REVIEW ARTICLE

Burn Mass Casualty and Disaster

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Background – The medical response to mass casualty incidents involving burns is complex, and requires coordination of resources and personnel. Casualties may have a combination of cutaneous burns, inhalation injury, and other traumatic injuries, some of which are not immediately apparent. These events require highly trained medical personnel to manage the initial response. Equally important is an organized system for triage, allocation of resources, and transport of patients to the correct treatment location, as errors in these arenas have the potential to cost many lives. Historic mass casualty events involving burn victims have propelled the advancement of burn care and the development of an organized mass casualty response system.

Summary – We revisit two historic disasters, the Cocoanut Grove Nightclub fire of 1942 and the terrorist attacks of September 11, 2001. These incidents, although resulting in the combined loss of thousands of lives, resulted in valuable lessons learned regarding the management of burn patients after a disaster. Next, the current response to a mass casualty incident in which a significant proportion of patients have thermal injuries is reviewed, with an emphasis on triage, transport to local medical facilities, and transport to regional burn centers. Finally, the role of the National Disaster Management System (NDMS), the Department of Defense (DOD), local/ state emergency response systems, and the American Burn Association (ABA) are discussed.

Conclusion – An organized and timely response to a mass casualty event involving burn victims is logistically difficult, but extremely important to minimize loss of life. The United States has made great strides in developing such a response and continues to refine the process.

Introduction

Burn mass casualty incidents can be devastating and require an integrated response at the local, state and sometimes national level. Burn care is highly specialized, but medical personnel with little or no training in burn care likely are the first to manage burn casualties. Patients are stabilized locally, and the most critically injured are transported to a burn center for more definitive care. Our ability to respond to these incidents has evolved greatly since the terrorist attack in 2001. We will review the local, state, regional and national responses to a disaster or mass casualty incident that involves a significant number of burn casualties.

The Cocoanut Grove Nightclub Fire

The Cocoanut Grove Nightclub, in Boston, became engulfed in flames on November 28, 1942. Although the cause of the fire is not known for certain, it is estimated that approximately 1000 people were present in the nightclub despite the fire code occupancy limitation of 600. In addition, the fact that all exits except one were either locked or blocked, and the mass panic that ensued, resulted in hundreds of patrons being trapped inside (1). The majority of patients affected by this fire were taken to either Boston City Hospital (BCH) or Massachusetts General Hospital (MGH). The Pearl Harbor attacks less than one-year prior had resulted in a significant number of burn-injured patients, bringing attention to the need for additional research into the care of burn casualties. As a result, the National Research Council had begun funding several such projects, two of which were being performed at BCH and MGH (2). A week prior to the Cocoanut Grove fire, a mass casualty training event had been conducted in Boston by the Regional Office of Civilian Defense in preparation for an attack against the east coast of US. As a result, thousands of medical workers and volunteers were assembled quickly after the fire (1).

However, despite these preparations, the city's response to this event was inadequate in several areas. First, the streets around the nightclub were soon rendered impassable by fire-fighting equipment and spectators. Second, the number of casualties quickly overwhelmed the city's supply of ambulances, resulting in the use of private and delivery vehicles to transport both living and dead victims. Third, at the receiving hospitals, too much time was spent attempting to resuscitate patients who should have been triaged into the expectant category. Finally, the lack of a central office for identifying the deceased and disseminating information resulted in large numbers of panicked family members crowding the hospitals (2).

However, the large number of burn casualties resulting from this fire led to several advances in burn care. Perhaps the most notable of these was the recognition of the concept of inhalation injury. The physicians at BCH and MGH noticed that many patients arrived at the hospital without significant cutaneous burns, but cyanotic and with edema of the face and neck; many of these patients went on to expire within a short period. Initially, an explosion at the nightclub was postulated, but the treating physicians soon realized that these patients were suffering from pulmonary inflammation as a result of the "irritating fumes and heat" they had been exposed to. Respiratory therapy was a relatively undeveloped field at that time, and, while most patients were administered supplemental oxygen, only a handful were treated with positive pressure ventilation. The

recognition of the entity of inhalation injury led to additional research on the subject, which has continued to this day (1). A second piece of knowledge gained through treating the victims of this fire was that hourly urine output was the best guide for fluid resuscitation of burn patients – a concept still accepted today. The staff at MGH developed a simple formula for initial fluid volumes to be administered, the predecessor of current formulas (1).

The Attacks of September 11, 2001

On the morning of September 11, 2001, terrorists caused three airplanes to crash into three buildings, resulting in the loss of thousands of lives. At 8:45 am, American Airlines Flight 11 crashed into the World Trade Center's (WTC) North Tower. This was followed twenty minutes later by a second collision, when United Airlines Flight 175 hit the South Tower of the WTC (3). Finally, at 9:38am, American Airlines Flight 77 crashed into the Pentagon (4). Although the attack on the Pentagon caused significant damage, it only resulted in nine patients who required treatment for burn injury (due in part to a renovation project on the portion of the Pentagon that was struck, with many employees having been relocated and the structure having been recently reinforced) (3). The remainder of this section will focus on the WTC attacks.

New York City has the largest population of any U.S. city as well as the largest number of trauma centers, seventeen. The Fire Department of New York (FDNY) controls the largest number of ambulances serving New York, but multiple other private ambulance services also respond to emergencies. Because of the unique aspects of the city and need for a unified response in case of a disaster, the Office of Emergency Management (OEM) had been developed prior to the 2001 attacks for the purpose of coordinating the city's emergency response to disasters. Unfortunately, the OEM headquarters were located in one of the buildings of the WTC and its communications relied on an antenna located another WTC building. These buildings were both damaged in the attacks, and difficulties with communications "probably resulted in more problems than all other factors combined" (5).

Partially as a result of impaired communications, triage after this disaster was suboptimal. Hospitals close to the WTC were overwhelmed with patients while other hospitals slightly farther away were not fully utilized. While FDNY ambulances were able to communicate with their own dispatchers, private hospital-based ambulances had no awareness of which area hospitals were already overwhelmed and where additional patients should be taken (5). In addition, there was no system in place for triaging burn-injured patients directly to burn centers at the time of the attacks (6).

The lessons learned from these attacks and their subsequent responses largely involved communication and coordination of care failures. While having an OEM was an excellent idea, this event highlighted the fact that its headquarters and communications towers should be in places unlikely to be damaged in an attack (although this is obviously difficult to predict), and there should be redundancy in command centers and antennas (7). The need for a clear triage plan for burn patients was also identified and has been addressed, as outlined below.

In response to the lessons outlined above, the Hospital Preparedness Task Force

for Patients with Burns was created in 2006 and has developed guidelines for the care of burn patients in a mass casualty situation within New York City. This includes a detailed triage algorithm, specific rules for which hospitals should receive burn patients and when they should be transferred to designated burn centers, and the circumstances under which virtual burn consultation should be used. It also includes educational training for participating facilities, and recommendations for patient tracking (8).

Burn Mass Casualty: Initial Stabilization and Management at Triage Site

Mass casualty incidents can result from natural and manmade disasters, as well as domestic terrorist events that can overwhelm local medical assets. Surge capacity is defined as a medical system's ability to adjust to an increase patient demand that a mass casualty incident would impose. An incident, which results in a significant number of burn casualties, increases the complexity of the situation since there are a limited number of burn centers and burn providers. These patients will need to be stabilized and initially managed in local medical facilities. Patients with larger burn injuries and those with combined thermal and multi-system traumatic injuries can be transferred to regional burn centers once stabilized. These events will tax Emergency Medical Services (EMS) and place demands on man-hours and supplies of area medical facilities. Several facilities will need to pool their resources to adequately respond to burn mass casualty incidents (9).

The proper triage of burn casualties is essential. The burn triage tool proposed by Palmieri et al. utilizes five triage categories: outpatient, high (probability of survival), medium, low and expectant (figure1).

Burn Disaster Decision Matrix

Burn Size (%TBSA)

Age/ years	0-10%	11-20%	21-30%	31-40%	41-50%	51-60%	61-70%	71-80%	80-90%	91+%
0-1.99	High	High	Medium	Medium	Medium	Medium	Low	Low	Low	Expectant
2-4.99	Outpatient	High	High	Medium	Medium	Medium	Medium	Low	Low	Low
5-19.9	Outpatient	High	High	High	Medium	Medium	Medium	Medium	Medium	Low
20-20.9	Outpatient	High	High	High	Medium	Medium	Medium	Medium	Low	Low
30-30.9	Outpatient	High	High	Medium	Medium	Medium	Medium	Medium	Low	Low
40-40.9	Outpatient	High	High	Medium	Medium	Medium	Medium	Low	Low	Low
50-50.9	Outpatient	High	High	Medium	Medium	Medium	Low	Low	Expectant	Expectant
60-60.9	High	High	Medium	Medium	Medium	Low	Low	Low	Expectant	Expectant
70+	High	Medium	Medium	Low	Low	Expectant	Expectant	Expectant	Expectant	Expectant

Figure 1. Burn Disaster Matrix (10)
Adapted from figure in Disaster Management and ABA Plan (10)

The combination of age and burn size (% total body surface area - %TBSA) will determine triage category. Patients who are older and have large burn size will have poorer prognosis. Elderly patients with burn size greater than 50% and very young patients (less than two years of age) with %TBSA greater than 90% should be designated – expectant (10). For the expectant patient the priorities are: to keep the patient comfortable and be very judicious about any resources devoted to the care of these patients. The casualties with the lowest acuity, often those who are ambulatory, will present early to local emergency rooms. Many of these patients can be rapidly assessed, treated and discharged with a plan for follow-up as an outpatient if necessary. It is important that these patients are expeditiously dispositioned in anticipation of more acute casualties many of which will require continued stabilization and resuscitation on an inpatient basis. A smaller cohort will need management in an intensive care setting. These patients should be targeted for transfer to burn centers as they will require this specialized care and should ideally be transferred within 48 hours of their injury (11).

Triage of burn casualties in a mass casualty situation should center on patients in the high and medium categories. These patients have good probability of survival but will require initial evaluation, stabilization and assessment for other life-threatening injuries. Only the injuries that absolutely require immediate attention should be addressed in the triage phase. Casualties who require more than simple interventions may need to be re-triaged to low category depending on availability of experienced medical personnel and equipment. Triage is a fluid process and priorities can change with changing patient status and triage environment. In a mass casualty event resulting from an incendiary explosive device or during

military operations casualties may need to be transported to a secure area away from the site of the incident where triage can occur safely. This will delay initial treatment of casualties but necessary to protect patients and first responders (12).

Assessment of life threatening injuries during triage should follow the "ABCD" (airway-breathing-circulation-disability) paradigm used in both Advance Trauma Life Support and Advanced Burn life Support (ATLS and ABLS). Patients who are unable to protect their airway are a priority. The ability to perform advance airway stabilization should be determined prior to triage and will depend of presence of properly trained medical first responders and equipment available. Before an advanced airway is placed consideration for whom will be designated for manual ventilation of the patient or use of transport ventilator should be made. Time must be budgeted wisely for each patient and time used to stabilize a difficult airway cannot usually be afforded. Simple interventions such as placement of supplement oxygen will be all that is required for most patients. Patients should be evaluated for inhalation injury, severe maxillofacial injury, large %TBSA, severe chest injury or severe traumatic brain injury and they may require airway stabilization early (13). A difficult airway will require attention of multiple trained personnel and consume time and resources that maybe better utilized elsewhere. These patients should be considered for low or expectant triage category.

Obtaining intravenous (IV) access in every casualty is an unrealistic goal. Many patients will not require intravenous medication or initiation of fluid resuscitation at the triage site and IV access can be obtained at the medical facility. IV access should be obtained, if possible, in all patients with immediate life-threatening injuries. Intraosseous (IO) access is an option that should be considered. First responders are likely trained in IO placement and this is a better option for obtaining access in pediatric patients (14). An event such as the detonation of an explosive device or explosion from an industrial accident will result in a high proportion of casualties with extremity injuries in addition to burn injuries and multi-system trauma. These injuries will range in severity from minor wounds and abrasions to traumatic amputation with high a likelihood of massive hemorrhage in addition to limb threatening injury. The severity of injury will be directly related to distance from the epicenter of the blast. The use of tourniquets has been shown in recent military conflicts to improve survival and these tactics have been adopted in the "Stop the Bleed" campaign recent promoted by Health and Human Services (HHS) (15).

A chemical weapons attack (blistering agent, phosgene, etc.) will result in chemical burns and can affect the respiratory tract and eyes. The first priority is to ensure the safety of first responders and proper protective equipment must be donned. The response, in this scenario, will likely be coordinated with the National Disaster Medical System (NDMS) and the US military. Such an attack can result in hundreds possibly thousands of casualties. Decontamination sites should be set up near but not inside local medical facilities to allow for patients to be decontaminated before entering. This prevents contamination of the facility and its personnel (16). A nuclear detonation in a densely populated city can cause casualties in the order of tens of thousands to hundredths of thousands. Disaster of this scale will require national response and the coordination of many government and civil agencies. The patients

will have radiation burns of varying severity but many will succumb to debilitating radiation sickness over the subsequent hours and days (17).

Care at Local Medical Facilities and Transport to Regional Burn Centers

Once patients are stabilized at the triage site, selected patients can be transported to local medical facilities. The coordination of medical resources in many cities and counties in the US for disaster response is done by regional trauma systems in conjunction with state and regional NDMS. Other countries have a similar response system. The dispatch of EMS for transporting patients from triage site to designated medical facility should be coordinated at the regional level with communication between areas hospitals to ensure patients are distributed evenly and no facility is overwhelmed. Most centers are required to have a disaster response plan and the plan should be nested in regional or state plans. With a mass casualty incident involving a significant number of burn patients, the decision should be made early to contact regional burn centers to allow sufficient time for them to prepare to receive casualties. The American Burn Association should be contacted as this is the only organization with a national plan to respond to a "burn disaster" (discussed in greater detail later). The patients should be re-triaged to decide whom to refer to burn center and when. Close monitoring by logistical support systems track the use of medical supplies as well as crystalloid and blood utilization and availability. These events can sap resources very quickly so a good plan for rapid re-supply is prudent.

Patients with %TBSA burn exceeding 20% who are admitted to local facilities will most likely require burn resuscitation. Oral resuscitation with oral replacement formulas is an option in patients with %TBSA up to 40% and who have an intact airway. Patient with %TBSA larger than 40% and/or are intubated should ideally be resuscitated with intravenous fluid (18). Burn resuscitation can be difficult for the provider who is not trained in the care of burn patients. ABLS courses sponsored by the ABA provide instruction on the fundamentals of burn care and was created for providers who do not care for these patients regularly. Wound care is another tense area for the provider who lacks training in burn care. Patients with large %TBSA can be covered with clean dry dressings for several hours until they can be referred to a burn center for more definitive wound care. Patients, who present with smaller burns, can be discharged after wounds are cleaned and placed in topical creams (silver sulfadiazine or mafenide acetate), bacitracin ointment (superficial burns) or other burn care products. Any patient whose wound care can be safely performed in the outpatient setting and has adequate pain control should be considered for discharge (19).

The Role of NDMS and ABA in Burn Disaster

In the current era of sustained military operations, terrorist activities and natural disasters, mass casualty burn disasters pose challenges for local, state, and national authorities tasked with disaster response. After a disaster has occurred, a chaotic environment can undermine even the most durable and well-developed plan. Cancio et al. extensively reviewed burn mass casualty disasters occurring between 1970 and 2003 and identified disordered conditions in nearly each circumstance. In almost every situation, the response lacked effective organization and

resource utilization (20). To combat these issues, the disarray and havoc that occurs at the incident site should be anticipated, and a multi-tiered disaster plan is required to ensure optimal patient care (10). Once patients are stabilized decision should be made which (if any) patients to transfer to burn center. Any patient that meet ABA transfer criteria can be considered for transport but it is prudent to transfer patients with larger %TBSA and/or significant inhalation injury. These patients will require specialized care that a burn center provides. If the regional burn center is in close proximity, ground transportation is a good option. If there is considerable distance to nearest burn center, aeromedical transport with large fixed wing aircraft is needed. Transport must be coordinated at several levels to insure evacuation assets and receiving burn centers are not overwhelmed with the increased patient load.

Background/ABA Definitions

In response to recent terrorist events and other mass casualty incidents causing burn injury, the ABA in association with local, state, regional and federal entities have developed specific plans of action to optimize burn care (10,21,24). Since burn injuries occur in up to 30% of victims of such incidents, burn centers have been identified by the HHS as integral to the development, maintenance, and sustainment of disaster plans (10). Compared to the numerous trauma centers throughout the country, a relatively small number of burn centers, burn surgeons and available burn beds exist in the United States (23). And, of the burn centers, even fewer are verified by the ABA and American College of Surgeons (ACS) (10). Since burn injuries are resource-intensive, verification ensures that the burn centers are capable of handling all aspects of burn care, as burn injuries require a multi-disciplinary, long-term approach to treatment and rehabilitation (23). The ABA defines a mass burn casualty disaster as an event resulting in a number of victims that exceeds the local burn center's ability to provide complete burn care (10). In addition, it defines a burn center's surge capacity as the ability to manage 50% more patients than its normal capacity (10).

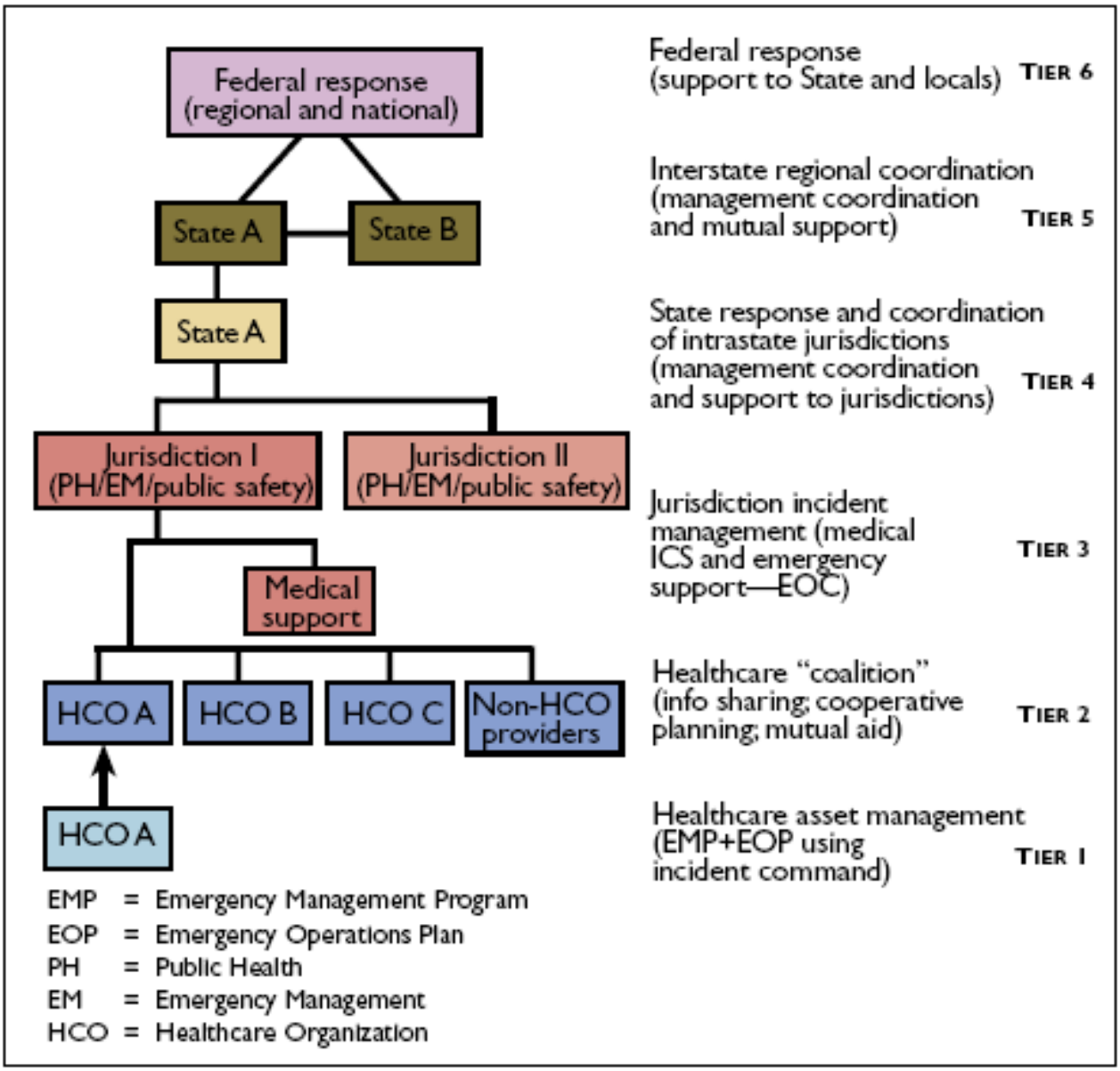

Figure 2. NDMS: tiered response system. (28)

Tiered Response Plans

As stated above, in the United States, disaster response involves a multi-tiered system (Figure 2). The involvement of each tier depends on the scale of the disaster and the necessary resources available to optimize patient care. The time for communities to implement a disaster plan and establish command and control must occur prior to such unfortunate incidents. To support the local hospital's disaster planning process, the ACS has published *Resources for Optimal Care of the Injured Patient*, which provides guidance to local hospitals developing a disaster plan (22). The burn center leadership should be an

integral part of any hospital's disaster planning committee (23). After a mass casualty event has occurred, the local disaster plan goes into effect. The local Incident Command System is activated and emergency responders and local hospitals are notified. In order to effectively manage the chaos, the Incident Command System takes the lead in providing command and control; communication; triage; and patient transfer (10,22). As with every critical situation, effective and persistent communication is critical to the successful implementation and sustainment of the disaster plan.

To support the disaster response, the ABA Plan, which was developed by the Committee on Organization and Delivery of Burn Care and the Board of Trustees, established triage policies to ensure proper patient transfer. Per the Incident Command's local disaster plan, primary triage occurs on site or in emergency rooms. According to the ABA's Primary Triage Policy, burn patients should be transferred to a burn center within 24 hours of injury under the direction of the Incident Command (10). To assist the Incident Command, the ABA has developed a triage table to guide the decision-making process (10,22,23). The local medical facility prepares to receive casualties and notifies regional burn centers of the situation in order for them to prepare to assist with management. When the burn center reaches surge capacity, the burn center director establishes patient transfer to another burn center in the region per the ABA's Secondary Triage Policy (10,21).

As stated above, the NDMS is activated if federally declared incidents occur. The NDMS is a part of the Federal Emergency Management Agency (FEMA) in the Department of Homeland Security. The NDMS provides medical support at the disaster site, assists with patient movement from the disaster site, and administers medical care away from the disaster site. For burn specific injuries, the NDMS established Burn Specialty Teams (BSTs) to assist local medical teams in triage, transfer and medical management. Per the ABA NDMS Policy, BSTs should assist the local burn center with secondary triage to other burn centers. The Department of Defense (DOD) is the last tier in the United States' disaster response system (27). The DOD provides Special Medical Augmentation Response Teams (SMART) to provide assistance for biochemical or radiation disasters (10,24,27). Concerning burn support, the U.S. Army Institute of Surgical Research, Brooke Army Medical Center, Fort Sam Houston, Texas provides two burn SMART teams. Per ABA Policy, the burn SMART teams should assist with secondary triage (Figure 3) (27).

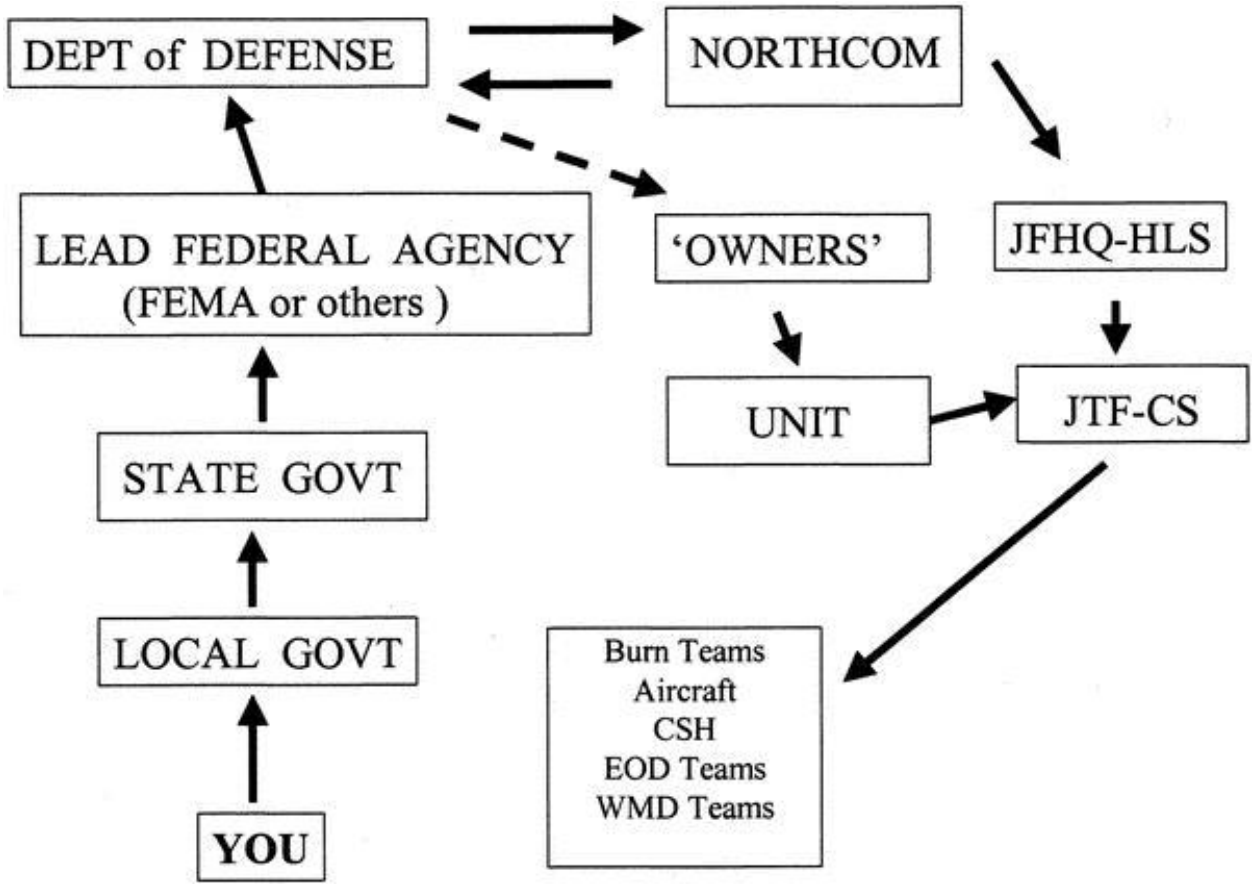

Figure 3. ABA Disaster Plan. (27)

Conclusion

Following disasters, an after-action review with sharing of information for performance improvement is an integral part of the disaster response process. In addition, continued education through Advance Burn Life Support (ABLS) courses should be offered to medical personnel to enhance their knowledge and comfort with managing burn injuries (25). Other aspects of disaster preparation include having a plan to obtain critical supplies and products such as: central line kits; endotracheal tubes; drugs; intravenous fluids; surgical and anesthesia supplies; and skin substitutes (20,26). Again, it is important to remember that a chaotic disaster environment is predictable; however, throughout the maelstrom, leadership, communication, and preparation will ensure that victims are properly cared for and the greatest number of lives are saved.

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