival and progress of the responses. The crowd's proximity to the bomb and the high buildings lining the street where the event occurred increased the pressure waves from the blast. These factors accounted for the severe blast injuries sustained by victims and their poor healing rate.[21] Underground fiber optic communication cables were severed by the blast, disabling most mobile lines. Other communication lines rapidly became overwhelmed. Minimal staff members were present at the hospital at the time of the blast, as it occurred on a weekend. The 50 emergency casualty cards used during triage soon were depleted. Initial evacuation of patients to other units in Ireland was not coordinated with communication between the various agencies and receiving hospitals. The documentation of some patients was non-existent, adding confusion to their triage status. Resuscitation equipment used during the evacuation of patients from Omagh was not returned, thus depleting stocks in Omagh.[20]

Bali Bombings, Indonesia, 2002

Injury/Death Toll—There were 202 deaths, with 66 patients evacuated from Bali to Australia.[22-24]

Burn Injuries—Full-thickness burns were prominent, burn injuries of 15%–85% TBSA.[22]

Non-Burn Injuries—Patients sustained shrapnel wounds or intra-abdominal injuries, tympanic membrane rupture, ophthalmic injuries, limb swelling, and/or peripheral ischemia.[22,25,26] Late shrapnel complications included optic nerve atrophy, eyeball laceration, hypopyon, corneal ulcers, partial division of the ulnar nerve, false aneurysm of the wrist, heterotopic bone, and an impaled meniscus of the knee joint.[22]

Responses—The Australian Commonwealth Government mobilized Operation Bali Assist,[27] with the Australian Defence Force (ADF) retrieving injured foreigners from Bali and transporting them to the Royal Darwin Hospital

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(RDH) in Darwin, Northern Territory. Retrieval teams consisted of ADF Medical Teams and Royal Australian Air Force Transport Personnel.[23] The RDH operated as a "Forward General Hospital", providing initial resuscitation and wound surgery prior to further evacuation of patients to burn units across Australia for definitive care.[25] In total, 62 patients arrived in Darwin during a 12-hour period, that commenced approximately 24 hours after the bomb blasts.[27] An airport team of anesthetists and intensive care nurses assumed the care of patients from ADF personnel. The leader of the hospital team liaised with the ambulance controller at the airport to ensure that patient arrivals at RDH did not over-inundate the emergency department.[28] An increase in hospital surge capacity was made possible through the clearance of the surgical floor, with patients either being discharged or transferred to other floors of Darwin Private Hospital, the Coronary Care Unit, and several rooms in the Renal Ward.[29] Prior to the arrival of patients, RDH staff underwent group tutorials covering burn dressings, escharotomies, and fluid and airway management.[29–31] Pre-established lines of command also were made explicit. Burn nurses rotated through the different areas for assessment and guidance. The interval between the different "waves" of patients that arrived, were used for restocking supplies and regrouping personnel.[31]

In accordance with the National Disaster Plan, this was followed by the secondary triage of patients to burn units across the country.[22,23] This included the transfer of 35 patients to Royal Perth Hospital.[32] Western Australian State Emergency Management Committee met early on 13 October and activated a major incident plan, which was coordinated from a RPH command post, facilitating intra-and-inter-hospital communication, as well as communication with a Perth airport medical team. Due to the risk of multi-resistant organisms, regular Infection Management Service meetings and briefings were held.[32,33] A multifaceted infection control response was implemented, which included restricted ward access to visitors, increased environmental hygiene, dedicated individual patient equipment, increased staff education, and the isolation of patients with established infections.[34]

Major Problems—Accurate information flow regarding flight arrivals, patient numbers, and injury severity lacked.[29,30] The overloading of communication systems in Australia hindered communication between key medical personnel. Inadequate coordination and communication between personnel arranging patient transport and the receiving burn units across Australia resulted in an uneven spread of patients across the interstate burn units.[35]

Many patients had combined burn and trauma injuries, as well as multi-resistant wound infections, which complicated patient progress.[34] The multiple nationalities of many of the patients created communications difficulties in Bali and Australia.[36] In Australia, and particularly at the RDH, difficulty was experienced in keeping staff away until absolutely necessary and ensuring that staff had regular breaks, meaning that a longer response would have been difficult to maintain had it been necessary.[31] Long-distance transport between Bali and Australia hampered the monitoring of fluid resuscitation and temperature control.[23]

Limited equipment and supplies in Bali resulted in inadequately performed procedures or, indicated procedures not done.[26,37] Triage by local authorities on-scene was non-existent, as there was no paramedic triage system in Bali.[37] Burn victims stretched Bali's hospital supplies to the limit, particularly SSD cream. The follow-up of the burn patients was lacking with staff experienced in burn care.[37]

Due to the uncertain security situation, only ADF personnel were given authorization to travel from Australia to Bali. This limited the number of personnel that could be utilized to assist with the responses in Bali.[25] The establishment of a consular help-desk, especially at the morgue in Bali, was delayed. This hampered the organization of the mortuary and identification responses, and also the briefing of victims' families.[38]

Terrorist Bombings in Madrid, Spain, 2004

Injury/Death Toll—There were >200 deaths, of which, 177 were immediate. A further 1,500 were injured.[39]

Burn Injuries—First and second degree burns were sustained by patients, but exact numbers are not available.

Non-Burn Injuries—At Gregorio Maranon University General Hospital (GMUGH), injuries included tympanic membrane perforation, chest injuries, shrapnel wounds, fractures, eye lesions, head trauma, and abdominal injuries.

Responses—Initial emergency management and triage occurred in the vicinity of the blast scenes. Emergency services established temporary field hospitals at each triage station. A psychological evaluation unit also was established immediately, which enabled 140 psychologists and psychiatrists to tend to relatives.[39] A total of 1,430 casualties had been treated by 21:00 hours (h) that day; 966 (66.7%) of which were taken to 15 public community hospitals. The majority of patients (53%) were transported to the two largest public hospitals in Madrid, the GMUGH and 12 de Octubre University General Hospital. Other victims with less severe injuries were treated in primary care facilities close to the blast scenes.[40] In the days following the blasts, many other casualties with minor injuries presented to various facilities. In total, >70,000 health personnel, 291 ambulances, 200 firefighters, 13 groups of psychologists, and 500 volunteers were involved in the responses.[40]

Three hundred twelve patients were taken to the hospital closest to the scene (GMUGH). Ninety-one (29.1%) of these casualties required admission, 89 (28.5%) of them for >24 hours.[39–41] Hospitals made room for incoming patients by canceling all surgical operations, discharging patients, and evacuating the surgical intensive care unit (ICU) and ICU patients to intermediate-care wards as appropriate. At the GMUGH, triage was performed by senior faculty members at the emergency department entrance. Advanced trauma life support (ATLS) protocols were followed. A teaching pavilion adjacent to the emergency department was converted into an information center for families, officials, and the media.[41]

Major Problems—Over-triage (the rate of non-critically injured patients being evacuated or hospitalized) was high, with the potential to cause overwhelming inundation of patients to surrounding hospitals.[40] Thousands of people gathering outside of the hospital to donate blood products interfered with the hospital triage processes.[42]

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Terrorist Bombings in London, UK, 2005
Injury/Death Toll—There were 56 deaths, including 52 (92.8%) at the scene. More than 700 people were injured.[43,44]
Burn Injuries—Burn injuries were prominent among survivors, but exact numbers were not available.
Non-Burn Injuries—Blast injuries, including perforated tympanic membranes, pneumothoraces, and perforated bowels occurred. Inhalation injuries and traumatic amputations, particularly of the lower extremities also featured prominently.[44]
Responses—The health response included bystander, prehospital, and hospital elements. Six London hospitals bore the brunt of the patients.[44] More than 100 London ambulance services were deployed as part of the disaster response.[43] These were staffed by >250 personnel. Action cards were given to all ambulance officers.[45] Central Ambulance Control mobilized groups of physicians to the scene, who performed scene management, evacuation, and medical care of injured survivors.[44] These groups consisted of "Gold Doctors", "Silver Doctors", and "Bronze Doctors".[46] The "Gold Doctors" included "major incident officers" and a number of members of the London Helicopter Emergency Medical Service. A team of doctors was assembled rapidly at each bombing scene. Each was experienced in providing prehospital care. "Bronze Doctors" cared for individual patients with serious injuries, while "Silver Doctors" took control of managing the scenes and evacuating casualties to area hospitals.[46]

Every hospital in London was put on alert. Those nearest to the scene were prepared to receive patients. The Royal London Hospital treated 208 people within four hours. In total, it saw more than 50% of all the victims.[47] This hospital has London's only emergency medical helicopter, which was used to shuttle medical teams to the bombsites. Royal Free Hospital treated 61 casualties. The Great Ormond Street Hospital for Children treated 22 patients with blast injuries and burns, despite having no emergency department and not usually treating adults. It was close to two of the bomb sites.[48] Two triage stations were set up at the front and back of the hospital. Hospitals, such as St. Mary's Hospital, which received 38 patients, prepared for the patient influx by calling all staff members in clearing the emergency department of all previous patients, and preparing operating rooms for emergency surgery. Available ICU beds also were identified. Trauma teams were deployed to each of the four receiving bays in the resuscitation room and one to the operating room in the emergency department. Pediatric teams also were on stand-by. Senior teams triaged patients as they arrived and assigned them to one of three areas in the emergency department depending on their treatment priority. A senior surgical consultant ensured that a thorough secondary survey was performed for all patients. Chaplains, patient-liaison teams, and mental health staff provided emotional support. Medical students also were used to bring supplies to various key areas. After initial treatment and stabilization, burn patients requiring specialty burn care were transferred to the regional burn center.[46]

A helpline was established by the Metropolitan Police to coordinate searches for missing people.[48]

Priority routes were established by police to ease the travel of medics and other personnel to the scenes. Emergency medical helicopters were used to transport the bronze and silver doctors as well as equipment required at the scenes. Scene Access Control was established rapidly. Duty Station Officer vehicles carried stocks of handheld portable radios and packs to the disaster scene. Occupational health and counseling services were offered to all staff involved in the incident.[45]
Major Problems—In some cases, burn injuries were combined with blast injuries as well as inhalation injuries, which complicated patient progress. The London Ambulance Service (LAS) Trust acknowledged that its reliance on and the subsequent breakdown of its mobile network and configuration of its radio system led to communication difficulties that hampered the National Health System (NHS) response.[49] Mobile telephone networks failed and conventional forms of radio and mobile telephone communication still were unable to work underground.[50] Due to these shortfalls, hospitals had to rely on television news bulletins for information on casualty numbers. The underground locations of some of the explosion sites impacted personnel safety and site access. Site access also was hindered by the threat of further attacks.[51]

Nightclub, Restaurant, and Hotel Fires

Cocoanut Grove Fire, Boston, USA, 1942
Injury/Death Toll—There were 491 (61.3%) deaths (>300 at the scene).[52]
Burn Injuries—Forty-two patients suffered burns of between 1–4% TBSA, of which, three died. Thirty-two patients suffered burns between 5–9% TBSA (including six subsequent deaths (18.8%)), 11 suffered 10–19% TBSA burns (including five deaths (45.4%)), seven suffered 20–29% TBSA burns (including three deaths (42.9%)), and 22 patients suffered >30% TBSA burns (including 20 deaths (90.9%)).[53]
Non-Burn Injuries—Inhalation injuries were prominent and complicated the progress of many burn patients.[53]
Responses—The majority of casualties were transported to the Boston City Hospital and Massachusetts General Hospital.[53] Non-resident staff was notified to report through a pre-determined and posted "fan-out" schedule. All leaves for hospital help were cancelled. Upon notification by radio, doctors from 30 miles around Boston, and medical students from greater Boston-area colleges reported. More than 200 of the Navy's medical personnel treated survivors and rescuers. Medical authorities from around the nation wired offers of help. The Boston Metropolitan Chapter of the American Red Cross mobilized >500 workers within 30 minutes of being alerted. Nurses Aides Corps mobilized nearly 500 aides to relieve overworked regular hospital staff and the nursing service mobilized nearly 300 volunteer nurses for the emergency services of the first few days. At the hospitals, wards especially equipped to receive disaster victims were opened. Other casualties were sent to any surgical or medical wards with available beds.[53]

Interns were stationed at the entrance and pronounced those patients who were dead-on-arrival. The dead bodies temporarily were placed aside, and the living patients permitted to enter.[53]

Many casualties were transported by taxis, trucks, and other private vehicles. A team was sent to the scene and to

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the hospital entrances to manage on-scene triage. Cocoanut Grove survivors were isolated from existing patients, with continual monitoring and reassessment of their injuries occurring through frequent ward rounds.[52,54]
Major Problems—Fire safety standards in the club were severely lacking and led to the trapping and subsequent deaths of >300 patrons, including 200 at the front revolving door, and 100 at an inward-opening side exit.[52] Ambulances sent to the scene had difficulties accessing the site due to the narrow street being crowded with firefighting crews and equipment, victims, and onlookers, and thus, soon were overwhelmed. Many casualties were transported to the hospital by taxis, trucks, and other private vehicles without any standardized transport or distribution protocol.

Initially, the number of dead arriving at the hospitals outnumbered the living. Staff initially used excess time and resources in an attempt to revive the dead, until special triage teams were deployed.[53] Identification and tracking of patients proved difficult with the establishment of an information dissemination office being delayed.[52]

The Summerland Fire, UK, 1973[55]
Injury/Death Toll—There were 48 deaths on arrival to the hospital, with two deaths (4.2%) occurring nine days post-admission. A further 102 patients were transported to the hospital, with 32 (13.4%) requiring admission.
Burn Injuries—A total of 24 patients were admitted with surface burns. Eleven (45.8%) had <10% TBSA, five (20.8%) had 10–20% TBSA, four (16.7%) had 20–30% TBSA, two (8.3%) had 40–50% TBSA, one (4.2%) had 55% TBSA (this patient died), and one (4.2%) had 65% TBSA (this patient also died).
Non-Burn Injuries—These often were combined with the burns and included fractures (including three pelvic fractures), lacerations, emotional stress, and a variety of injuries to the chest, abdomen, and limbs.
Responses—A total of 104 beds were made available at the receiving hospital through the transfer of patients to day rooms, with two wards of one- and four-bed units on the same floor as the theater suite were used as a burns unit. Intravenous infusions were established in the casualty department, with patients given intravenous (IV) morphine or pethidine if necessary, and to assist with documentation and ensure continuity of treatment, each patient was assigned a nurse.
Major Problems—It took 30 minutes after the fire had started for the fire services to be notified of the situation.[55] Roads leading to the hospital became severely congested, hindering the arrival of personnel and ambulances. Incoming calls received by the hospital's overloaded telephone lines and the delay of outgoing calls required the mobilization of extra personnel and equipment. Initial problems occurred during the triage of patients entering the Casualty Department. A lack of crowd control occurred in the Casualty Department, with large numbers of relatives, friends, and patients overcrowding the department. This impaired communication and coordination between staff members.

Beverley Hills Fire, USA, 1977[56]
Injury/Death Toll—There were 165 deaths and >200 injuries.
Burn Injuries—Burns predominated, but exact details were unavailable.
Non-Burn Injuries—Information was unavailable.
Responses—A minister trained in counselling and grief work was used to counsel victims and rescue personnel. Further information was unavailable.
Major Problems—Fire safety standards were lacking in the club, including poorly marked fire exits and flammable decorations.

MGM Grand Fire, USA, 1980
Injury/Death Toll—There were 85 deaths and 726 people sent to local hospitals, of which, 322 (44.4%) were admitted. Another 1,700 were sent to a secondary triage-refuge center.[57,58]
Burn Injuries—Burn injuries were sustained, but exact details not available.
Non-Burn Injuries—Information not available.
Responses—A primary triage station was deployed rapidly outside the secondary main entrance. A second and a third primary triage station were established on the south and east sides of the hotel, respectively.[58]

Within five hours, 3,000 (50%) of the 6,000 people in the casino had been processed by the Las Vegas Emergency Medical System at the primary triage stations. A total of 1,700 victims were referred to a secondary triage-refugee center at the nearby convention center, which was used as a makeshift, acute care hospital with 200 beds and 100 additional cots. It was staffed primarily by Red Cross personnel and other volunteer services, with a duty roster for professional staff. A further 726 casualties were sent to local hospitals, of which, 322 (44.4%) were admitted.[58] The rest of the injured victims were discharged to the refugee center. Medical facilities included four major, full-service hospitals, providing 1,400 acute beds, 17 advanced life support units, and 23 emergency medical technician units. Hospital beds were cleared quickly by early discharge and transfer of the minimally ill, canceling surgical lists, and the mobilization of medical teams. Internists, pulmonary technicians, and blood gas and radiology services were needed. Helicopters were used in the evacuation of critical patients. School buses with radio communication were used to transfer the less seriously injured patients to the secondary triage station.
Major Problems—Communication lacked between the three primary triage stations and between the primary and the secondary triage stations. Thus, some patients were processed multiple times and some uninjured onlookers also were processed. Radio communication between responding agencies, particularly helicopter units, also lacked, which increased the risk of collision and decreased coordination. The first medical helicopter was too close to the aid station and flattened it. Initial access of ambulances to the scene was hindered and triage stations were difficult to identify. This delayed the evacuation of patients and initiation of treatment.[58]

Disco Fire in Dublin, UK, 1981
Injury/Death Toll—There were 48 deaths, of which 40 (83.3%) were at the scene,[59–61] All fatalities suffered burn injuries.

A further 214 casualties; 128 (40.8%) required hospital admission, and were sent to one of six main hospitals with Mater Hospital receiving most of the patients (36.4%).[60]
Burn Injuries—Eleven of the 128 admissions sustained severe burns. Burns mainly were flash burns to exposed

areas (arms, face, etc.).[60] Severe burns to the shoulders, arms, and backs resulted from molten plastic dripping from the ceiling.[61] The majority of burns were partial thickness. Eighty-six of the 214 survivors (40.2%) were treated in outpatient clinics for small, superficial burns and shock.
Non-Burn Injuries—Thirteen of the 128 admissions (10.2%) were admitted due to respiratory distress.[59]
Responses—Within minutes, the Dublin major accident plan was put into effect. All available fire engines and ambulances were sent to the scene, with the six main Dublin hospitals placed on "red alert". A total of 214 casualties were distributed among these six hospitals. At the Mater Hospital, the disaster plan was activated once it was clear that a mass-casualty incident had occurred, and involved the clearing of a large general surgical ward to be used as a reception and treatment area for most of the victims. A psychiatrist evaluated patients early in their treatment course, with supportive counseling given throughout.[60] Follow-up counseling also was arranged for after the patients discharge. Dublin's main center (Dr. Steeven's Hospital) for the treatment of burns and plastic surgery set up an emergency supply of camp beds in the Casualty Department in order to meet the increased patient demand. Four nurses were deployed from quieter wards to assist. A priest provided patient and relative reassurance. Routine hospital admissions were cancelled and some in-patients were transferred to rural hospitals.[61] The Joint Hospitals' Service Board ensured that Dr. Steeven's Hospital remained well stocked while it supplied other area hospitals with special burn dressings. Ten days later, Dr. Steeven's Hospital received patients transferred from other hospitals for further grafting. Regular observations and continual physiotherapy were maintained throughout the entire process.[61]
Major Problems—Fire safety standards were inadequate. Several exits were chained and locked, the main entrance was obstructed by metal shutters, and windows in the toilets were welded shut. Burning PVC chairs created toxic fumes, which further hindered access by rescue crews.[61] Initial assessments of patients at the hospitals was difficult due to the large numbers of patients arriving.[60]

Gothenburg Fire, Sweden, 1998
Injury/Death Toll—There were 63 deaths; (61 (96.5%)) at scene due mainly to inhalation of toxic fumes, with a further 213 casualties transported to hospitals.[62]
Burn Injuries—There were severe burn injuries with a mean value of TBSA of 16%.[63]
Non-Burn Injuries—Inhalation injuries were common among survivors.[162]
Responses—The first rescue force was dispatched approximately three minutes after receiving the first call about the fire. A standard ambulance and a mobile intensive care unit ambulance were dispatched immediately, and the Police Command Center was informed. A doctor-on-call in Gothenburg arrived on-scene shortly after. The SOS Alarm response system also automatically dispatched a medical team from Osra hospital, but only one-and-one-half hours later.[64] No on-scene medical director was called.[63] One medical team from Sahlgrenska Hospital and one from Molndal Hospital arrived at the scene of the event after all of the patients were evacuated. When more telephone calls were received, the SOS Alarm issued a major alert with call-outs from three fire stations and 14 extra ambulances.[64] Fifty firefighters and 42 police officers were on-scene, providing life support, cordoning off the scene, and supervising the Casualty Assembly Point during the initial few hours.[63]
Major Problems—Blocked exits and excessive crowds in the club hindered the evacuation of patrons from inside the building.[62] Initial on-scene medical resources and personnel were inadequate, and quickly were overwhelmed.[65] Oxygen, in particular, was not in sufficient supply. Emergency personnel were abused by bystanders, hindering the treatment and evacuation of victims. Communication overload made it difficult for hospitals to receive accurate information.

Not all of the hospitals involved activated a disaster alert, even though it later was established that they should have. The chief physician educated in disaster medicine was not ordered to the scene as rescue crews assumed he would be coming.[65] There was a lack of trained triage officers and extra medical personnel on-scene, since it was nighttime. Disaster plans at receiving hospitals were hard to follow. Psychosocial services faced difficulties with the multicultural characteristics of the victims.[64,66]

Volendam Café Fire, The Netherlands, 2001
Injury/Death Toll—There were 10 deaths following admission to hospital, with 173 patients hospitalized.[67]
Burn Injuries—Sixty-four burn patients presented, and required intubation.[67]
Non-Burn Injuries—More than one-third of the burn patients had an inhalation injury.[68]
Responses—Approximately 200 rescue workers were deployed to the scene. Evacuation of casualties during this response was delayed until initial on-site treatment was provided. This is known as the "sit and play" method.[69] The original plan was to evacuate most patients from the scene by air, but this changed when it was established that some hospital helipads were not suitable for medium-sized helicopters, forcing them to land at an airfield some distance away. Each trip was used to transport three patients and a burn team of four (one anesthetist, two intensive care nurses, and one respiratory therapist).

Nineteen critical burn patients were transferred to burn centers in Belgium the day following the fire.[67]
Major Problems—Not all rescue workers were familiar with protocols used at the scene, and only a few of the workers used a standardized triage protocol and registered their findings.[68,70] Rescue workers in the Netherlands are not given any specific standardized training in disaster management, and burn teams also operated on a voluntary basis.[68]

Rhode Island Station Nightclub Fire, US, 2003
Injury/Death Toll—There were 100 deaths, including 96 (96%) at the scene.[71,72] A further 215 people were injured, of which 79 (36.7%) were admitted, with Kent County Hospital and Rhode Island Hospital (RIH) seeing the majority of patients.[71]
Burn Injuries—There were 196 burn victims 35 (17%) required intensive care and ventilatory support.[71]

Of those admitted at RIH, 70% had burns <20% TBSA, 12% had burns 21–40% TBSA, and 4% had burns >40%

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TBSA. Head, neck, chest, and upper extremities were the most common sites involved.[71]

Non-Burn Injuries—Details not available.

Responses—Patients were evaluated by one of 16 area hospitals. Of these patients, 79 were admitted.[73] Internal disaster plans were activated by each hospital.[74] A medical triage station was set up at an inn across the street. Rescue units were stationed in a staging area and sent to the triage station in small groups when victims were identified as needing transport.[74] Less injured patients left the scene and presented independently to the nearest area hospitals. Priests and ministers were on-scene and at hospitals to provide counseling and guidance.[75]

After receiving a call on the rescue telephone with information of a fire with multiple burn victims, the RIH disaster plan was initiated. The Hospital Emergency Incident Command System (HEICS) was deployed to coordinate the hospital care.[72] First, the emergency department was cleared of patients, and triage was set up in the ambulance bay outside of the department. A single floor in the main hospital was converted into one large burn unit. Ten attending surgeons, six emergency physicians, and approximately 30 surgical residents were called in.[74] Stretchers, oxygen tanks, and disaster identification packets were set up by the triage nurse and medical technicians to prepare for the arrival of mass casualties. Designated teams were assigned to a specific room. Each room received a critical fire victim. Those with inhalation injuries were labeled a priority, with immediate airway management, respiratory support, and fluid resuscitation administered.[72]

Major Problems—Inhalation injury complicated the progress of several burn patients. Ambulance personnel decided where patients would be transported, thus resulting in an uneven distribution of patients among hospitals. Inter-hospital communication also lacked, particularly when some emergency departments were overwhelmed. At RIH, problems experienced included poor communication with the personnel at the scene, and a disaster response plan lacking specific instructions for patient relocation or movement.[71,73] A family support plan also was lacking. Traffic congestion outside of the hospitals delayed the arrival of extra staff at the receiving hospitals.[72]

Industrial Accidents

The Texas City Disaster, US, 1947[76]

Injury/Death Toll—There were 560 deaths (or people declared missing), with 800 patients admitted to a hospital and another 3,000 people with minor injuries.

Burn Injuries—Victims suffered mild-to-severe burns.

Non-Burn Injuries—These often were combined with burn injuries and included head injuries, lacerations, lung injury, abdominal injury, kidney and bladder injury, perforated eardrums, ocular injuries, amputations, and fractures.

Response—Initial priority was given to rescue work and the evacuation of the injured from the immediate danger zone, with the first call going out for medical and nursing personnel, as well as equipment. As the only hospital beds in Texas City were in small, private clinics, patients were distributed to larger hospitals in Galveston, Houston, and other neighboring cities. Hospitals initiated plans to clear wards for incoming patients. The American Red Cross provided assistance through the provision of beds, linen, blood, penicillin, and other supplies.

First, patients were taken to the outpatient clinic for an initial brief physical examination and then triaged according to injury severity. Triage distribution was as follows:

1. Patients with minor injuries were sent to several minor surgery rooms;
2. Critically injured patients, other than those immediately taken for surgery, were sent to shock wards to prepare for surgery; and
3. Seriously injured patients were taken to pre-operative wards after wound cleaning, dressings, and x-rays. Specialists were available for consultation.

A note was pinned to each patient's gown outlining details such as their name, general observations, injuries sustained, and whether plasma or morphine had been given.

Medical students assisted each ward officer by taking histories, performing physical examinations, running tests, and applying dressings. A messenger system was used by wards to stay in contact with the Chief of Operations, in regards to supply and equipment needs.

Major Problems—Existing first-aid equipment on-site was destroyed, thus causing a delay in the initial administration of first aid to casualties. There also was a shortage of temporary splints for fractures. The event site was overcrowded with personnel who had insufficient experience and equipment, thus complicating medical command, which already was problematic due to the lack of designated personnel-in-charge. There also was a level of media interference, particularly through the distribution of false or misleading information. This created a sense of panic and interrupted the flow of accurate information between hospitals and the disaster scene.

Gas Explosion in Osaka, Japan, 1970[77]

Injury/Death Toll—There were 79 deaths, 68 (86.1%) of which were immediate. A total of 428 persons were injured by the explosion and subsequent fires.

Burn Injuries—Burns comprised 19.9% of injuries, with 85 cases in total. Forty-nine of these burn cases (57.6%) occurred in combination with multiple injuries.

Non-Burn Injuries—Fractures were the second most common injury (17.3%). Other medical problems requiring treatment included neck and head injuries, anginal pain, hypertension, asthma, spontaneous abortion, and aggravation of a gastric ulcer. Emotional distress also was a common feature among survivors.

Responses—Victims with slight injuries walked or were driven to local hospitals. It was not until 20–30 minutes after the explosion that emergency medical technicians actually were able to evacuate the seriously injured from the scene, and another four hours for gas lines to be closed and the fire finally brought under control.

Major Problems—The event occurred on the day that the dispatch room of the City Fire Department was relocating to a new building and was not operating at full capacity. A lack of communication and leadership resulted. The lack of an adequate triage system in Japan led to the delayed evacuation and treatment of casualties and confirmation of the deceased. Emergency medical technicians were not authorized to diagnose deaths, which required physicians to spend considerable amounts of time performing this function. There also was a lack of disaster tags that could have been used to identify and categorize patients. The mass media also had full access to the receiving hospital, interfering with staff function and communications.

Brasov Factory Fire, Romania, 1979[78]
Injury/Death Toll—A total of 93 casualties were transported to the hospital, of which, 82 (88.2%) were admitted. Forty-four (53.7%) of the admitted patients died.
Burn Injuries—A total of 19 patients (11.0%) had <10% TBSA burns, four patients (4.9%) had 11–20%, seven patients (8.5%) had 21–30% TBSA burns, 12 patients (14.6%) had 31–40% TBSA burns (six died), five patients (6.1%) had 41–50% TBSA burns (four died), six patients (7.3%) had 51–60% burns (five died), seven patients (8.5%) had 61–70% TBSA burns (seven died), and 22 patients (26.8%) had >75% TBSA burns (22 died).
Non-Burn Injuries—Non-burn injuries consisted of pulmonary complications (mostly bronchopneumonia), cardiac complications, pulmonary embolism, and late, digestive tract hemorrhages.
Responses—Patients mainly were taken are for burns by private vehicles without triage or initial resuscitation to a the Brasov County Hospital, a 750-bed center with 14 operating theaters and a plastic and reconstructive surgery department consisting of 60 beds (15 burns beds). Following notice of the fire, all operating theaters were cleared and prepared for patients. An anesthetics and surgery team was formed, and the hospital pharmacy and catering department was put on alert. On the second day after the fire, a special, isolated ward was set up for the Brasov burn patients with patients grouped together by injury severity.
Major Problems—The arrival of ambulances to the scene was delayed. No on-scene triage or first aid was administered. Emergency care and equipment at industrial workplaces in the Brasov area were inadequately prepared for big emergencies.

Cardowan Colliery Fire, UK, 1982[79]
Injury/Death Toll—There were no deaths. Forty miners received injuries.
Burn Injuries—A total of 36 patients sustained burn injuries. These were mostly to the hands, face and neck, shoulders, and the upper trunk. Eight patients (22.2%) had <15%TBSA burns, 14 (38.9%) had 15–34% TBSA burns, and four (11.1%) had 35–55% TBSA burns.
Non-Burn Injuries—One patient suffered minor wounds; three suffered contusions of the trunk and legs, and four had head injuries (one severe). Respiratory dysfunction (mild to moderate arterial hypoxemia) was common, with 19 requiring oxygen.
Response—A little more than one hour after the explosion, the Accident and Emergency Department (A&E) at Glasgow Royal Infirmary were told to expect eight casualties. The casualty ward was cleared, the resuscitation area was prepared, and the scheduled fracture clinic was cancelled. Initial hospital triage was performed, but was abandoned when patients arrived eight people at a time. An initial group of eight patients arrived in one ambulance approximately two hours after the explosion. Casualties were diverted to the neighboring second-line hospital. Patients who arrived at the Royal Infirmary after this and who deemed suitable for transport also were transferred to the other hospital. The Glasgow Royal Infirmary contains the regional burn unit and most A&E staff are aware of standard burn treatment protocols. Eleven patients were taken directly to the Western Infirmary in Glasgow.
Major Problems—Organization of the response was hindered by the lack of information transfer between hospitals and the accident scene.

San Juanico LPG Explosion, Mexico, 1984[80]
Injury/Death Toll—There were 550 deaths, of which, 300 (54.5%) occurred at the scene. The remaining 250 (45.5%) died following admission to hospital. More than 7,000 people were injured; 2,000 (28.6%) of whom were admitted to the hospital.
Burn Injuries—A total of 625 people (31.2%) admitted to the hospital had severe thermal injuries.
Non-Burn Injuries—This information was not available.
Responses—Thirty-three hospitals were involved in patient care, with 363 ambulances and five helicopters used to transport patients. More than 7,000 rescue workers were involved in the response during the first 24 hours, including 250 firefighters, 1,000 physicians, 1,800 nurses, 1,300 medically trained personnel from the Red Cross and other organizations, and approximately 2,000 military personnel and volunteers.

The first firefighting units arrived on-scene shortly after the initial explosion. Then, the police closed the roads accessing the site. Emergency services (ambulances, rescue teams, etc.) then reached the site with extra firefighting crews. The Disaster DN-111-E Plan (earthquake plan) was activated. The ambulance chief from Mexico City took command of rescue operations at the scene. A relief center was established at the Basilica of Guadalupe where the administration of first aid and triage of patients occurred. Three more relief centers were established in three outpatient clinics when the nearest hospitals became overcrowded. In total, 33 hospitals received injured patients, with nine of these hospitals located within 10 km radius of the site.

The chief commander from the Department of Home Affairs in Toluca took command of rescue work shortly afterward. Medical and nursing personnel assisted with first aid and triage at the disaster scene and at the relief centers. A parking area was set up for ambulances, water-carrying lorries, vehicles, and helicopters. A forensic pathologist, prosecutor, and sanitary personnel were deployed to perform victim identification.

Some (exact number not available) of the 625 burn patients were taken straight to a specialized burns unit, while others went to a provisional burn center first. Three days after the disaster, the 625 burn patients were distributed among 12 different hospitals with good burn facilities where patients could be isolated. To increase surge capacity, hospitals either discharged or transferred existing patients, or enlisted a large number of extra personnel.
Major Problems—The patient numbers, especially those with burn injuries, were enormous. Roads became congested with displaced persons and patients began to overcrowd

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nearby hospitals. Panic set in among survivors due to inaccurate media information. In the first hour of the medical response, total chaos at the site ensued. Rescue work was improvised without guidance. At one stage, emergency personnel had to withdraw temporarily due to further explosions and fires.

Piper Alpha, UK, 1988

Injury/Death Toll—There were 167 deaths on-scene, with a further 62 patients transported to the hospital.[81,82]

Burn Injuries—Burns typically were of the face and hands.[83]

Non-Burn Injuries—Shock, inhalation injury, hypothermia, wounds, and fractures were common among survivors.[81]

Response—A Multi-Function Support Vessel (MSV), the MSV Tharos, was anchored close to the Piper Alpha, with its primary role to provide support in firefighting, diver support, fabrication and repair, and hospital services, consisting of a six-bed, fully equipped hospital unit. An operating theater also is located on-board. The on-board medical crew consisted of an experienced offshore doctor, and a first-aid crew consisting of stewards employed by the catering contractor, with no formal training, but significant experience in emergency drills on-board the ship.[81] This first-aid crew also was augmented by several divers with extensive first aid experience. Rescue crews picked up 62 survivors, most of whom had jumped almost 100 feet from the platform into the sea.[82] These survivors initially were treated on-board, and subsequently, all survived. Then, they were transported to the mainland, where they were assessed further at the Aberdeen Royal Infirmary. A psychiatric response was part of the overall initial emergency plan, consisting of a small team of senior and experienced clinicians. This team was most actively concerned with survivors and members of the police force involved particularly in the retrieval and identification of the deceased.[83,84]

Major Problems—The scene was remote and difficult to access by crews due to a layer of ignited oil surrounding the structure. This prevented the rescue of several victims and the subsequent delayed evacuation and treatment of survivors. Emergency services on the rig, including emergency lighting and fire detection systems and firefighting facilities, together with all telecommunications and alarm systems were disabled. Fire on deck impaired the launching of lifeboats and survival craft. Extra injuries were sustained by survivors as they leapt from the structure into the ocean. This complicated subsequent treatment and patient progress.

Bashkir Pipeline Explosion, Soviet Union, 1990

Injury/Death Toll—There were 400 deaths, with >800 additional casualties.[85]

Burn Injuries—Of 800 people injured, >97% suffered burn injuries.[86]

Non-Burn Injuries—Thirty-three percent of the burned patients also had inhalation injuries.

Responses—Ground ambulances arrived on-scene approximately three hours after the fire started. The most seriously injured patients were transported during the following 12 hours to the nearest hospitals in Ufa and Chelyabinsk, 120 km and 250 km from the site, respectively. Then, international assistance was requested, with specialists from Britain, the US, and Israel providing assistance within the first day. A total of 318 victims were evacuated to the largest burn centers for further treatment, including 166 to Moscow. Of the 806 injured, 633 (78.5%) survived.[86]

Major Problems—Long delays were experienced in the resuscitation and evacuation of patients. Ambulances arrived on-scene approximately three hours after the fire started.[85]

West Pharmaceutical Plant Explosion, US, 2003[87]

Injury/Death Toll—There were three deaths at the scene, with >30 people admitted to surrounding hospitals.

Burn Injuries—Ten critically ill burn patients presented, also with suspected inhalation injury.

Non-Burn Injuries—Several patients suffered multiple concurrent trauma, but exact details are unknown.

Response—Local EMS was dispatched immediately upon notification of the event, with the North Carolina Emergency Management being notified and told to expect a potential of >200 victims.

On-scene triage initially was directed by the fire department, then EMS, and finally, by a private emergency department physician arriving on-scene. Patients were transported to one of three area hospitals, including Lenoir Memorial Hospital, Pitt County Memorial Hospital, and the University of North Carolina (UNC) Hospital (Level-1 Trauma and Burn Center, approximately 100 mi (160 km) from the site).

The staff of Lenoir Hospital established a triage area outside of its emergency department and received most of the walking wounded. Twenty-seven patients were triaged in the emergency department, with 16 (59.2%) eventually being admitted. Two of these later were transferred to the UNC Burn Center, having been intubated.

Four critically ill patients were transported from the scene to the Level-1 Trauma Center at Pitt County prior to transfer to the UNC Burn Center, and another four critically injured burn patients were sent directly to UNC. An hour after the explosion, UNC had an Incident Command Center established, involving the holding and recalling of staff, ensuring adequate security, freeing up beds, and canceling elective surgery.

Major Problems—Burn injuries were combined with multiple traumatic injuries, which caused problems during triage. There was (and still is) no comprehensive integrated disaster plan in the US that encompasses both burn and trauma patients. Communication between the hospitals and the scene was inadequate, and information flow was inaccurate. There seemed to be little knowledge on how to activate the regional disaster response.

Transportation Accidents

SS Yarmouth Castle Disaster, Bahamas, 1965[88]

Injury/Death Toll—There were 90 deaths. Information on the total injury toll was not available.

Burn Injuries—Five of the immediate survivors were badly burned (30%, >78%, >48%, 88%, and one with burns over the upper half of their body). A sixth patient was transferred on the fourth post-burn day to the hospital with <10% TBSA burns.

Non-Burn Injuries—Information was not available.

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Response—Responders transferred the injured and rescued to Princess Margaret Hospital in Nassau (Bahamas). The burn patients were transferred to Miami the following day.
Major Problems—The remote location of the ship delayed transport of patients.

Nakivubo Fire, Uganda, 1973[89]
Injury/Death Toll—There were 11 deaths at the scene (all due to >90% TBSA burns), with 71 casualties admitted to hospital. Twenty-six (36.7%) of these patients died in the days following the disaster (14 (53.8%) within four days, and 12 (46.2%) after four days).
Burn Injuries—More than 80 initial survivors suffered burn injuries, of whom, 71 (88.8%) needed hospital treatment. A proportion of these (exact number not available) patients suffered burns to >20% TBSA.
Non-Burn Injuries—Information not available.
Responses—Doctors and nurses reported spontaneously to the Casualty Department of the hospital. After initial estimation of burn wounds, patients were assigned into one of two groups: (1) <20% TBSA; and (2) >20% TBSA. Intravenous fluids were given to those with >20% TBSA. A 20-bed surgical admission ward and a 20-bed thoracic surgical ward were used. Part of a general surgical ward and an ear, nose, and throat (ENT) ward also were used.
Major Problems—Finding 71 beds was difficult. Pulse rate and blood pressures were not monitored. Oral administration of fluids was difficult due to insufficient feeding cups and straws. A number of complications arose, hindering patient progress. These included vomiting, diarrhea, peptic ulcer, anuria, pain, confusion, necrotic ear, bed sores, contractures, keloid and hypertrophic scars, itching, abscess in calf, headache, maggots, and lice.

Los Alfaques Disaster, Spain, 1978[90]
Injury/Death Toll—There were 102 deaths on-scene, with a further 108 deaths following hospital admission.
Burn Injuries—A total of 148 victims were burned, with >122 of those receiving at least 50% TBSA full-thickness burns.
Non-Burn Injuries—Information was not available.
Responses—Police forces assisted with the cordoning off of the disaster site, and setting up roadblocks.

As the overturned tanker split the campground into two groups, 58 patients were transported north, and 82 were transported south. Those patients who were transported north eventually received care at the Francisco Franco Hospital in Barcelona, which has 31 burn unit beds. On the way, patients received appropriate care at Amposta and Tortosa. The 82 severely burned patients taken south were transported to the La Fe Hospital in Valencia, which has 14 burn unit beds. No medical treatment was given to most of the patients during the journey. These patients were transported in a coach to Valencia, an approximate 160 km journey. Treatment given at both burn units was similar.

The burn unit at the Francisco Franco Hospital in Barcelona and nearby plastic surgery wards almost completely cleared their beds, and within three hours, mobilized 60 nurses and 10 doctors, all with burn care experience. Patients with a reasonable chance of survival were sent to the burn unit, while patients with >90% TBSA (36 of the 58 (62.1%) patients) were transferred to the two plastic surgery wards. A week later, seven patients still were being nursed in the burn unit, six had died, and 45 were transferred to burns units in France, Belgium, Germany, and Holland.

The La Fe Hospital in Valencia had two plastic surgery wards and a special burn unit with 14 beds. This hospital put its disaster plan into effect as soon as the extent of the damage was clear. The gymnastics and rehabilitation hall on the ground floor also was set up with beds, and infusion equipment. Fourteen doctors from the ICU and surgery block, and 50 nurses were mobilized rapidly. After initial triage and initiation of treatment, patients were split into three groups. Those with a reasonable chance of survival were taken to the burn unit; those with 70–90% TBSA were taken to one of the plastic surgery wards; and patients with at least 90% TBSA burns were taken to the other plastic surgery ward.
Major Problems—The driver of the tanker had taken the wrong route and several parts of the tank were faulty.

Initially, due to lack of designated personnel in-charge, the transport of patients was uncoordinated, and no triage occurred. Telephone lines were lost shortly after the first alert was issued, with an insufficient quantity of available ambulances. Their arrival also was delayed. In Spain, a lack of legislation on emergency services meant that no central fire-service authority was responsible for emergency services, and there was no common alarm center. Each EMS had to be called in turn. No medical aid was sent to the site of the event, and no detailed disaster plans existed in the countryside surrounding the disaster site. The overturned tanker split the burn victims into two separate groups. The group taken south received minimal treatment en route, which led to a drop in survival rate to 45%. Several arrived in shock, also due to lack of monitoring en route. The intravenous fluid regime administered to each patient at the receiving hospitals varied depending on the doctor's speciality, which disrupted the continuity of patient care. Information given to relatives and the media was disorganized and hindered by language barriers.

King's Cross Underground Fire, UK, 1987
Injury/Death Toll—There were 13 deaths at the scene, with a further 45 victims transported to the hospital. Of these, 16 were dead-on-arrival to the hospital.[91]
Burn Injuries—Twenty-eight patients suffered thermal injuries, nine (33.3%) with severe burns. Burns were mainly to the face, ears, neck, trunk, and limbs.[91]
Non-Burn Injuries—Information not available.
Responses—Ambulances were called and arrived approximately 30 minutes after the initial fire started. Salvation Army personnel assisted police, firefighters, and the general public. Ten casualties already had been admitted before the London Ambulance Service (LAS) declared a major incident. Casualties were distributed by 14 LAS ambulances to four hospitals. On-scene medical support consisted of eight doctors (five from the BASICS group) who supervised triage and on-site certification of the deceased. University College Hospital (UCH) was utilized as the primary hospital for treatment due to its close proximity to the scene, and its Plastic Surgery Unit that had the capacity to manage burns patients, in particular, those with

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inhalation injuries. The majority of burn patients were taken to UCH. One also was transferred to Whittington Hospital, while another was sent to St. Bartholomew's Hospital. Eleven different specialties were required in the response, including ICU, bacteriology, hematology, ENT, nephrology, emergency, ophthalmology, gynecology, psychiatry, anesthesia, and plastic surgery.[91] A specific staff counseling service was available for all staff members.[92]
Major Problems—Confusion among station staff led to the delayed calling of the fire brigade. Emergency fire safety measures were lacking (e.g., non-functioning sprinklers, inaccessible fire hydrant). Communication networks and radios were unable to function in the underground station.[91] Many of the deceased were transported by ambulance to the hospital, while many of the injured were left on the street waiting for the ambulance to return.[93]

Motorway Tunnel Fire, Italy, 1996[94]
Injury/Death Toll—There were five deaths due to burns; further 34 people were injured.
Burn Injuries—A total of 11 patients suffered 10% TBSA burns, one suffered a 15% TBSA, two sustained 20% TBSA burns, one had a 35% TBSA burn, and one received a 50% TBSA burn. Of these patients, five had partial thickness burns, with 11 suffering full thickness burns.
Non-Burn Injuries—Inhalation injuries were likely, but not qualified, with all of the patients admitting to inhaling hot gases and smoke.
Responses—Patients were transported by ambulances and private vehicles to a small hospital in the town of Carini, 4 km from the site, or to the town of Palermo 10 km from the site, which has a burn center and two emergency hospitals. Twelve less seriously injured patients were taken, principally by passers-by, to Carini or one of the two emergency hospitals in Palermo rather than to the burn unit. Twenty-four patients arrived at the burn center within the first four hours of the event, of which, 20 were hospitalized. Sixteen (75%) of these resulted from the motorway fire. The Palermo Burn Center consists of 12 intensive burn care beds and 18 beds for patients with less serious burns. The Plastic Surgery Department (50 beds) is located in the floor below it, with operating theaters occupying the floor above. An on-duty police patrol at the motorway alerted EMS and police headquarters of the accident, which then alerted the hospitals in Carini and Palermo. When the Burn Center heard about the event, its emergency plan was activated. Three physicians were present at the unit at the time, with another on-call in the afternoon and evening. The chief of the department and another six physicians also were alerted. Nursing teams in both of the burn unit sections (ICU and standard beds) were reinforced with extra staff and equipment, including linen and intravenous fluids. The four physicians formed two groups, one going to the emergency department to assess and administer anti-tetanus prophylaxis to arriving patients, and the other remaining in the Burn Center.
Major Problems—The 16 patients transported to the burn unit received no IV fluids en route, but the consequences of this are unknown.

Aircraft Disasters
Manchester Aircraft Fire, UK, 1985
Injury/Death Toll—There were 55 deaths, of which, 52 (92.9%) occurred on the aircraft. A further 79 patients were transported to local hospitals.[95]
Burn Injuries—Two of those admitted to the hospital had severe burn injuries. The most severely burned patient had 24% TBSA burns.[95]
Non-Burn Injuries—Fifteen people were admitted for smoke inhalation.
Response—Seventy-six survivors (96.2%) were taken to the Wythenshawe Hospital in Manchester, and another three patients were sent to Withington Hospital. Ten minutes after the explosion, the hospitals became aware of the incident, and 10 minutes later, they were informed by ambulance services that 40 patients were in transit. The hospital switchboard activated the Major Disaster Plan, which involved clearing the emergency department and five-day ward of non-urgent cases. The senior nursing officer delayed the departure of night-shift staff in order to increase staff capacity. The ICU was prepared to receive critically ill patients, and a 22-bed surgical ward was emptied. Triage was coordinated by the consultant-in-charge and began 15 minutes after the disaster plan was activated.

A choke point was established in the emergency department to record all movements of patients in and out of the department. A police documentation team correlated lists of inquiries with survivors and a telephone was set up for less seriously injured patients to use to contact relatives. Hospital chaplains and social workers together with Women's Royal Voluntary Service staff were used to comfort relatives and inform them of the deceased.[95]
Major Problems—The initial on-scene disaster response was hindered by airport fire hydrants having been switched off, fire crews attending a different rendezvous spot, the airport senior fire officer could not be recognized, and a subsequent lack of on-scene command, and a specialized firefighting vehicle being over-looked.[96] Patient progress was complicated by life-threatening airway obstruction.[95]

Ramstein Airbase, West Germany, 1988
Injury/Death Toll—There were 34 deaths at the scene (due to mutilating trauma or extensive, third-degree burns and inhalation injuries) with 363 people hospitalized. Of these, 36 people (10%) died on the day after admission.[97]
Burn Injuries—Survivors had extensive, yet mainly second degree flash burns. At the trauma center in Homburg/Saar, 24 victims had deep dermal or full-thickness burns of up to 90% TBSA.[97]
Non-Burn Injuries—Head trauma, thorax injuries, fractures, and amputations were present.
Response—Forty-six hospitals in West Germany were utilized during the responses. Four Medical Aid Stations (MAS A, B, C, and D) were located at the air show, operated by members of the German Red Cross (DRK) and United States Air Force (USAF).[98] Medical Aid Station A was the main control center, and the only one with radio and land-line communications. In total, 15 doctors and 163 paramedical personnel, consisting of dentists, medical assistants, and technicians, were at the airfield. Fifteen ambu-

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lances stood by at the four MASs, the VIP enclosure, and the Base Clinic.

The main Disaster Response Team (DRT) consisted of USAF medical personnel, two ambulances, and a dedicated Blackhawk casualty evacuation (CASEVAC) helicopter, which subsequently was destroyed by two of the aircraft that collided. A second CASEVAC helicopter was on standby at the hospital helipad. Twenty-eight medical personnel were on standby at the DRK headquarters in Landstuhl and other nearby towns. A further 91 personnel were on telephone standby in villages around Ramstein. Four triage and treatment areas were established on-scene. Doctors and paramedic staff from MAS-A and C moved to the scene of disaster. Personnel from the VIP section and MAS-D set up minimal treatment areas near the control tower. The DRT gave medical assistance to the crew of the damaged CASEVAC helicopter and others within the vicinity before assisting MAS-B.[98] In total, 18 military and civilian helicopters evacuated hundreds of casualties. A "scoop and run" method was used, whereby patients were moved quickly to the nearest medical resources without significant on-scene treatment. A cinema was opened to act as a meeting place for separated persons, with telephone lines and computer systems quickly set up to compile lists of missing persons. Within two hours, a Medical Control Center was established at the Base Clinic to keep track of all casualties. Chaplains supported the relatives and casualties. In subsequent days, support groups were established on a "walk-in" basis to assist patient recovery.[98]

The Landstuhl Army Regional Medical Centre (LARMC) triaged 120 casualties within the first 30 minutes after evacuation of patients from the scene. Fourteen (11.7%) of these were admitted, 86 (71.7%) stabilized and were transferred to German facilities, 16 (13.3%) treated and released, and four (3.3%) were expectant. A further six patients eventually were transferred to the LARMC. In total, seven patients were transferred several days later to the Brooke Army Burn Unit. Inhalation injuries and pediatric casualties were featured heavily. Many physicians, nurses, and para-professionals arrived at the hospital within 15 minutes of the event. In total, 66 physicians responded, including 30 surgical specialists and 36 medical specialists. Transfers occurred by air and by road. All patients were treated according to the ABC principles of the American College of Surgeons, including the immediate approach to burn victims.[99]

Within an hour, an additional 47 patients were transferred by air and by road to the university hospital trauma center in Homburg/Saar. Most underwent no initial triage, and received no on-scene first aid.[97]

Major Problems—Two of the aircraft that crashed collided with and caused severe damage to a CASEVAC helicopter stationed at the airbase, subsequently killing the two helicopter pilots.[98] The congestion of roads around the crash site resulted in the delayed arrival of crews responding to the scene.

A lack of communication from the scene resulted in hospital staff having no idea of the exact number of casualties expected. Adequate tracking of patients was difficult to maintain, particularly those transferred to units across Europe.[98]

Airliner Crash, Taiwan, 2000[100]

Injury/Death Toll—There were 79 deaths, with 100 initial survivors.

Burn Injuries—Burn injuries were sustained, but exact numbers were not available.

Non-Burn Injuries—Information not available.

Responses—A two-phase response model was adopted, which involved the EMS systems of the airport, the county fire department, and the multiple hospital-based Site Medical Teams (SMTs). These hastily formed teams consist of physicians and nurses from various general hospitals throughout the county, and provide field medical care and command. Within the first 15 minutes after the event, 13 severely injured victims were transported directly to the university hospital by ambulances or a mass-casualty transport truck. Other victims were directed to the flight information center, arriving on foot or by riding in transport vehicles. The first SMT arrived only 30 minutes after the crash.

Ninety minutes after the crash, 16 SMTs were on scene. These consisted (in total) of 24 doctors, 41 nurses, and 32 EMTs. By the time these teams reported at the casualty collecting point, many groups of casualties already had been evacuated by vehicles available on-scene. Only a few victims with minor injuries were left. No team member reported treating any patients. The nearest facility became overwhelmed with the sudden patient influx, resulting in seven patients with severe burns having to be transferred to another hospital.

Seventy-five patients were distributed among seven hospitals in the county. A further six patients were seen at medical centers outside the county.

Major Problems—Information flow between the scene, responding units, and receiving hospitals was insufficient and inaccurate. Lack of sufficient patient stabilization and monitoring in the field (e.g., hypothermia in burn patients before arrival at the hospital), and lack of airway control and oxygen therapy in patients with suspected inhalation injury. Two other major problems that arose included a lack of compliance with the existing MCI plan and an ineffective SMT response. Also, not all personnel were involved in the drill held four months prior to the crash, resulting in their unfamiliarity with the response plan. Drills also were not practiced at night or during rough weather conditions, such as those experienced during this incident. Personnel had no protective clothing, and soon became victims to the weather.

9/11 Terrorist Attacks, US, 2001

Injury/Death Toll—There were approximately 3,000 deaths in total, including 2,823 in New York, 189 at the Pentagon, and 44 in Pennsylvania. More than 6,000 people were treated for injuries.[5,6,101]

Burn Injuries—Approximately one-third of hospitalizations in New York were for severe burn injuries. Eleven burn patients were seen following the Pentagon attack.[101]

Non-Burn Injuries—Cuts and lacerations, general pain and soreness, musculoskeletal injuries, blisters, punctures, back pain, foreign bodies, fractures and crush injuries, infections, inhalation injuries, and other upper respiratory complaints, ocular injuries and disorders, headaches, ear injuries, gastric and esophageal complaints, diarrhea, nausea and vomiting, dental pain, inflammatory and infective skin conditions, and psychological stress were encountered.[102]

Responses—In New York, the initial rescue response involved local authorities and responding agencies, but after an initial

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assessment and the collapse of the two Trade Center buildings, activation of the National Disaster Medical System (NDMS) was requested.[5,6] This led to the immediate activation of the subsequent though delayed through bureaucratic reasons, deployment of several DMATs. These were supplemented with an International Medical Surgical Team, Burn and Pediatric specialty teams, a Veterinary Medical Assistance Team, a Disaster Mortuary Response Team, a Centers for Diseases Control and Prevention (CDC) team, and a Commissioned Core Readiness Force, the military equivalent to a DMAT. Their initial mission was to assist local New York City resources in the care of casualties, but their mission soon changed when it became clear that they would see more mass fatalities than casualties.[6] Then, the federal resources were used to assist with injuries sustained by the many rescue workers on-scene. A DMAT operations base was set up at the disaster scene outside the main field of debris. This consisted of a main treatment facility and a command and communications tent. Four satellite treatment facilities were established in areas surrounding the Trade Center buildings, where the majority of rescue work was being performed. Physicians, nurses, paramedics, EMTs, and logistic personnel staffed these areas. Armed police officers ensured personnel safety on-scene and crowd control.[5]

Following the attacks, a 12-hour National Pharmaceutical Stockpile (NPS) Push Package was deployed to assist with treating casualties.[103] This consisted of antibiotics, chemical antidotes, medical and surgical supplies, airway management equipment, IV fluids, and other equipment.

Hospitals prepared for the influx of extra patients by canceling elective surgeries, clearing the emergency department of non-critical patients, discharging or transferring patients to make extra surgical and ICU beds available, and mobilizing extra personnel. At some hospitals, residents were organized into small triage teams. All non-critical patients would be cleared quickly from the emergency department, either through discharge or follow-up in treatment clinics, so as to avoid overwhelming the emergency department and to keep beds available for any critical patients that were yet to arrive.[104]

At the Pentagon, triage stations were established rapidly in the vicinity of the incident scene, but needed frequent evacuation and relocation due to the threat of further attacks. Airmedical services were on-scene shortly after the incident occurred, but were grounded due to the possibility of further air attacks. These crews remained at the scene to assist rescue personnel. Local and urban search-and-rescue technical rescue teams and officials from the Department of Defense and the Federal Bureau of Investigation (FBI), joined on-scene EMS and firefighting personnel.[105] The nearby Washington Hospital Center, which has a burn center and the largest trauma center, activated its disaster plan when they spotted smoke billowing from the Pentagon. Expecting a large number of casualties, hospital staff cancelled elective surgeries and discharged 200 patients.[106] Ten cardiac surgery recovery room beds, 25 post-anesthesia recovery room beds, and 40 monitored ICU beds were made available. As the major injuries expected were trauma- and burn-related, the hospital called together a large team of medical and surgical personnel, consisting of attending trauma surgeons, full-time burn attending physicians, senior-level residents with trauma experience, full-time intensivists, anesthetists, respiratory physicians, laboratory personnel, and security staff. Patients were assessed using a standard "trauma" evaluation procedures, and then triaged based on their burn injuries.[106] The burn unit received extra stocks of burn equipment from supply companies, and was supplemented with extra surgical, anesthesia, and operating theater staff.

Major Problems—In New York, rescue efforts were hampered by the collapse of the twin towers, the potential collapse of other surrounding buildings, and the threat of further attacks. Communication was disrupted by the loss of the sole communications antenna and headquarters of the Office of Emergency Management, located at the World Trade Center. Communication downfalls also meant that the order to evacuate the buildings probably did not reach the firefighters in the Trade Center in time.[102] It also complicated medical command and on-scene organization. Prior authorization was not arranged for supply trucks, thus delaying the arrival of extra supplies to hospitals and the disaster sites. Several freelancing personnel entered the scene with inadequate training and equipment. Due to the threat of further attacks, triage and aid stations constantly had to be relocated or evacuated. A no-fly zone around the scene resulted in the grounding of medical evacuation (MEDEVAC) helicopters. Following the collapses, rescue crews and other personnel working at and close to the scene were exposed to several airborne pollutants, which have been linked to the development of various respiratory diseases.[107] Symptomatic, persistent bronchial hyperresponsiveness was experienced by many.[108] Dust masks and eye protection also proved to be in inadequate supply. At several hospitals involved in the response, internal and external telephone lines became overwhelmed, pagers/cellular telephones worked only on an intermittent basis, and information flow was unreliable and often inaccurate. Ventilation systems were switched off at several hospitals, particularly those in close vicinity to the scene, in order to stop dust from circulating throughout the hospitals. Several facilities were affected by power outages and system failures, with one hospital losing its steam system, affecting the sterilization of medical and surgical equipment.[109]

At the Pentagon, scene safety was a major consideration for personnel due to the rapidly spreading flames and intensity of the fire.[110] More fatalities were found than survivors. Command and coordination at the Pentagon was impaired by self-dispatching fire and EMS crews arriving at the scene having received no official orders or roles. There also were shortages in personnel, particularly in the areas of burn and trauma surgery, intensive care, and critical care nursing.[111] At some of the receiving hospitals and facilities, a lack of staff familiarity with and regular rehearsal of the disaster plan led to impairment of the effectiveness and efficiency of the overall response.

Public Events

Bangalore Circus Fire, India, 1981[112]

Injury/Death Toll—There were 92 deaths, all attributed to burn injuries. At least 300 more were injured.

Burn Injuries—Approximately 500 people were treated for major and minor burns in various private and public hospitals and general practices. A total of 190 burn patients were treated at the burn center at the Victoria Hospital. Of these patients, 119 had salvageable major or minor burns, while the remaining 71 were badly burned and dying. Forty-two of the 119 patients were treated as outpatients, and 77 were admitted.
Non-Burn Injuries—Head injuries and fractures were present in several patients, and in numerous cases associated with burn injuries. Respiratory distress also was common. Exact numbers were not stated.
Responses—After hearing of the fire, the fire force officer deployed all fire units in Bangalore. Patients were sorted into the following groups: (1) 71 charred beyond recognition and sent to mortuary for identification; (2) 42 with minor burns treated with first aid, and sent home; and (3) the remaining 77 were admitted and treated.

The burn unit already was full with 50 burn cases, which they either transferred to three general wards or discharged. The adjacent plastic surgery ward with 30 beds also was vacated, with a new ward waiting to be opened used to hold 15 old burn cases. The burn unit consisted of an emergency room for three serious burn patients, a male ward for 16 cases, a similar-sized female ward, and a children's ward with 10 beds. Additional space was found in the receiving room, nurse's room, two doctor's duty rooms, and a burns seminar hall. The burn center admitted burn patients, while the remaining 20 cases went to the adjacent plastic surgery ward. Many doctors from public sector hospitals and some general practitioners volunteered.
Major Problems—The local burn unit already had 50 burn patients. This created issues in acquiring sufficient beds for new patients. The circus was located close to high-tension power lines, with appropriate fire safety standards lacking. Fire crews took >3 hours to extinguish the fire. This hindered scene access and the retrieval of patients and bodies. Patient progress was complicated by shock, peripheral circulatory failure, uremia, bacterial and fungal wound infections, toxemia and septicemia, contractures, hypertrophic scars, and keloid scars.

Bradford City Fire, UK, 1985
Injury/Death Toll—There were 53 deaths, all due to burns. A further 250 were injured, with 83 (33.2%) requiring hospital admission.[113,114]
Burn Injuries—There were 147 patients (58.8%) with <5% TBSA burns, 47 patients (18.8%) with >5% TBSA burns, and 20 patients (33.2%) with >10% TBSA burns. The majority of burns were to the backs of hands, scalp, back, or backs of legs.[113]
Non-Burn Injuries—These consisted of one dislocated elbow, one fractured tibia, one dislocated ankle.
Responses—The following triage system was used to evenly distribute patients among hospital departments and to avoid overload:[113]

1. Inevitably fatal (burns too extensive for patient to survive);
2. Life-threatening but not necessarily fatal (purpose built an isolatable area in the hospital with air-conditioned treatment rooms);
3. Disabling but affecting <20% TBSA (ordinary hospital accommodation suffices); and
4. Small burns not necessitating immediate admission to hospital (appointments made for moderately specialized outpatient care).

Major Problems—Inadequate fire safety standards led to the trapping of several victims, especially the elderly, inside the stadium.[115] Police radio frequencies became overloaded rapidly. Admitting hospitals first became aware of the event as patients arrived, hindering the planning process. A media throng at the hospitals interfered with staff communication and work. The establishment of separate sites for the storage and autopsy of bodies led to the high probability that key evidence could be lost.

Wedding Fire, Saudi Arabia, 1999[116]
Injury/Death Toll—A total of 169 people were involved, with 37 deaths within the first hour. In total, 74 people were reported deceased approximately six months later.
Burn Injuries—Burn injuries ranged between 5 and 85%.
Non-Burn Injuries—Information not available.
Response—Following initial resuscitation at the hospital, patients were further distributed among 17 provincial and national hospitals following the activation of the government disaster plan.
Major Problems—The nearest hospital was filled with patients within 15 minutes. No triage or resuscitation was performed on-scene, but no details are available as to the consequences.

Analysis

Overview

After a review of the recommendations and strategies derived following past disasters to indicate whether they have been implemented into standard practices over time. It is evident that things are improving in many aspects of preparedness and response, and there was a surge in greater global community interest and interagency collaboration in regards to burn disaster planning in the period immediately following the 11 September 2001 attacks.[1] However, this interest has gradually waned,[2] and current emergency medical services and disaster responders still are experiencing similar problems, particularly in the areas of communication, hospital overload (staff and casualties), hospital surge capacity, equipment and supplies, casualty documentation and tracking, staff planning and roles, burns and disaster experience, hospital staging areas, and patient transport. As each disaster has its own unique qualities, conducting a comprehensive review proved useful in that it enabled the lessons learned from a large number of past disasters to be incorporated and utilized in future disaster plans. This also has enabled the formulation of several strategies for the future, particularly including increased education to healthcare providers, medical students, and members of the general public in the management of burn injuries and patients resulting from mass-casualty incidents.

Discussion

Problems Faced during Burn Disasters

Burn disasters can have unique problems associated with them in comparison to non-burns disasters, including impaired access to the scene by smoke and flames, severity of injury (particularly in the long term), the need for large quantities of specialized procedures such as escharotomies, and the often high incidence of inhalational injuries needing intubation. While each burn disaster is different and has its own characteristics, there are a number of major problem areas that are shared. These are described below. Problems that have been experienced by responders during some, specific, major, burn disasters can be found in Table 1.

Strategies for the Future

Education—Experience generally is based only on hospital and possible international experience (though this is not common in Australia), and not at the undergraduate level. This limits the exposure of health personnel to proper burns and disaster management techniques.

Due to lack of experience with burn injuries and disaster management protocols, burn wound size often is over-estimated, and thus, the efficacy of triage is decreased. The risk of inhalation injuries and airway compromise are often missed, the evacuation of high-risk patients are often delayed, and finally, on-scene personnel often fall victim themselves.

Communication—Communication systems have consistently been unable to withstand the influx of calls that occurs during a disaster. Standard communication lines such as landlines, mobile telephone systems, and radio frequencies quickly are overloaded with calls from emergency services, hospitals, as well as victims and families. For example, during the Bradford City Football Club fire, police radio frequencies became so overloaded that they were unable to be used. Therefore, the admitting hospitals only became aware of the incident when patients started arriving at the hospital.[113]

This overloading of the system severely hampers the communication between, and coordination of, various emergency service agencies and thus, can jeopardize the disaster response, particularly in the areas of casualty retrieval and identification, triage, staff allocation and coordination, patient transfer, receiving hospital surge capacities, and coordination of delivery of supplies and equipment. During the Bali response, other standard forms of communication, such as e-mail, were found to be too time-consuming for personnel during an emergency situation, and standard landlines found to be disadvantageous in that they are not portable.[27]

Reliance on these public and mobile telephones by ambulance units and emergency dispatchers during the 2005 London terrorist bombing response created major communications problems. Hospitals were forced to rely on television news reports to get updates on casualty numbers.[49]

Communication was found to be most often lacking between hospitals and the disaster scene. This resulted in hospital staff being unaware of estimated times of arrival of patients, patient numbers, and injury severity, and thus, were unable to effectively prepare for patient arrival. This was evident in many disasters, but particularly during the West Pharmaceutical Plant explosion in 2003, where a Level-1 Trauma Center 30 minutes away was at no stage involved in communications from the scene in regards to patient transport and distribution.[87] This was also an issue during transport of patients to Australia following the 2002 Bali bombings, where RDH staff received no information on flight arrival times, patient numbers or injury severity until the first wave of pataients arrived.[28,29] Staff at the LARMC during the Ramstein Airbase disaster at no stage during the response, had an accurate idea of the exact number of casualties expected.[99]

Intra-hospital communication often was found to be lacking or inadequate. What commonly occurred was that the contact numbers for key contacts involved in the hospital's response were either not available, out-of-date, or no longer connected. Runners were needed in order to transfer messages by word-of-mouth, such as in the response to the 11 September Pentagon attacks,[111] which left room for added human error. During disasters such as the Rhode Island Station Nightclub fire, inter-hospital communication also lacked, particularly when some emergency departments were becoming overwhelmed.[72]

There also have been situations, such as with the 11 September responses, when entire communications systems were wiped out, with no back-up system in-place. During the 9/11 attacks in New York, the Office of Emergency Management (and its sole communications antenna) established by NYC to coordinate communications and direct resources should a disaster occur, which was located in the World Trade Center (WTC) building, was destroyed by the subsequent collapse of the two WTC buildings[10,11] There was no contingency or back-up system in place, with a resultant loss of organization and management of the subsequent disaster response.[10] Normal landlines also were destroyed during numerous disasters, including the Los Alfaques disaster in Spain in 1978, disrupting information flow between the scene and the receiving hospitals.[90] Again, no back-up system was arranged.

It also was found that any responding agencies will self-dispatch to the scene, i.e., arrived at the scene without prior approval by or coordination with scene commanders or disaster managers. In these situations, many of these responding agencies also used separate radio frequencies that could not be used to communicate with other agencies, responding ambulance units, or disaster personnel. This decreased coordination and, at times, had the potential to endanger lives. For example, during the MGM Grand Hotel fire, there were numerous helicopter units that self-dispatched to the scene. At one time, there were up to 20 helicopters in the air surrounding the casino, many of which didn't have compatible radio communications systems. This decreased the efficiency of the response and the establishment of a temporary helipad too close to the scene also was responsible for the flattening of the initial triage station.[58]

This lack of communication between responders at the scene also was displayed between primary triage stations and the secondary triage station during the MGM Grand fire. This resulted in the screening of patients more than once, as well as the processing of uninjured bystanders.[58]

Several communications devices used in past disasters were unable to be used in certain disaster locations. This was highlighted during the King's Cross fire in London in 1987, standard mobile and hand-held radio devices did not function in the underground rail network.[91] This same problem was experienced 18 years later during the 2005 London terrorist bombings.[50]

Staff communication and coordination, particularly in hospital emergency departments, often was disrupted by

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crowds gathering at hospitals as well as by members of the media. This particularly was the case following the gas explosion in Osaka, where the media had full access to the hospital.[77] Also, the media often have given inaccurate information, which was the case following the San Juanico LPG gas explosion, when a general panic among the public resulted based on information released by the media.[80]

Hospital and Event Site Overload and Triage—One of the key characteristics in nearly all disasters is that a majority of patients self-evacuated to hospital or were transported to hospital by private vehicle. Most arrived at the hospital closest to the scene of the event, which overwhelmed the emergency department and overall capacity of the hospital. This was the case following the wedding fire in Saudi Arabia in 1999, when 169 people were taken to the hospital closest to the scene, filling it to capacity within 15 minutes.[116]

It also was common for patients with minor injuries, often known as the "walking wounded", to arrive to the hospital before those with serious injuries. If an adequate triage system was not in place at the hospital, these patients often occupied beds required by more seriously injured patients. This often was directly related to inter-agency communication as well. It was very common for ambulance units to self-dispatch and transport patients to facilities not designated as receiving units in official disaster plans, as occurred following the Station Nightclub fire in Rhode Island. In this case, ambulance personnel were allowed to decide to which hospital they would transport patients. This resulted in an uneven distribution of patients among area hospitals.[72] The delayed arrival of ambulances at the disaster scene also encouraged patients to self-evacuate, typically to the hospital closest to the scene. This occurred during the Brasov factory fire in Romania in 1979.[78]

Triage still is one of the most common areas of shortfall during a disaster response. This problem has been consistent since the Cocoanut Grove fire in 1942. Without effective triage and communication, medical resources often became overwhelmed. There still is no standardized triage protocol that is used among states in Australia, let alone nationally or even internationally. Numerous different triage standards exist, even between hospitals in the same states, which can be problematic, especially when multiple nations are involved. In past disaster planning and triage systems, burn injuries and the various, often life-threatening complications associated with them, usually were neglected by these triage strategies or were triaged incorrectly.[20] Concurrent trauma often played a role in many of the aforementioned burn disasters. These combined burn trauma injuries, such as those that occurred from the West Pharmaceutical Plant explosion, make the job more difficult for responders, particularly because there is no comprehensive, integrated disaster plan that encompasses both burn and trauma patients. These injuries led to the query as to whether these patients should be taken to a trauma center or a burn unit.

Immediately following a mass-casualty incident, the hospitals, scenes, and areas surrounding them often have become overcrowded with passers-by and anxious family members in search of loved ones. Following the Gothenburg fire in 1998, ambulance crews had difficulty accessing the scene due to the crowds gathered outside of the club.[64] Following the Hipercor department store bombing in Barcelona in 1987, traffic congestion surrounding the receiving hospital led to a delay of four hours in the arrival of extra off-duty staff.[11]

However, it is not only patients and families that overloaded hospital areas, but also well-intentioned volunteers. As with ambulance and other emergency personnel, doctors and nursing staff also volunteered themselves at hospitals or even at the site of the event. They tended to add to the chaotic situation that usually occurs in the initial stages of a response, especially when they had not been given any official roles or had any significant experience or training to work in such disaster zones.[24] This created issues in confirming staff credentials and staff experience, which is a particular issue in the treatment of burn patients. During the response to the Omagh bombing, verification of staff identification was extremely problematic, due to the large number of volunteers, so only staff who were recognized by key hospital personnel were allocated to the major treatment areas.[20]

This also was the case during the response to the Texas City explosion where the disaster scene became overcrowded with personnel.[76] They tended also to have inadequate medical equipment and clothing, and often placed themselves in serious danger, particularly following the 11 September attacks. Inadequate protective clothing exposed responding personnel to the adverse weather following the Singapore Airliner crash in Taiwan in 2000. Many of the on-scene personnel became victims to the typhoon.[100] Losing available surgeons and other key personnel who would play far more effective roles in their own hospitals than attending the scene, particularly when not authorized to do so, as occurred especially during the 11 September responses, severely hampered certain hospitals' responses. This loss of key sugical staff was a major issue for burn units, which required a large number of personnel for each patient. This "free-lancing" also created difficulties in accounting for personnel.

Patient Evacuation—Patient evacuation and the reaching of casualties by rescue crews has been problematic, particularly during events that occurred within enclosed spaces. Here, victims often became trapped and succumbed to toxic smoke and gases before rescue personnel could reach them. During indoor burn disasters, this often was exacerbated by a lack of adequate fire safety standards. During the Cocoanut Grove fire, the main entrance was in the form of a revolving door and the secondary exit was an inward-opening door. This was attributed to the trapping and subsequent death of 300 potentially salvageable victims.[53] At the Stardust Disco fire in Dublin, evacuation of victims was impeded by steel shutters in front of the main entrance and the toilet windows being welded shut.

In the period immediately following the precipitating event, patients (especially those with minor injuries) often were transported in private vehicles to the nearest hospital by bystanders and passers-by, overloading hospital emergency departments. For example, following the 9/11 terrorist attacks in New York City, only 504 (6.8%) patients were

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transported by ambulance. This also involved the possible mobilization of patients requiring appropriate stabilization prior to mobilization.[28]

Evacuation often was delayed, either due to the remote location of the disaster site or the delayed establishment of medical command. This increased the time taken to the initiation of therapy. The Bashkir pipeline explosion is an example of when a delay in patient evacuation occurred, highlighted by the fact that it took approximately three hours for ambulance units to reach the scene.[85] The Los Alfaques event is another example of extensive patient transport times; several patients underwent a 160 kilometer journey to a definitive treatment facility. In this case, this hasty and uncoordinated evacuation and transport of patients was due to the delayed and inefficient establishment of medical command.[90]

During transport, patients often were not adequately monitored, with several patients arriving in shock with immeasurable blood pressures.[90] This was the case following the Los Alfaques event. Evacuation often was hindered by scene safety issues, such as the high-intensity flames on the deck of the Piper Alpha oil rig.[81,83]

Long-distance evacuation, such as the air-medical evacuation of patients from Bali, was found to cause particular problems with the stabilisation of burn victims. En route monitoring of fluid resuscitation and temperature control was difficult, with two patients developing oliguria and hypothermia on the way, which delayed surgical management.[26] Another problem experienced during airmedical evacuation and transfer of patients, such as during the Volendam fire in the Netherlands, was the incompatability of resuscitation and monitoring equipment found on the airmedical transports as compared to that used by the hospitals.[67] In cases such as the Omagh bombing, where patients were being transferred from overloaded hospitals to additional burn centers by helicopter, hospital resuscitation equipment (oxygen cylinders, etc.) was kept with the patient during transfer but not returned to the hospital, depleting their equipment supplies.[20]

Local transport often is used sporadically during the initial phases of disaster responses but, particularly in developing countries, often is inadequate. For example, the transport of Bali bombing victims to hospital by local garbage trucks led to contamination of burn wounds by various multi-resistant organisms.[67]

Access—Scene access by rescue crews and medical personnel at burn disaster sites was hindered by the remote location of the scenes as well as numerous safety issues, including the dense smoke filling the King's Cross Underground station,[91] the collapse of buildings, and the fragility of their remains as occurred in Oklahoma[12] and New York[5] respectively, the layer of ignited oil on the surface of the ocean surrounding the Piper Alpha oil rig,[81] and the threat of further terrorist attacks as experienced during the terrorist bombings in Bologna.[10] This delayed the arrival of services and provision of care to patients, and particularly in the case of the building collapses, often resulted in an excessive number of deaths, especially of people who potentially were salvageable.

Hospital and scene access by responding physicians, medical supply trucks and other staff was hampered by the congestion of roads leading to hospitals and surrounding event sites. Often, this congestion was a result of the gathering of crowds, who did not allow rescue personnel to perform their tasks. For example, ambulance crews attending the Gothenburg fire were physically and verbally abused by angry crowds insisting that they were not doing enough and demanding they do more.[64]

Staff Planning and Staff Roles, including Medical Command—Several past disasters, such as the Gothenburg and Omagh disasters have occurred during after-hours or on weekends.[20,63] Subsequently, during these events several hospitals have had only the usual skeleton night shift or weekend staff on-duty, and thus, had insufficient staff to deal with the rapid influx of patients. In the case of the Gothenburg fire, there were insufficient numbers of extra on-call staff able to be mobilized.[64]

It has occurred that staff members were placed on high alert for a long period of time, usually due to insufficient communication updates regarding the arrival of patients, decreasing the sustainability of the response. This was particularly the case following the Bali bombings, where Royal Darwin Hospital (RDH) staff awaited the flight arrivals of patients evacuated to Australia by the Australian Defence Force (ADF) and other commercial airliners.[31]

Medical command either was not rapidly established at the scene and at the receiving hospital, or even at all. Following the Texas City explosion, establishing medical command was difficult as there was no dedicated personnel-in-charge.[76] During the Gothenburg fire, medical command was not established at the scene, as the chief physician educated in disaster medicine was not ordered to the scene because rescue crews assumed he would be coming.[64] During the Rhode Island nightclub fire, a central command was established, but it was not easily identifiable.[71]

Large numbers of visiting staff caused problems in maintaining an organized response both at the scene and at the hospitals, and in the assigning of staff tasks. For example, at the Ramstein Airbase, initial triage failed as volunteers, without official guidance, filled incoming ambulances and helicopters indiscriminantly.[98]

At times, house staff have been unsure of their role and helped out wherever they chose, decreasing coordination. During the Singapore Airlines crash in Taiwan, command, roles, and responsibilities of the various responders was unclear.[100] Following the Texas City explosion, managers also found problems in attempting to ensure accreditation of personnel prior to the assigning of tasks. This created the potential for unskilled personnel to attempt difficult procedures.[76]

Surge Capacity—As one can never be fully prepared for a disaster, surge capacity has been an area for which disaster plans often has fallen short. This refers to a hospital's ability to suddenly increase its patient capacity in order to provide acute care to critical and non-critical mass casualties that would normally severely challenge or overload the capacity of the health system.[42] During past disasters, hospitals often were notified once the first patients either were on their way or already had arrived at the hospital, such as during the Ramstein Airbase crash.[99] In order to make

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room for the sudden influx of new patients, hospitals had to increase the number of available beds, often through discharge or transfer of existing patients, and cancellation of all outpatient clinics and elective surgeries. If an adequate surge capacity was not in place, the hospital tended to struggle. The recall of extra staff and mobilization of extra resources was a major issue for burn units due to the specificity of treatment protocols and equipment that was required, as well as the extensiveness of the staff and the resources the response necessitated.

Increasing surge capacity depends on the ability to increase and maintain a continuted supply of specialized equipment and resources. However, during past disasters, the re-supply of hospitals often was delayed and chaotic. This was the case especially in terrorism-related disasters, such as the 11 September attacks on New York City, where several roads were closed for security purposes. As happened in this case, several supply trucks were turned away as previous clearance with city officials had not been arranged. Hence, the drivers were not given immediate access to the site or to the surrounding hospitals.[43]

Burns disasters differ from most other disasters as they require substantially more specific and larger quantities of equipment and supplies, such as SSD cream and IV fluids. Treatment duration for burn injuries was generally far more prolonged than for other injuries, necessitating the need for a more sustainable surge capacity. Many hospitals had stockpiles and disaster carts consisting of extra equipment and supplies designated for use during a disaster, but they tended to be insufficient in quantity or specialty. For example, the disaster carts from central supply during the Oklahoma City bombing response were not sufficiently stocked for the injuries sustained by victims as a result of the blast, particularly those who had sustained burn injuries.[13]

Patient Identification and Documentation—During past disaster responses, burn patients frequently were transferred from unit to unit or hospital to hospital, or to burn units in different countries. This increased confusion and difficulty in tracking patients, particularly during the Los Alfaques event in Spain, where patients were then evacuated to burn units in their homelands of France, Germany, Belgium, and Holland.[12] Following the Ramstein Airbase crash, casualties were transported to 21 different medical facilities during the first 24 hours.[98]

Many burn victims, particularly those who lost their lives during the St. Valentine's Day Disco fire in Dublin, were severely charred, making the identification of their bodies extremely difficult.[61] The removal of identification from both the deceased and from the injured following the Ramstein Airbase crash[99] created subsequent problems in the identification and accounting of victims. Many patients could not provide identification due to being unconscious, having received inhalation injuries and not being able to speak, having sustained bilateral tympanic membrane perforations[20] and not being able to hear, and/or due to language difficulties.[36]

Like triage protocols, there are no current labelling standards in consistent use between hospitals and responding agencies or at state, national, or international levels. This enhances problems in the identification of patients for triage and transport to a hospital.

Disaster tags are used by mobile response teams, namely ambulances and rescue teams, to label patients for triage and transport purposes, but as occurred during the Osaka gas explosion and the Ramstein Airbase crash, ambulances were not supplied with sufficient quantities of disaster tags.[77,97] Similar to this concept, hospital emergency departments have prepared for the processing of mass casualties through the use of pre-prepared disaster packs consisting of identification bracelets, laboratory request forms, and documentation forms. However, as with the Omagh bombing, insufficient quantities of such packs were prepared.[20]

With this, documentation at the scene and in receiving hospitals also has often been found to be inadequate, incomplete, or completely lacking. During the Gothenburg fire, patient notes were scribbled on scraps of paper and later misplaced.[65]

Meanwhile, documentation and monitoring of burn patients during retrieval and transfer from the scene to a hospital also has been neglected, such as during the response to the Singapore Airlines crash in Taiwan, where the lack of en route stabilization and monitoring resulted in several burn patients developing hypothermia, thus complicating patient progress.[100]

In the periods immediately following a disaster-producing event, emergency agencies and hospitals become inundated with queries about missing persons. As occurred in Ramstein, missing person lists were not updated once patients already had been re-united with their families.[71]

Disaster Tourists—This is a term given to free-lancing personnel with inadequate training and equipment who attend the scene and end up endangering themselves and hindering the overall coordination and efficiency of the disaster response. This was prominent during the 11 September responses.

Lack of Personnel Experience—It was a frequent finding that staff were insufficiently experienced with burn care or disaster management, especially amongst the free-lancing staff that attended Ground Zero following the 11 September attacks.[24] During the burn unit responses following the Hipercor terrorist bombing, additional personnel mobilized as part of the response, but inexperienced in burn care, treated some burn wounds with silver-sulphadiazene before wound depth and size were estimated, so time was wasted as wounds were uncovered again to confirm the diagnosis. Some diagnoses, such as burns requiring escharotomies, were not complete before several patients were treated and moved to an ICU. Furthermore, these wounds also had to be uncovered again to administer appropriate treatments.[11] Burns experience was lacking by triage officers, such as following the West Pharmaceutical Plant explosion—some burn patients were transported directly to a burns center for treatment, but others not. The burn patients who were not transported directly to the burns unit, but rather to a general trauma hospital, were further transferred to that same burns unit.[87]

In some countries, burn units operated on a voluntary basis such as in Holland during the Volendam disaster;[68,70] they did not have official status. Rescue workers in the Netherlands were not provided with any specific standardized training in disaster response or disaster management.[68]

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Experience of many industrial plant staff often was lacking in fire and evacuation procedures, highlighted by the King's Cross underground fire, where the unfamiliarity of rail staff in emergency procedures led to the delayed evacuation of commuters and notification of the fire services.[14] After the Manchester aircraft crash, airport fire crews went to a different rendezvous point and a specialized firefighting vehicle was not used.[53] Both workplace and emergency fire equipment were faulty or not switched on. For example, both the San Juanico and Bashkir pipeline explosions were due to the leakage of gas from the pipelines.[80,85] During the King's Cross fire, escalator sprinklers were not functioning and the fire hydrant was concealed behind a temporary structure.[91]

The lack of experience with combined burns and other injuries, such as that experienced during the West Pharmaceutical plant explosion, complicated triage decisions, treatment regimes, and distribution priorities.[87]

Staging and Identification of Key Areas—Certain key hospital areas were unidentifiable. For example, a makeshift pharmacy during the Bradford City fire[13] and triage areas during the MGM Grand fire[58] were not easily identifiable by staff and approaching ambulances—delaying the provision of supplies and services respectively.

Staff were often not identifiable. For example, during the Ramstein Airbase event, doctors were indistinguishable from untrained personnel.[71]

The absence of specifically designated areas, such as resuscitation rooms and holding areas increased overcrowding in certain hospital areas. The lack of crowd control resulted due to inadequate staging areas for relatives and volunteering doctors, as well as media representatives. For example, large crowds of friends, relatives, and public at the receiving hospital hindered the treatment of victims from the 1981 Bangalore circus fire for 24 hours.[112]

Management of the Mass Media

As mentioned previously, inadequate staging areas or lack of official media releases and briefings, has led to the overcrowding of hospitals and at the scenes by members of the media, as well as the spread of inaccurate information and panic among the gathering public.

Often, the media is the only way for responders and planners to communicate with the masses, and thus, the management of the media is a crucial component of a disaster plan.

Increased Training of Doctors in Burns Management and Post-Graduate Education and Training in Disaster Management—These courses, such as Major Incident Medical Management and Support (MIMMS), Emergency Management of Severe Burns (EMSB), are vital for future preparedness, but are provided infrequently and have low capacities for attendance. This capacity should be upgraded and aimed at medical, paramedical and especially all allied health staff (particularly physiotherapy and occupational therapy) as a large multidisciplinary approach is pivotal during the treatment and rehabilitation of mass burn casualties. Increasing awareness of the potential scope, prognosis, implication of burn and inhalation injuries, and assessment of burns and their management, at all levels of burn disaster response will help increase the efficacy of burn injury triage and management, and work to minimize many of the problems seen previously.

Communications—There has been a rapid surge in the implementation of state-wide and national disaster plans and communication databases and networks, particularly in the immediate post-11 September period. The US Department of Defense, in coordination with the American Burn Association (ABA), trialled the use of such a database, during Operation Iraqi Freedom. Following successful trials in the military setting, it was suggested that this system could be modified for use in the management of civilian mass burn disasters; led to the development of the ABA TRACS database and National Burn Repository.[55] This tracking system allows for "real-time" data on burn-bed availability and enables the distribution of patients to appropriate, definitive, burn care facilities, and thus, helping to avoid unnecessary secondary triage and giving an idea of what equipment is available and where it is needed most. The UK has implemented a similar system as part of the current UK National Burn Plan, in which there is a National Burn Bed Bureau, which can pre-determine burn bed availability and inform the coordinating burn surgeon at the receiving hospitals.[56]

However, rural integration and the use of such databases still is somewhat lacking outside of the US and the UK, particularly in developing countries. The Australian and New Zealand Burn Association currently is in the process of developing a similar database, but as yet it still is retrospective. Communication systems still are becoming overloaded immediately following an event, with families ringing to check up on loved ones, and emergency responders communicating with various other responding agencies. Effective communication and relaying accurate information is particularly lacking between the hospitals and the scene as well as between the various responding agencies. However, internal hospital communication systems are being updated with back-up systems being tested regularly and integrated into daily practice. There also have been advances in wireless and more reliable communications networks for use at responding hospitals during the initial phases of disaster responses, as well as the development of sturdy, hand-held devices capable of use in the field. In the US, mobile communications vehicles have been developed to act as temporary mobile command posts. This was by the New York-Presbyterian Emergency Medical Service (NYP-EMS) in response to incidents that occurred during the 11 September terrorist attacks in New York in which fixed communications networks were lost following the collapse of the World Trade Center buildings. Global positioning units also have been fitted to emergency personnel vehicles to accuratley track response vehicle movement and enhance coordination between response agencies.

Burns Experience—Medical schools and universities, particularly in Australia, are attempting to get disasters and burns first aid into their curricula. Public burns first aid still is a work in progress. In the US, statewide burn education courses have been established following the West Pharmaceutical Plant explosion. In Australia, courses such as the Emergency Management of Severe Burns and Emergency Management of Severe Trauma, and the Blasts, Bombs, and Bullets course serve to increase awareness of the potential injuries that can result from such events and mass-casualty incidents and accidents, as well as provide updated information on treatment protocols and standards. However, the frequency and student capacity of such courses is a major limiting factor. To counter this, healthcare providers and universities are developing numerous online courses and diplomas in various aspects of disaster response, including patient triage, decontamination, and bioterrorism.[58] Healthcare institutions in the US, such as the NYP-EMS, are integrating incident command system training and mass-casualty incident management into the orientation course for all new employees.[57] These training updates and capabilities are then integrated into their disaster plans and response exercises. Unfortunately, access to these courses by disaster responders in the developing world is difficult and costly.

Triage—Currently, standardized triage protocols for use in disasters are lacking, particularly for victims with burns. Triage remains a major shortfall. This is exacerbated by communication problems and often still coincides with inadequate medical command on-scene and prioritization of patients for transport to hospital. Thus, hospitals closest to the scene continue to become overloaded. There are numerous triage algorithms currently being used, such as the "Triage Sieve and Sort" and "Simple Triage and Rapid Treatment" (START) systems, and has to increased triage accuracy during drills. However, drills are not always realistic and accuracy is still not 100%. Limitations of these existing algorithms can lead to under-triage and inaccuracy, and thus encourage responders to make their own modifications, further decreasing standardization.[59] Thus, changes to current algorithms are needed.

Access—Site access remains problematic—but it is in the area of pre-arranged authorization and access passes that causes problems. Improvements must be made.

Surge Capacity—Augmentation of surge capacity is receiving higher priority by hospitals. Consistently underdeveloped capacity continues to be a major problem for many responders.

Identification and Documentation of Casualties—The need for stringent documentation together with continuous monitoring and reassessment of burn victims is being recognized. A standardized classification system can be used at the local, regional, state, and federal levels such as that utilised by the Israeli Ministry of Health[60] still has not been recognized globally, but is being increasingly addressed through the implementation of new flexible standardized burn disaster plans such as the Southern Region Burn Disaster Plan.[61]

Transport of Patients—Specialized transfer teams and personnel experienced in the extrication of victims from vehicles and other structures would be useful both at the scene and at hospitals. Instructing the public on the proper extrication of patients from vehicles and building remains, and on which patients can be mobilized and which cannot, should be addressed by the incident commander in a quick briefing at the scene, but also in public basic life support and first aid courses.

Airmedical evacuation can be especially useful, particularly in rapid transfer of patients to definitive care as well as to international burn units. This was especially useful following the Bali bombings; aeromedical transport can be provided by military services. This military-civilian link should be encouraged and expanded by close coordination in the future, and not be limited only to certain types of events.

The coordination of transport should work hand-in-hand with triage coordinators and be included in the centralized communications systems.

Accessing the Scene—Accessing the scene is usually difficult with any disaster, but can be exacerbated in a burns disaster, due to heat, smoke, unstable debris, and the possibility of secondary terrorist attacks. Difficult site access can delay the provision of care and initiation of definitive treatment, which can be crucial to the prognosis of burn patients. Some barriers to access, such as heat, smoke, unstable debris, and the possibility of secondary terrorist attacks cannot be avoided. However, things like congested roads leading up to hospitals and areas surrounding the disaster site can be easily managed through effective crowd control and the establishment of alternative routes for personnel to access their normal hospitals. This was effectively displayed during the Tower of London response where police created a clear-way for ambulances to reach the hospitals, thereby rapidly evacuating patients to a definitive care facility.[74] Triage stations and patient transport zones at the scene should also be clearly identifiable for approaching ambulances and rescue personnel so that the initiation of on-scene treatment and subsequent evacuation of patients is swift and effective.

Conclusions

All disasters are unpredictable and have their own unique properties. By analysing the available literature we must learn from past burn disasters. From this analysis, the key areas for improvement are communication, triage, surge capacity, staff experience in burn management, disaster plans, staff roles, and patient identification. In order to develop the science of disaster health it is important that we have accurate information upon which to base our future planning and preparedness. Therefore, reviews and publications of all disasters, should be encouraged so that potential problem areas and valuable lessons learned can be shared with and built upon by the disaster and burns community.

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References

1. Bradt DA, Abraham K, Franks R: A strategic plan for disaster medicine in Australasia. *Emerg Med (Fremantle)* 2003;15(3):271–282.
2. Ahuja RB, Bhattacharya S: Burns in the developing world and burn disasters. *BMJ* 2004;329(7463):447–449.
3. Gunn SWA: The Scientific Basis of Disaster Medicine. In: Masellis M, Gunn SWA, (eds): *The Management of Mass Burn Casualties and Fire Disasters: Proceedings of the First International Conference on Burns and Fire Disasters.* Dordrecht: Kluwer Academic, 1992: pp 13–18.
4. Quenemoen LE, Davis YM, Malilay J, Sinks T, Noji EK, Klitzman S: The World Trade Center bombing: Injury prevention strategies for high-rise building fires. *Disasters* 1996;20(2):125–132.
5. Forgione T, Owens PJ, Lopes, Briggs SM: New horizons for OR nurses—Lessons learned from the World Trade Center attack. *AORN J* 2003;78(2):240–245.
6. Suner S: On-site medical care during the September 11th WTC terrorist attack rescue and recovery effort and the National Disaster Medical System (NDMS). *Med Health R I* 2003;86(11):354–356.
7. Gutman D, Biffl WL, Suner S, Cioffi WG: The station nightclub fire and disaster preparedness in Rhode Island. *Med Health R I* 2003;86(11):344–346.
8. Tarnow PF, Gewalli F, Cassuto J: Fire disaster in Gothenburg 1998—Surgical treatment of burns. *Burns* 2003;29(5):417–421.
9. Tucker K, Lettin A: The Tower of London bomb explosion. *Br Med J* 1975;3(5978):287–290.
10. Brismar B, Bergenwald L: The terrorist bomb explosion in Bologna, Italy, 1980: An analysis of the effects and injuries sustained. *J Trauma* 1982;22(3):216–220.
11. Gomez Morell PA, Escudero Naif F, Palao Domenech R, Sospedra Carol E, Bañuelos Roda JA: Burns caused by the terrorist bombing of the department store Hipercor in Barcelona. Part I. *Burns* 1990;16(6):423–425.
12. Teague DC: Mass casualties in the Oklahoma City bombing. *Clin Orthop Relat Res* 2004;(422):77–81.
13. Anteau CM, Williams LA: What we learned from the Oklahoma City bombing. *Nursing* 1998;28(3):52–55.
14. Dellinger AM, Waxweiler RJ, Mallonee S: Injuries to rescue workers following the Oklahoma City bombing. *Am J Ind Med* 1997;31(6):727–732.
15. Tucker P, Pfefferbaum B, Vincent R, Boehler SD, Nixon SJ: Oklahoma City: Disaster challenges mental health and medical administrators. *J Behav Health Serv Res* 1998;25(1):93–99.
16. McLain SR: The Oklahoma City Bombing: Lessons Learned by Hospitals, online article. American Hospital Association.
17. Ray S: Coping with terrorism: Lessons of Oklahoma City. *Health Trends* 2001;14(2):9–12.
18. Glass RT: The Oklahoma City bombing: The roles of the dental teams...and the lessons learned. *J Okla Dent Assoc* 1998;89(2):20–21,25–32,34–36.
19. Hollander D: Nairobi bomb blast—Trauma and recovery. *Trop Doct* 2000;30(1):47–48.
20. Carter GE: The Omagh bombing—A medical perspective. *JR Army Med Corps* 2000;146:18–21.
21. Miller IS, McGahey D, Law K: The otologic consequences of the Omagh bomb disaster. *Otolaryngol Head Neck Surg* 2002;126(2):127–128.
22. Kennedy PJ, Haertsch PA, Maitz PK: The Bali burn disaster: Implications and lessons learned. *J Burn Care Rehabil* 2005;26(2):125–131.
23. Hampson GV, Cook SP, Frederiksen SR: Operation Bali assist. *Med J Aust* 2002;177(11–12):620–623.
24. Lain RC, Griffiths C, Hilton JM: Forensic dental and medical response to the Bali bombing. A personal perspective. *Med J Aust* 2003;179(7):362–365.
25. Read D, Ashford B: Surgical aspects of Operation Bali Assist: Initial wound surgery on the tarmac and in flight. *ANZ J Surg* 2004;74(11):986–991.
26. Southwick GJ, Pethick AJ, Thalayasingam P, Vijayasekaran VS, Higg JJ: Australian doctors in Bali: The initial medical response to the Bali bombing. *Med J Aust* 2002;177(11–12):624–626.
27. Stephens DP, De Keulenaer BL, Collins S, Harbison PW, Weidmann G, Potter AW: Operation Bali assist—The Royal Darwin Hospital Intensive Care Unit. *Anaesth Intensive Care* 2003;31(3):300–305.
28. Spain BT, Blum PG, Hams SC: The role of anaesthetists in the Darwin response to the Bali bombing. *Anaesth Intensive Care* 2003;31(3):306–308.
29. Palmer DJ, Stephens D, Fisher DA, Spain B, Read DJ, Notaras L: The Bali bombing: The Royal Darwin Hospital response. *Med J Aust* 2003;179(7):358–361.
30. Fisher D, Burrow J: The Bali bombings of 12 October, 2002: Lessons in disaster management for physicians. *Intern Med J* 2003;33(3):125–126.
31. Taylor RM, O'Connor B, St. Leone M, Halpern JS: The voice of experience: Australian nurses caring for victims of Bali bombing. *Disaster Manag Response* 2003;1(1):2–7.
32. Heath C, Orrell T, Lee R, *et al*: A review of the Royal Perth Hospital Bali experience: An infection control perspective. *Aust Inf Control* 2003;8(2):43–54.
33. McCullough C, Christiansen K, Coombs G, *et al*: Bali Bugs. *Australian Society for Antimicrobials Newsletter* 2003;No 13.
34. Silla RC, Fong J, Wright J, Wood F: Infection in acute burn wounds following the Bali bombings: A comparative prospective audit. *Burns* 2006;32(2):139–144.
35. Tran MD, Garner AA, Morrison I, Sharley PH, Griggs WM, Xavier C: The Bali bombing: Civilian aeromedical evacuation. *Med J Aust* 2003;179(7):353–356.
36. Edgar D, Wood F, Goodwin-Walters A: Maintaining physical therapy standards in an emergency situation: Solutions after the Bali bombing disaster. *Burns* 2005;31(5):555–557.
37. McGuire D: Terror in paradise. *Emerg Med Serv* 2003;32(3):55–59.
38. Watts J: Bali bombing offers lessons for disaster relief. *Lancet* 2002;360(9343):1401.
39. Bosch X: Horror as Madrid death toll climbs to over 200. *Lancet* 2004;363(9413):955.
40. Gutierrez de Ceballos JP, Turégano Fuentes F, Perez Diaz D, Sanz Sanchez M, Martin Llorente C, Guerrero Sans JE: Casualties treated at the closest hospital in the Madrid, March 11, terrorist bombings. *Crit Care Med* 2005;33(1):s107–112.
41. de Ceballos JP, Turégano-Fuentes F, Perez-Diaz D, Sanz-Sanchez M, Martin-Llorente C, Guerrero-Sanz JE: 11 March 2004: The terrorist bomb explosions in Madrid, Spain—An analysis of the logistics, injuries sustained and clinical management of casualties treated at the closest hospital. *Crit Care* 2005;9(1):104–111.
42. Frykberg ER: Terrorist bombings in Madrid. *Crit Care* 2005;9(1):20–22.
43. Dolan B: London 2005, bruised but not broken. *Disaster Manag Response* 2005;3(4):94–95.
44. Arnold JL: The 2005 London bombings and the Haddon matrix. *Prehospital Disast Med* 2005;20(5):278–281.
45. Hines S, Payne A, Edmondson J, Heightman AJ: Bombs under London. The EMS response plan that worked. *JEMS* 2005;30(8):58–60,62,64–67.
46. Redhead J, Ward P, Batrick N: The London attacks—Response: Prehospital and hospital care. *N Engl J Med* 2005;353(6):546–547.
47. Wong JM, Marsh D, Abu-Sitta G, Lau S, Mann HA, Nawabi DH, Patel H: Biological foreign body implantation in victims of the London July 7th suicide bombings. *J Trauma* 2006;60(2):402–404.
48. Parish C: The London bombings: How EDs and nurses responded to the terrorist attacks of July 7. *Am J Nurs* 2005;105(9):102–103.
49. Harding ML: Comms failure hampered London bombing response. *Health Serv J* 2006;116(6009):9.
50. Lockey DJ, Mackenzie R, Redhead J, Wise D, Harris T, Weaver A, Hines K, Davies GE: London bombings July 2005: The immediate pre-hospital medical response. *Resuscitation* 2005;66(2):ix–xii.
51. Ryan J, Montgomery H: The London attacks—Preparedness: Terrorism and the medical response. *N Engl J Med* 2005;353(6):543–545.
52. Saffle JR: The 1942 fire at Boston's Cocoanut Grove nightclub. *Am J Surg* 1993;166(6):581–591.
53. Finland M, Davidson CS, Levenson SM: Clinical and therapeutic aspects of the conflagration injuries to the respiratory tract sustained by victims of the Cocoanut Grove Disaster. *Medicine* 1946;25(3):215–283.
54. Davidson CS: The Cocoanut Grove disaster. *J Infect Dis* 1972;125:s58–s59.
55. Hart RJ, Lee JO, Boyles DJ, Batey NR: The Summerland disaster. *Br Med J* 1975;1(5952):256–259.
56. Eisentrout TH: Story of the Beverly Hills fire: Minister's role in a major disaster. *Bull Am Protestant Hosp Assoc* 1978;42(2):105–108.
57. Birky M, Malek D, Paabo M: Study of biological samples obtained from victims of MGM Grand Hotel fire. *J Anal Toxicol* 1983;7(6):265–271.
58. Buerk CA, Batdorf JW, Cammack KV, *et al*: The MGM Grand Hotel fire: Lessons learned from a major disaster. *Arch Surg* 1982;117(5):641–644.
59. Woolley WD, Smith PG, Fardell PJ, *et al*: The Stardust Disco fire, Dublin 1981: Studies of combustion products during simulation experiments. *Fire Safety Journal* 1984;7:267–83.
60. Duignan JP, McEntee GP, Scully B, Corrigan TP: Report of a fire disaster—Management of burns and complications. *Ir Med J* 1984;77(1):8–10.
61. Sadler C: Accident and emergency: The St Valentine's day disaster. *Nurs Mirror* 1982;154(20):14–16.
62. Tarnow P, Gewalli F, Cassuto J: Fire disaster in Gothenburg 1998—Surgical treatment of burns. *Burns* 2003;29(5):417–421.
63. Gewalli F, Fogdestam I: Triage and initial treatment of burns in the Gothenburg fire disaster 1998. On-call plastic surgeons' experiences and lessons learned. *Scand J Plast Reconstr Surg Hand Surg* 2003;37(3):134–139.

https://doi.org/10.1017/S1049023X00008761 Published online by Cambridge University Press

64. Brandsjo KA, Hedelin A, Lundin T, Lundälv J, Swedish Disaster Medicine Study Organization: KAMEDO Report No. 75: Fire catastrophe in Gothenburg 29–30 October 1998. *Prehosp Disaster Med* 2005;20(4):258–261.
65. Cassuto J, Tarnow P: The discotheque fire in Gothenburg 1998. A tragedy among teenagers. *Burns* 2003;29(5):405–416.
66. Dyregrov A, Frykholm AM, Lilled L, Broberg AG, Holmberg I: The Goteborg discotheque fire, 1998. *Scand J Psychol* 2003;44(5):449–457.
67. Pirson J, Degrave E: Aeromedical transfer to Belgium of severely burned patients during the initial days following the Volendam fire. *Mil Med* 2003;168(5):360–363.
68. Welling L, van Harten SM, Patka P, Bierens JJ, Boers M, Luitse JS, Mackie DP, Trouwborst A, Gouma DJ, Kreis RW: The cafe fire on New Year's Eve in Volendam, the Netherlands: Description of events. *Burns* 2005;31(5):548–554.
69. Welling L, Perez RS, van Harten SM, Patka P, Mackie DP, Kreis RW, Bierens JJ: Analysis of the pre-incident education and subsequent performance of emergency medical responders to the Volendam cafe fire. *Eur J Emerg Med* 2005;12(6):265–269.
70. van Harten S, Welling ML, Perez RS, Patka P, Kreis RW: Management of multiple burn casualties from the Volendam disaster in the emergency departments of general hospitals. *Eur J Emerg Med* 2005;12(6):270–274.
71. Mahoney EJ, Harrington DT, Biffl WL, *et al*: Lessons learned from a nightclub fire: Institutional disaster preparedness. *J Trauma* 2005;58(3):487–491.
72. Dunbar JA: The Rhode Island nightclub fire: The story from the perspective of an on-duty ED nurse. *J Emerg Nurs* 2004;30(5):464–466.
73. Gutman D, Biffl WL, Suner S, Cioffi WG: The station nightclub fire and disaster preparedness in Rhode Island. *Med Health R I* 2003;86(11):344–346.
74. Biffl WL, Cioffi WG: Medical disasters: are we really prepared? An analysis of the station fire. *Med Health R I* 2003;86(11):342–343.
75. Dacey MJ: Tragedy and response—The Rhode Island nightclub fire. *N Engl J Med* 2003;349(21):1990–1992.
76. Blocker V, Blocker, Jr, TG: The Texas City disaster; A survey of 3,000 casualties. *Am J Surg* 1949;78(5):756–771.
77. Ishida T, Ohta M, Sugimoto T: The breakdown of an emergency system following a gas explosion in Osaka and the subsequent resolution of problems. *J Emerg Med* 1985;2(3):183–189.
78. Aburel V, Visa L, Grigorescu D: The 1979 fire disaster (93 casualties) in Brasov (Romania)—The importance of rapid transport and unitary treatment in a hospital. *Ann Medit Burns Club* 1994;VII(1).
79. Allister C, Hamilton GM: Cardowan coal mine explosion: Experience of a mass burns incident. *Br Med J (Clin Res Ed)* 1983;287(6389):403–405.
80. Arturson G: The tragedy of San Juanico—The most severe LPG disaster in history. *Burns Incl Therm Inj* 1987;13(2): 87–102.
81. Olley D: Piper alpha—A personal experience. *J R Soc Health* 1991;111(5):193–195.
82. Clark DH: Dental identification in the Piper Alpha oil rig disaster. *J Forensic Odontostomatol* 1991;9(2):37–46.
83. Alexander DA: Psychiatric intervention after the Piper Alpha disaster. *J R Soc Med* 1991;84(1):8–11.
84. Fraser DE: Occupational health management of police officers involved in the Piper Alpha disaster. *J Soc Occup Med* 1991;41(4):174–175.
85. Kulyapin AV, Sakhautdinov VG, Temerbulatov VM, Becker WK, Waymack JP: Bashkiria train-gas pipeline disaster: A history of the joint USSR/USA collaboration. *Burns* 1990;16(5):339–342.
86. Masellis M: Thermal Agent Disaster and Fire Disaster; Definition, Damage, Assessment, and Relief Operations, Chapter 1. In: Masellis M, Gunn SWA, (eds.): *The Management of Mass Burn Casualties and Fire Disasters: Proceedings of the First International Conference on Burns and Fire Disasters*. Dordrecht: Kluwer Academic, 1992, pp 7–12.
87. Cairns BA, Stiffler A, Price F, Peck MD, Meyer AA: Managing a combined burn trauma disaster in the post-9/11 world: Lessons learned from the 2003 West Pharmaceutical plant explosion. *J Burn Care Rehabil* 2005;26(2):144–150.
88. Polk HC, Jr, Tessler R: The Yarmouth Castle disaster. Further experience in the treatment of large human burns with aqueous silver nitrate (0.5 per cent). *J Fla Med Assoc* 1966;53(11):1059–1062.
89. Carswell JW, Rambo WA: A fire at Nakivubo, Kampala: A case report. *Burns* 1976;2:178–183.
90. Baux S, Saizy R, Porte A, Zumer L, Mayer G, Mole B, Monsaingeon I: [The Los Alfaques disaster]. *Ann Chir Plast* 1981;26(2):185–187. (in French).
91. Brough MD: The King's Cross fire. Part 1: The physical injuries. *Burns* 1991;17(1):6–9.
92. Sturgeon D, Rosser R, Shoenberg P: The King's Cross fire. Part 2: The psychological injuries. *Burns* 1991;17(1):10–13.
93. Deahl MP, Bisson JI: Dealing with disasters: Does psychological debriefing work? *J Accid Emerg Med* 1995;12(4):255–258.
94. Masellis M, Laia A, Sperrazza G, *et al*: Fire disaster in a motorway tunnel. *Annals of Burns and Fire Disasters* 1997;X(4).
95. O'Hickey SP, Pickering CA, Jones PE, Evans JD: Manchester air disaster. *Br Med J (Clin Res Ed)* 1987;294(6588):1663–1667.
96. Samuels A: The Manchester airport disaster. *Med Sci Law* 1987;27(2):118–120.
97. Kossmann T, Wittling I, Buhren V, *et al*: Transferred triage to a level I trauma center in a mass catastrophe of patients; many of them with burns. *Acta Chir Plast* 1991;33(3):145–150.
98. Martin TE: The Ramstein airshow disaster. *J R Army Med Corps* 1990;136(1):19–26.
99. Seletz JM: Flugtag-88 (Ramstein Air Show Disaster): An Army response to a MASCAL. *Mil Med* 1990;155(4):152–155.
100. Lee WH, Chiu TF, *et al*: Emergency medical preparedness and response to a Singapore airliner crash. *Acad Emerg Med* 2002;9(3):194–198.
101. Cyganik KA: Disaster preparedness in Virginia Hospital Center—Arlington after Sept 11, 2001. *Disaster Manag Response* 2003;1(3):80–86.
102. Waage A, Hamberger B, Lundin T, Suserud BO, Riddez L, Swedish Disaster Medicine Study Organization: KAMEDO report no. 84: Terrorist attacks against the World Trade Center, 11 September 2001. *Prehosp Disaster Med* 2006;21(2):129–131.
103. Havlak R, Gorman SE, Adams SA: Challenges associated with creating a pharmaceutical stockpile to respond to a terrorist event. *Clin Microbiol Infect* 2002;8(8):529–533.
104. Gottlieb S: The casualties that never arrived. *BMJ* 2001;323(7314):654.
105. Ward MJ: Attack on the Pentagon. The initial fire & EMS response. *JEMS* 2002;27(4):22–30,32,34.
106. Jordan MH, Hollowed KA, Turner DG, Wang DS, Jeng JC: The Pentagon attack of September 11, 2001: A burn center's experience. *J Burn Care Rehabil* 2005;26(2):109–116.
107. Banauch GI, Dhala A, Prezant DJ: Pulmonary disease in rescue workers at the World Trade Center site. *Curr Opin Pulm Med* 2005;11(2):160–168.
108. Nemery B: Reactive fallout of World Trade Center dust. *Am J Respir Crit Care Med* 2003;168(1):2–3.
109. Pesola GR, Dujar A, Wilson S: Emergency preparedness: The World Trade Center and Singapore airline disasters. *Acad Emerg Med* 2002;9(3):220–222.
110. Roche M: Eyewitness to terror: EMS responds to the attack on the Pentagon. *Air Med J* 2001;20(6):4–5.
111. Wang D, Sava J, Sample G, Jordan M: The Pentagon and 9/11. *Crit Care Med* 2005;33(1 Suppl):s42–s7.
112. Das RAP: 1981 Circus fire disaster in Bangalore, India: Causes, management of burn patients and possible presentation. *Burns* 1982;10:17–29.
113. Sharpe DT: Management of burns in major disasters. *Natnews* 1989;26(12): 9–10.
114. Sivaloganathan S, Green MA: The Bradford Fire Disaster. Part 1. The initial investigations: Who died, where and how? *Med Sci Law* 1989;29(4):279–283.
115. Sivaloganathan S, Green MA: The Bradford Fire Disaster. Part 2. Accident reconstruction: Who died, when and why. *Med Sci Law* 1989;29(4):284–286.
116. Al-Hoqail R: A fire disaster at a wedding in a village in the eastern province, Saudi Arabia. *Annals of Burns and Fire Disasters* 2004;XVII(3).

Editorial Comments: Burn Disasters—An Audit of the Literature

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This article presents information that is all too real to all of us who care for patients with burns. How can we ever be prepared for a large-scale burn disaster? When thinking of disasters, one might think of hundreds of patients being injured. In many areas of the country, where burn centers are limited or sparse, more than one patient with severe burns is a disaster. Over the past several decades, the number of patients admitted to hospitals with large burns has been decreasing. This is due to safety items including fire suppression systems and escape plans in large buildings, and smoke detectors in individual residences. Many hospitals are closing their burn centers as they are finding it hard to keep up with the high cost of the care of patients with burns. Currently, the American Burn Association lists 128 burn care facilities in the United States, with 53 being verified burn centers. Only six states, Idaho, Montana, Wyoming, North Dakota, South Carolina, and New Hampshire, do not have burn care facilities. There also are fewer surgeons choosing burn surgery as their career, with many burn centers currently looking to hire burn surgeons. This leads to fewer people and fewer hospitals that have the expertise to care for burns and teach others what to do in the event of a burn disaster. Hopefully, this article will reach institutions that do not have a burn center, or providers who know how to care for burns, to reach out to the burn center nearest them and develop a plan for the initial care and evacuation of those with burn injuries. This plan must be integrated into the disaster planning of the local prehospital system, the state emergency management system and the hospital emergency department and trauma service. I also would like the Accreditation Council for Graduate Medical Education to keep burn surgery training a requirement for all surgical trainees. We need to expose surgical trainees to the wonders of caring for those with burn injuries so that they might choose to care for patients with burns throughout their career.

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Editorial Comments: Burn Disasters—An Audit of the Literature

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Introduction

In this issue of *Prehospital and Disaster Medicine*, Broeze *et al* have provided strategies for enhancing future preparedness in burn disasters.[1] The authors reviewed previously published reports and analyzed them for commonality of problems identified during the disaster and subsequent recommendations after analysis of the disaster response.

Burn Disasters and Disaster Analysis

The authors appropriately point out the significance of burn disasters in terms of the numbers of victims. Analysis of 36 disasters indicates an astonishing number of fatalities and an injury rate three times the fatality rate. The focus of the analysis is on both prehospital and hospital responses. The prehospital issues are common to many multi-victim scenarios; for example, ineffective communication still is one of the major unsolved issues that has yet to find an effective solution. Other prehospital issues include staging, triage, and transport.

The hospital responses to burn disasters also have many issues common to multi-victim response scenarios; however, burn injury has many unique complicating characteristics. For example, the multiple-injured trauma patient requires stabilization and treatment, and lifesaving interventions by general surgeons and neurosurgeons. Trauma is defined by the "golden hour". In contradistinction, burn resuscitation lasts for 24 hours or more. The daily care is extremely nursing-intensive, the patients often require multiple operative interventions, and the length of stay is prolonged. The multidisciplinary nature of burn treatment (physician, nurse, therapist, nutritionist, respiratory therapist, health psychologist, etc.) can place additional burdens on multiple, hospital-based services.

The lack of experienced burn personnel has been a common finding in previous burn disasters. Inexperience leads to over/underestimation of burn size which affects triage and determines resuscitation formulas. The thermally injured patient is at risk for laryngeal edema or inhalation injury that mandates early endotracheal intubation. These clues often are subtle and easily missed. The awake and alert patient with normal vital signs may be the one with the most urgent need for intubation. This lack of experience also may delay scene transport or interhospital transfer of critically injured patients and inappropriate early triage of patients with obvious, but non-life-threatening burns.

Recommendations

The article's major recommendation is burn education for healthcare personnel. Burn education courses are infrequent, but when given, often have poor attendance. Non-burn specialist healthcare personnel treat burn injuries relatively infrequently, and medical personnel that are not routinely exposed to burn injuries would not inherently seek additional training in this area. However, there is a clearly increased international interest in disaster preparedness. Disaster preparedness should be a major component of education at all levels and in all disciplines. Burn education would be well served as a specific module of disaster preparedness. Specifically instilling concepts such as recognition of pending laryngeal edema and the need for emergent endotracheal intubation, resuscitation techniques, and escharotomy has tremendous potential to improve care and overall outcomes in a disaster situation.

Additional recommendations are made towards nationalization of disaster preparedness as exemplified by the United States' weekly reporting system for burn bed availability and surge capacity. Ideally, this information will help to expedite triage and transport if a national burn disaster occurs. Unfortunately, local and regional burn disaster plans are not well established as demonstrated by ongoing efforts to establish a regional burn disaster plan.

Finally, the specialty burn treatment team is an exciting, if yet unproven, concept. The burn treatment team could interface with other disaster services, including military transport, to aid in triage, stabilization, and extrication in areas without an established infrastructure to handle an acute influx of injured patients. Every issue associated with disaster management will be exacerbated in these settings. The specialty treatment team may be a more realistic approach than attempting to establish burn disaster education and burn disaster plans these areas. The burn treatment team's impact will depend heavily on solving issues of supply and transport through a cooperative public/private/military effort.

Conclusions

Burn physician experience is a vital component of skilled care and good outcomes, but the multidisciplinary nature of the burn center also is an essential component. Unfortunately, burn surgeons are in high demand but low supply. A recent survey demonstrated that 70% of burn centers anticipate needing to recruit an additional burn surgeon within the next five years, and 90% of those anticipate difficulty finding another burn surgeon.[2] The survey warns of a severe burn surgeon shortage in the immediate future. From a nursing perspective, 62% of burn units experienced a nursing shortage, and 77 of 124 units with current vacancies had an average of 4.6 positions open.[3] The US Department of Health and Human Services puts the number of US burn beds at just 1,500, and 70 to 80% of those beds are already filled.

The burn disaster likely is the most challenging multi-victim scenario. Responses are complicated by prehospital communication and transport problems, the lack of burn care experience, and the intensive efforts required for patient management. With the current state of burn care specialists and burn beds, burn treatment teams may be the best way to respond to a mass-casualty incident in developing countries, and the only way to respond to a mass-casualty incident in undeveloped countries.

References

1. Broeze CL, Falder S, Rea S, Wood F: Burn disasters—An audit of the literature. *Prehosp Disaster Med* 2010;25(6):555–579.
2. Faucher LD: Are we headed for a shortage of burn surgeons? *J Burn Care Rehabil* 2004;25(6):464–467.
3. Yurko L, Coffee T, Yowler CJ: The burn nursing shortage: A burn center survey. *J Burn Care Rehabil* 2004;25(2):216–218.
4. US Department of Health and Human Services

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The WADEM Board of Directors, pursuant to its decision at the World Congress on Disaster and Emergency Medicine in Edinburgh, Scotland in May 2005, offers the designation of WADEM Chapters to regional organizations of WADEM members who share the mission and dedication of the WADEM.

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A regional WADEM Chapter consists of a group of WADEM members in a particular region who, as a matter of geographic convenience, organize to promote the goals of the WADEM cooperatively. Chapters have an academic, research, and/or operational focus, and work to further develop the goals of WADEM and of the individual Chapter membership. Chapters provide an organized way for its members to share their professional experiences and provide educational, training, and research opportunities for the advancement of disaster health and management.

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