

LESSONS LEARNED IN DELIVERY OF POST-EARTHQUAKE ORTHOPEDIC SURGICAL CARE IN HAITI

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between all authors. Author JWH designed the study, managed the literature searches, reviewed the articles, and wrote the initial draft. Author RLB reviewed all manuscript drafts and guided the study. Author DMV anchored the field study and provided photographs. All authors read and approved the final manuscript.

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ABSTRACT

In 2010, Haiti was devastated by an earthquake, which resulted in a large death toll and left the country in ruins. Many organizations, both governmental and non-governmental, mobilized rapidly in mounting a humanitarian response to the disaster. Pertinent to this natural disaster, orthopedic care remains one of the most important surgical specialties in post-earthquake care due to the abundance of fractures and crush injuries. Despite many volunteer disaster relief providers responding to the call, teams experienced difficulty providing high-level medical care, specifically delivery of orthopedic care. Examining lessons from prior earthquakes is of particular importance for planning the necessary response required for inevitable future earthquakes. This review will examine barriers to care as well as lessons learned in delivery of post-earthquake orthopedic care experienced in Haiti. The lessons compiled in this review will highlight the need for pre-disaster training and implementation of minimum surgical standards, pre-planned logistics and team management, cooperation of military and civilian teams, and effective use of communication technology.

Keywords: Orthopedic; injury; earthquake; Haiti; disaster response.

1. INTRODUCTION

Over one million earthquakes occur each year worldwide equating to about one occurrence every 2 minutes [1]. Earthquakes affect countries all over the world and have led to over 780,000 deaths in the last ten years [2]. They represent a devastating, sudden natural disaster leading to thousands of deaths in a mass casualty situation. The dangers of earthquakes have increased with urbanization and concentration of populations in large city centers. Earthquakes often overwhelm medical response in addition to destroying critical infrastructure necessary for transportation, coordination, and rapid care. Additionally, earthquakes are even more devastating when they

affect low-middle income countries (LMIC) with poor pre-existing infrastructure and medical care bringing high morbidity and mortality rates. Examining lessons from previous literature is an important endeavor in improving future post-earthquake care. Earthquakes are unpredictable and require a multidisciplinary approach to both productively and efficiently manage medical care.

On January 12, 2010, a Richter scale 7.0 earthquake hit the capital city of Haiti, Port-au-Prince, affecting an estimated 3 million people [3]. The earthquake resulted in approximately 222,570 deaths and over 300,000 injuries [4]. Haiti is one of the poorest and least developed countries in the Western Hemisphere

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with a pre-existing shortage of medical and orthopedic care [3]. The impact of earthquakes and the number of casualties is directly related to their magnitude and proximity to urban centers, thus making the earthquake in Haiti one of the most devastating natural disasters in recent years [3].

The majority of deaths and injuries in earthquakes are the result of collapsing buildings and mechanical injuries [1]. Fractures are a frequent earthquake related injury, the second most common musculoskeletal injury behind lacerations [2]. Open fractures, long bone fractures, pelvic fractures, compartment syndrome, multiple fractures, and other complications are several injuries requiring tertiary orthopedic care [2]. In Haiti's 2010 earthquake, most of the survivable injuries were musculoskeletal, accounting for 25.9% of surgical procedures performed at a field hospital [4]. These data illustrate the fact that orthopedic surgical care is an important and imperative early component of earthquake care teams.

Understanding the public health effects and examining the epidemiology of earthquakes can help save future lives in earthquakes to come. Many papers have been published on experiences and lessons learned by orthopedic field teams. Herein, we review lessons in delivering orthopedic care in post-earthquake Haiti.

2. METHODS

Literature was reviewed from Pubmed, Medline (OVID), Web of Science, Embase, and Scopus on

12/26/2015. Free text keyword searches, orthopedic; earthquake, were used in all databases. MeSH terms "earthquake" and "orthopedic" were used in PubMed, Embase, and OVID. Articles written after the earthquake, January 4, 2010 were included for review. Articles on pediatric populations were not included due to the focus on general adult care in this review. Articles were then further selected by title and abstract. The search was aimed at articles focusing on delivery of care as opposed to surgical procedures and injury breakdown. Literature and systematic reviews were not included. Many sources found were commentaries and narratives from experiences in field hospitals; these have been included in this review. The search did not exclude other languages however, the selected articles were written in the English language. Once narrowed, the articles were selected by full text reading and evaluation of qualitative value.

3. RESULTS

Please see Fig. 1 for details of article selection. Overall, 454 articles were initially identified in the search of web-based publication databases. After deleting duplicates, articles were eliminated if they did not describe the earthquake in Haiti, they were not focused on orthopedic care, or if they were specific to population or procedure. Once above inclusion and exclusion criteria were applied to the articles' titles, 20 articles were explored in depth by the authors. Finally, 12 articles were chosen for inclusion in this review due to detail, timing, and pertinence to topic.

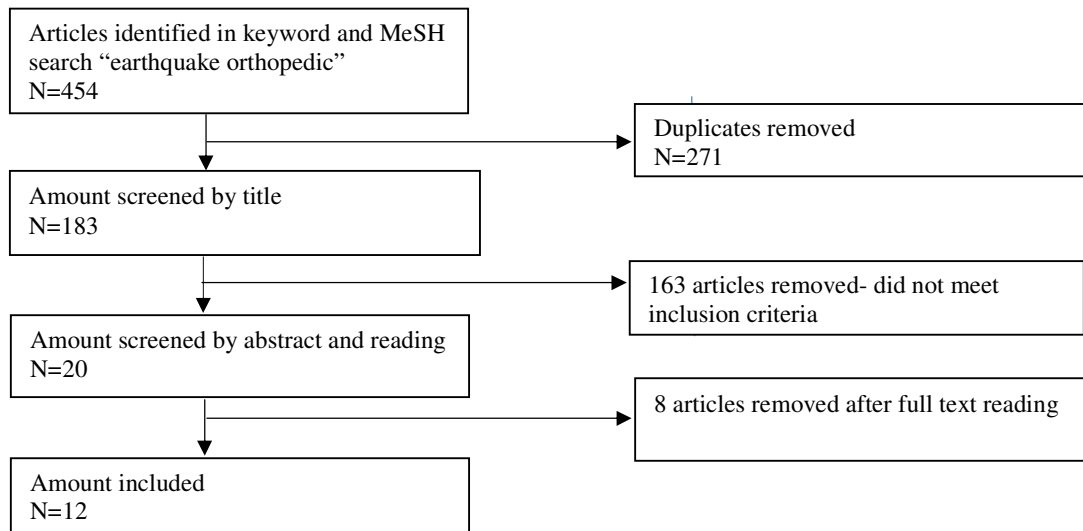


Fig. 1. Articles screened for review and inclusion

4. DISCUSSION

The earthquake in Haiti was a humanitarian catastrophe with thousands of casualties. The trauma burden was further amplified by the low existing baseline socioeconomic status of the country and inherent damage patterns inflicted by earthquakes [5]. Immediately following the earthquake, both governmental and non-governmental humanitarian groups rushed to provide much needed medical support. Many American doctors with or without mass casualty experience formed groups to provide medical care in the days following the earthquake. Consequently, many have written narratives and articles on their challenges and experiences on the ground in post-earthquake Haiti. Specifics to the challenges and experiences of orthopedic surgeons participating in the humanitarian effort were reviewed for similarities and lessons on delivering care.



Fig. 2. Dr. Vanderpool (co-author) performing an above knee amputation in Jimani, Dominican Republic. Jimani is located at the border of Haiti and the DR and is the busiest thoroughfare between the two countries. Many Haitian earthquake victims were transported to this region for care

4.1 Barriers to Care

Earthquakes present several challenges because of a concentrated short episode of immense mechanical energy: 1. Extreme overload of medical facilities, 2. An extremely high proportion of musculoskeletal injuries, and 3. Suboptimal surgical conditions due to lack of equipment and infrastructure. Post-earthquake Haiti presented a multitude of additional challenges in providing medical care including lack of preexisting infrastructure, collapse of the national government and social services, and absence of referral centers [6]. Physicians, through narrative commentaries, further describe these challenges and barriers to care on their experiences in Haiti.

Peranteau et al. [7] provide a commentary illustrating the experiences of their mission in cooperation with the Haitian Ministry of Health, Partners in Health, and Zanmi Lasante to restore surgical services to the General Hospital at Port-au-Prince. Their surgical team was able to systematically manage functional orthopedic operating rooms (OR) through volunteer group coordination and clear triage and documentation. They were one of 7 nongovernmental-organization (NGO) teams recruited to administer surgical services to the hospital. Upon their arrival, the team observed devastating conditions with no running water, scant electricity, and a lack of medical equipment including ventilators and autoclaves. People were scattered in tents overrun by sepsis and gangrene with no system of patient identifiers or physical records indicating diagnosis, medications administered, or treatment plan. There was only a limited triage system with no central operation scheduling system for the 7 functional ORs. The lack of coordination among volunteer groups also created competition for scheduling operations.



Fig. 3. Dr. Vanderpool treated an earthquake victim in a makeshift clinic with multiple extremity injuries as well as facial burns

Peranteau and his team established 4 fully functional ORs within a week and assembled multidisciplinary teams with integrated Haitian medical personnel. After operations, patients often suffered from infection and sepsis making wound care and antibiotics critical needs for the situation. The team also worked to improve documentation through labeling dressings and assigning patients charts to prevent repetitive treatments with already limited resources. Additionally, they organized the physical layout of the facilities to create clearly labeled triage, preoperative, and postoperative tents. The volunteer surgical teams at the hospital worked together to create an OR scheduling system that allowed more experienced surgeons to triage while others provided patient care and completed cases. They also shared a

supply manager who came with a different institution, but helped manage a central supply depot. Patients' families were united, thus allowing them to play a role in pre- and post- operative wound care, hygiene, and nutrition. During a six-day period, the ORs performed more than 117 cases, majority orthopedic cases, and eased the hand off to Haitian staff who returned to the hospital [7].

Dr. Lorich and Dr. Helfet also assembled a humanitarian team with 6 orthopedic trauma surgeons, 1 general surgery trauma surgeon, 2 orthopedic anesthesiologists, 2 orthopedic OR nurses, and 1 trauma triage nurse practitioner. Their published description highlights the lack of operative and care resources, team safety, and security of both the team and their resources as major barriers to delivery of care. Their initial stock of supplies including external fixator equipment, battery-operated power equipment, fracture tools, and other orthopedic OR equipment were company donated. Despite logistical coordination with NGOs, they experienced their initial difficulty with several postponed landing times in Port-au-Prince. After seeing the General Hospital, the team decided to relocate to the community Hospital of Haiti where they found approximately 750-1000 patients, many with infected wounds, lying on the ground around the hospital. The hospital did have running water, electricity, and two functional ORs. However, they lacked functional anesthesia machines, equipment sterilizers, blood, and lab equipment. The team communicated their needs back to the United States and as a result, was sent another airplane with additional supplies. This set of equipment never made it to the hospital and was presumed to have been hijacked. Security was lacking at the hospital necessitating a member of the team to provide round-the-clock guarding of equipment, food, and belongings. The team operated 24 hours a day, mostly on long bone and ankle fractures, attempting to salvage, instead of amputate, necrotic and infected wounds. Three days after beginning to operate, families began to flock in to the hospital because they had heard there was a team trying to save limbs instead of going straight to amputation. The hospital was forced to implement lockdown procedures. The team then left that day due to increasing personal safety concerns and decreasing supplies. Jamaican soldiers escorted the team out of the hospital where they were able to hitch a ride on a pickup truck then commercial cargo plane to return to New York [8].

Within these narratives, we can see numerous barriers to delivering the necessary orthopedic surgical care. Firstly, the teams were not prepared for the magnitude of the disaster and the stark lack of infrastructure upon arrival. Peranteau et al. experienced challenges

in lack of coordination between volunteer organizations leading to duplication of care with already limited resources [7]. However, the team experienced success through communication with organizations and establishment of a critically needed triage and charting system allowing a more efficient allocation of resources. Lorich et al. [8] describes their unpreparedness for lack of Haitian governmental support and poor existing infrastructure, difficulties with logistic organization, lack of security, and the unsustainability of the effort due to a lack of replacement surgical team.

Table 1. Orthopedic procedures most commonly performed post-disaster

Orthopedic surgical procedures post-earthquake [1,2]
External fixation
<ul style="list-style-type: none"> • Femur • Tibia • Humerus
Internal fixation
Joint reduction
<ul style="list-style-type: none"> • Shoulder • Hip • Knee • Ankle
Spica cast
Amputation
<ul style="list-style-type: none"> • Above knee • Below knee • Foot • Above elbow • Hand

4.2 Lessons Learned

The lessons-learned compiled in this review can be divided in to several categories: training and minimum surgical standards, logistics and management, military support, and communication technology.

4.2.1 Training and minimum standards

Sonshine et al. [9] conducted interviews and surveys of orthopedic surgeons who volunteered in Haiti and identified ten recurrent themes. Two of the themes were: 1. Volunteers should have prior disaster experience and 2. Volunteers should have pre-disaster training. A minority of respondents in the survey reported disaster training, experience, or credentialing. However, in a comparison of difficulty of disaster equipment management in trained versus untrained volunteers only two categories showed a

significant difference. Those who were trained reported 19.5% and 16.5% less difficulty, respectively in transporting to treatment site ($p=0.0397$) and security during storage at site ($p=0.0473$). The other categories, plane unloading, security during transport, installing equipment, maintaining equipment, and managing distribution, did not show a significant difference in mean difficulty scores between trained and untrained individuals.

The American Academy of Orthopedic Surgeons (AAOS) has now developed a disaster preparedness platform in order to prepare members for future catastrophic events [9]. Herard and Boillot recommend again adhering to World Health Organization's (WHO) Foreign Medical Team (FMT) minimum standards for a guide on surgical team capabilities. Although they recommend training programs, they believe that nothing can replace previous disaster experience [10]. A project team was created by AAOS and Orthopedic Trauma Association (OTA) following the earthquake to provide guidelines on volunteer requirements, training, and credentialing [11].

Médecins sans Frontières (MSF), a major provider of orthopedic care in natural disaster settings, created and studied the imposing of a set of minimum standards on orthopedic surgery in austere environments. Their standards were:

1. Adequate infrastructure, including protection from the external environment and appropriate electricity and lighting.
2. Adequate water and sanitation provisions, waste management being a key priority.
3. Availability of all essential disposables, drugs, and equipment.
4. Strict adherence to hygiene requirements and universal precautions.
5. Mandatory use of sterile equipment for surgical and anesthesia procedures.
6. Capability for blood transfusion.
7. Adequate human resources in quantity and quality.

They also created a more extensive list of requirements for internal fixation procedures due to inherent risks and invasiveness of the procedure. These minimum standards were implemented at two locations post-earthquake, Cite Soleil and Chancerelles in Haiti. It was not possible to implement internal fixation criteria in either hospital due to structural requirements. Intraoperative mortality for orthopedic procedures was 1.9% and 0.6% in Cite Soleil and Chancerelles respectively. MSF concluded that good surgical outcomes indicated

by low intraoperative mortality rates can be achieved with implementation of the minimum standards and calls for implementation in LMIC disaster settings [5].

4.2.2 Logistics and management

Three of the ten recurrent themes in Sonshine's interviews include local contacts before arrival, resource self-sufficiency, and group organization. These are some themes echoed in previously mentioned papers, Peranteau et al. [7] and Lorich et al. [8] Both groups had logistical support through NGOs. However, Lorich cited many problems with coordinating transportation and preparing for the scene before arrival. They were surprised by having access to even fewer resources than they had anticipated and many more patients than they could handle. Herard and Boillot suggest adhering to WHO's FMT Working Group minimum standards for logistical and operational needs. WHO emphasizes providing safe and effective patient care through solid logistical support including waste, water, and power [10].

Group organization, 31 occurrences in 14 interviews, was the most mentioned topic in the interviews and a prime area for improvement in delivery of care [9]. One of the difficulties discussed was the competition with other volunteer groups for resources and OR time. In times with limited resources and hundreds of patients arriving for care, triage becomes an important step to care to minimize any preventable morbidity and mortality [3]. Steinman et al. [3] calls for a "shift in paradigm" during times of disaster from investing unlimited resources in to benefits of individual patients to spreading limited resources for care of the largest number of patients³. Triage allows patients with limb threatening injuries or infections to be treated as top priority. Triage tents should be positioned near the entrance of the complex allowing experienced surgeons to prioritize patient's needs. Documentation allows for clear communication on the triage status, other necessary information on patients, and prevention of duplication. The establishment of a central command and supply center is also important in mounting a surgical response to care [7]. A central command facilitates group organization and can aid in organizing OR booking systems in a setting with multiple volunteer groups. A supply manager can also play a critical role in providing the optimal allocation of resources among a variety of groups. Ethical considerations also play a strong role in patient care and spreading of resources. Bar-On et al mentioned considering ethical questions on priority of care and treatment policies. They had daily staff meetings to discuss and reassess current situations. An ethical

committee was also consulted to aid in difficult ethical decisions [6].

4.2.3 Military support

In disaster situations, the military plays a critical role. Sonshine identifies short-term military involvement as one of the most mentioned themes at 19 occurrences [9]. There were over 30 total ships that responded from the US Navy, Coast Guard, Maritime Administration, and Military Sealift Command [12]. The United States government cared for approximately 777 patients in Haiti through the *USNS Comfort* and *USS Bataan* [13]. The *USNS Comfort*, docked on January 20th for 7 weeks, is a hospital ship built with features equivalent to tertiary care centers in the United States [13]. Hospital ships have about a 1000 bed capacity, an ICU, a recovery ward, and 12 operating rooms. A smaller casualty receiving and treatment ship (CRTS), *USS Bataan*, with medical and surgical capabilities was also deployed from January 18th through February 12th. These ships were positioned offshore and functioned to augment established medical care. Patients in need of advanced surgical care were transported aboard and cared for by the military medical crew. The majority of patients required orthopedic procedures including internal and external fixations. On deployment, the *USNS Comfort* only had one orthopedic surgeon leading to need for cooperation with other organizations including AAOS and OTA to obtain more personnel [11,12]. The *USNS Comfort* also did not carry sufficient orthopedic equipment to meet the needs of the situation. Many of the limitations of military hospital ships come because of their intended usage in battle-inflicted trauma [13]. The hospital ships were originally built and staffed to care for patients 18-53 years' old. There is a critical need to adapt these hospital ships to civilian populations for disaster response through creating guidelines on specialties needed, caring for pediatric and elderly populations, and obtaining optimal equipment and resources. They were also limited by the ability to bring patients aboard the ship.

In addition to hospital ships, the US Department of Defense (DOD) and Health and Human Services (HHS) deployed civilian disaster medical assistance teams (DMAT) and International Medical-Surgical Response Teams (IMSuRTs) to aid on the ground. Volunteer surgical teams were able to work with the US Army to triage and evacuate patients on the *USNS Comfort*. Peranteau describes working in conjunction with US Army physicians to create evacuation plans for critically injured patients.

The US military was also able to work with an Israeli field hospital established by the Israel Defense Forces

(IDF) mounting a rapid medical response to the earthquake [6]. The IDF hospital consisted of 121 IDF servicemen/women and 7 divisions, including orthopedics, and was able to admit their first patient within 4 days of arriving in country [6]. Some lessons from the Israeli response include the benefits to security, a challenge affecting previously mentioned groups, and airlift capacity [11]. They were also able to transport advanced surgical patients on to the *USNS Comfort* through cooperation with the US government.

4.2.4 Communication technology

Given the rapid rate of technological advancement, there is a great potential for growth and improvement regarding its application to disaster response. Two studies evaluated technology in Haiti. Finestone, Levy, and Bar-Dayana examined telecommunications used in the Israeli Defense field hospital. Their field hospitals strive to practice 6 principles of telecommunication:

1. The use of a wide variety of telecommunication modalities that could provide backup to each other.
2. Independence from the local infrastructure.
3. Use of a wide spectrum of radio frequencies.
4. Communications that make use of the mass media.
5. Direct interpersonal communication.
6. Use of computerized pictures for managing and identifying patients.

The team used the AMOS-3 satellite to communicate back to Israel. Additionally, they had access to phone, fax, internet, email, and video conference. Many of those methods were available for classified and regular use. Within the camp, they used walkie-talkies, a loud speaker system, and a wire telephone system. Cameras also proved to be a valuable resource for patient identification and reconnection with families. A lesson learned from studying communication during the response is the need for better long distance communication. The walkie-talkies did not work off base, making it difficult for teams who left the base to communicate [14].

Callaway et al. [15] studied an implementation of mobile health (mHealth) technology in improving disaster health care. As mentioned in previous sections, documentation and communication among the medical team is critical to resource management. mHealth technology was developed as an iPhone platform for patient charting and implemented at the FDP Disaster Rescue Camp. A satellite antenna was set up creating a wireless network allowing the use of

mHealth technology. The application iChart version 1.39 was adapted for use with or without internet connectivity for volunteers with iPhones. They initially began using the app in triage, but by the third week of implementation, it was the main census of the hospital. Prior to the app, the patient tracking system consisted of handwritten lists or writing on bandages. Of the injuries documented in iChart, 64% were orthopedic in nature. The physicians were able to use the app to facilitate triage, patient handoffs pre and post operation and patient tracking. There is currently no suitable and cost-effective mobile technology developed for disaster situations. Disaster software is currently limited by cost, connectivity requirements, or facility. This is an area that has shown promising results on implication, but will require further development and research.

5. CONCLUSIONS

Assessing delivery of care and disaster response is imperative in improving our response in the next disaster. Disasters are unpredictable and unavoidable; thus, now is the time to prepare and create guidelines for delivering care. Identifying problems and lessons in orthopedic surgical care now will allow us to implement solutions and plans for the next impending disaster response situation.

CONSENT

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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