Infection Control in Field Hospitals after a Natural Disaster: Lessons Learned after the 2010 Earthquake in Haiti

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After the January 12, 2010, earthquake in Haiti, Project Medishare and the University of Miami organized, built, and staffed a 200-bed field hospital (the University of Miami Hospital in Haiti [UMHH]) on the outskirts of Port-au-Prince. We describe the operational challenges of providing a safe environment at the UMHH. Furthermore, we compared how these issues were addressed at this ad hoc hospital with how they were addressed at the field hospital of the Israel Defense Force, a fully deployable hospital with an organization fine-tuned as a result of prior disaster situations, also in Haiti.

In January 12, 2010, a series of earthquakes struck Haiti around the capital city of Port-au-Prince, with the strongest tremor reported at 7 on the Richter scale. It was estimated that 220,000 persons died, more than 300,000 were wounded, and more than half a million lost their homes.1

Haiti is considered to be the poorest country in the Western Hemisphere.2 Before the earthquake, less than half of the 9.7 million Haitian population had clean water, and 83% did not have access to adequate sanitation facilities. The damage and loss of life had a catastrophic impact on the function of the government, healthcare facilities, and rudimentary utilities in Haiti.2

Within a week of the earthquake, Project Medishare (a nongovernmental organization active in Port-au-Prince before the earthquake) and the University of Miami organized and erected a 200-bed field hospital (the University of Miami Hospital in Haiti [UMHH]), on the grounds of the Port-au-Prince airport. The UMHH replaced the provisional hospital that was erected immediately after the earthquake and that was recently described elsewhere.3 All healthcare workers were volunteer personnel who faced diverse infectious diseases–related issues, including the management of wounds from initial trauma, the diagnosis of infectious diseases without laboratory resources, and the development of strategies for the early control and prevention of the spread of infectious diseases in a poor sanitary environment.3

Our aim is to discuss the infection control challenges encountered at the UMHH, specifically during the first couple of weeks of its operation. Furthermore, we felt that it would be valuable to compare how these issues were addressed at this ad hoc hospital with how they were addressed at the field hospital of the Israel Defense Force (IDF), a fully deployable hospital (hereafter referred to as the IDF field hospital) with an organization fine-tuned as a result of prior disaster situations.

Field hospitals in Haiti varied in size and design. Some of them consisted of a series of small tents, each one providing a specific type of care. Others were either structured as large tents or organized within buildings that previously functioned as hospitals, churches, or schools. Air-conditioning units constituted luxury items to which only a few had access. In addition, the lack of running water was a common problem in most of these makeshift healthcare centers.

The UMHH consisted of 4 large tents: 2 tents were patient-care wards, 1 tent served as lodging for healthcare workers, and 1 tent included an operating room, a temporary morgue, and a小伙子 ward. The IDF field hospital included 2 tents—1 for patients and 1 for administrative purposes—plus another 6 tents for additional patient care.

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and the fourth tent was for the storage of supplies. All but the latter were air-conditioned. The tents were made of waterproof, UV-light–resistant white material, and their wooden floors were elevated inches above the grass to prevent flooding (Figure 1A).

The operating rooms, recovery area, and critical-care unit were located at the end of one of the patient-care tents (ie, the surgical ward). The second patient-care tent had an open pediatric and general medical ward. This design allowed for faster patient care; nevertheless, limitation of space was a common problem. Inside the UMHH, patient beds were distributed in 4 rows, 2 on each side of a main corridor (Figure 2A); this design allowed people to transit through the tent. To prevent horizontal transmission of bacteria between patients, we aimed to distance patients at least 3 ft (91.44 cm) from each other; however, the high demand for beds made overcrowding unavoidable.

A wound-care station was located outside a patient-care tent adjacent to the triage area. The wounds of ambulatory patients were cared for at this station. The hospitalized patients requiring wound care were treated at their bedside or at a wound-care station within the patient-care tent.

The IDF relief contingent consisted of 121 medical personnel who were responsible for setting up and staffing a 72-bed field hospital. They were accompanied by a 109-member support and rescue team. Infection control was overseen by a dedicated 3-person team led by the head of the IDF Army Health Branch, a physician and epidemiologist with experience in a field hospital that was deployed after an earthquake in India.

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**Figure 1.** Aerial views of (A) the University of Miami Hospital in Haiti (photograph courtesy of the University of Miami, Miller School of Medicine) and (B) the Israel Defense Force field hospital (reprinted with permission from the *Annals of Internal Medicine*), which were built after the January 12, 2010, earthquake. GYN, gynecology; ICU, intensive care unit; OB, obstetrics; OR, operating room.
The IDF field hospital was deployed on a soccer field in a series of 16-bed (maximum capacity), regular army tents made of heavy canvas, with each tent devoted to a specific type of medical care (Figure 1B).5 There was no air-conditioning or flooring. The pediatric section comprised 2 adjacent tents (emergency and hospitalization wards). The adult emergency ward consisted of 2 tents laced together. The internal medicine ward and outpatient clinics each occupied 1 tent. There were also designated tents for the operating theater, the 4-bed intensive care unit, the recovery ward, and the orthopedic service. Only the operating theater had a floor, which was made of an airline cargo pallet.

Three small connected tents housed the obstetrics and gynecology service, including the labor ward. Two smaller tents were used for imaging and laboratory purposes (microbiology, hematology, and biochemistry). Two additional tents were used as pharmacy and general storage. The complete hospital was set up within hours; patients arrived less than 5 hours after the first tent was pitched. Initially, the staff slept outside, ate cold rations, and had no access to showers. Nevertheless, bottled drinking water was unlimited.

**Operating Rooms**

At the UMHH, 4 operating rooms were located in the same area without physical separation between them. The wooden floor was covered with plastic, and kitchen tables were used as surgical tables.

Surgical hand disinfection was performed by use of 80% ethyl alcohol (Sterillium; Medline Industries). Small tabletop sterilizers were used for sterilization of instruments. High-level disinfection was performed initially with bleach; this was later switched to either 0.55% ortho-phthalaldehyde (Cidex OPA; Johnson & Johnson) or 2% hydrogen peroxide (Resert XL; Virox Technologies), depending on daily availability. A chlorine dioxide–based electrostatic spraying system (ByoGlobe Technologies) was used for environmental disinfection within the UMHH’s operating rooms.

At the IDF field hospital, the operating room was located within a partially enclosed, air-conditioned tent. Reusable surgical instruments were manually cleaned, then soaked in disinfectant, and subsequently sterilized by use of a steam autoclave.

**Toilet Facilities**

The localization, distribution, and hygiene of toilets constituted a major problem. During the first days after the UMHH was erected, no toilets were available for healthcare workers, patients, or family members of patients.

Later on, 17 portable toilets were shipped from Miami, Florida, to the UMHH. Arrangements were made with the United Nations to have them pumped out once a day. Locally hired Haitian personnel were responsible for daily cleaning. Once they were available, toilets were allocated to healthcare workers, patients, and family members of patients. Plastic bedpans were removed and emptied into large metal bins by the family members of patients.

The Israeli team was able to rent 9 chemical toilets. These were emptied once or twice daily by a waste truck with a suction system. The location of these toilet facilities was carefully planned: patient and family member latrines were located near the hospital entrance, accessible not only to patients but also to families and to those awaiting admission,
and clearly separated from staff facilities. In case of overflow or leakage, the runoff was directed to the outside of the hospital compound. Staff toilets were placed at the other end of the grass field, with 1 cubicle dedicated to those with diarrhea, to facilitate isolating and monitoring affected staff members. See Table 1 for recommendations regarding toilets.

**ISOLATION TENTS**

Before the earthquake, tuberculosis was the seventh most common cause of death in Haiti, accounting for 4.7% of deaths among young adults. Therefore, in the UMHH, 4 small tents were erected near the main patient-care tents. These “isolation tents” were each allocated to 1 patient. Healthcare workers and the family members of these isolated patients were instructed to wear N95 respirators while inside the tents. Any patient with signs or symptoms suggestive of a contagious disease (such as tuberculosis, meningitis, or typhoid fever) was placed in one of these isolation tents at admission to the UMHH. Arrangements were subsequently made for patients with suspicion of tuberculosis to be transferred to a functioning hospital in the Port-au-Prince area that specialized in tuberculosis.

The average length of stay at the IDF field hospital was short and, therefore, precluded screening for tuberculosis. As a result, there were no separate isolation facilities in the IDF field hospital.

**FAMILY MEMBERS OF PATIENTS**

In both field hospitals, patients were accompanied by a family member throughout their hospitalization. At the UMHH, the initial plan was to allow 1 adult family member to stay with the patient; however, the overcrowding of families around patients’ beds was a common occurrence. In comparison, at the IDF field hospital, both visitors and patients were required to wear identification stickers at all times, and only 1 relative per patient was allowed inside the facility.

Nevertheless, family members played an important role in keeping the tents clean at the UMHH. Each patient’s family was responsible for feeding and bathing the patient, cleaning his or her cot, and disposing of his or her waste. Family mem-

<table>
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<tr>
<th>Issue</th>
<th>Recommendations</th>
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<tr>
<td>Design of field hospitals</td>
<td>Consider accessibility, security, and safety (eg, secondary events like aftershocks and tsunamis). Avoid possibility of cross-contamination, overcrowding, and poor aeration when distributing medical wards. Organize beds to facilitate daily census. A minimum distance of 3 ft between patient beds should be implemented. Provide identification for both patients and family members.</td>
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<tr>
<td>Toilets</td>
<td>Locate latrines and/or toilets away from patient-care areas. Determine quantity of toilets according to staff and patient volume. Provide separate cubicles for patients with diarrhea. Plan for cleaning and disinfection of toilets on a regular basis.</td>
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<tr>
<td>Pest control</td>
<td>Global precautions for avoidance of mosquitoes should include DEET-containing repellent, mosquito nets, elimination of uncovered water reservoirs, and fly traps. Warfarin-based bait should be used for rodent control. All facilities should be fumigated daily with a chlorine-and-quaternary-ammonium–based solution. Contract local fumigation services, if available.</td>
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<tr>
<td>Human waste</td>
<td>Large plastic or metal bins should be used for waste disposal. Biohazard bags should be used to collect body parts and fluids. Plan for disposal of all bodies and body parts according to local circumstances (ie, allocate a holding area). Secure location away from patient-care area for waste, pending removal or incineration. Arrange for final disposition of human waste via incineration or pickup by local agencies.</td>
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<tr>
<td>Water, food, and general supplies</td>
<td>Provide adequate supplies of bottled water. Alcohol-based hand sanitizers for hand hygiene should be widely distributed throughout the facility. Use chlorinated nonpotable water (eg, for showering and cleaning). Provide nonperishable meals if refrigeration is not available. Supplies and food should be separate from contaminated areas (eg, toilets and waste disposal areas), and protection from flooding should be taken into account.</td>
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<tr>
<td>HCW safety</td>
<td>Predeployment health checkups should be administered to update vaccinations and give counseling specific to the area of travel. Consider following the recommendations given by the CDC (<a href="http://www.cdc.gov">http://www.cdc.gov</a>) and/or the WHO (<a href="http://www.who.int">http://www.who.int</a>). Measures for prevention of mosquito bites should be instituted. Rapid HIV tests and postexposure prophylaxis should be readily available because HCWs are at risk of occupational exposure to infection. HBV and HCV testing should be performed on site or after deployment. Containers for needles and other sharp medical devices, gloves, and disposable gowns for procedures should be provided. Work shifts should be scheduled to avoid fatigue and fatigue-related accidents.</td>
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**Note:** CDC, Centers for Disease Control and Prevention; DEET, N,N-diethyl-meta-toluamide; HBV, hepatitis B virus; HCV, hepatitis C virus; HCW, healthcare worker; HIV, human immunodeficiency virus; WHO, World Health Organization.
bers were frequently observed helping neighboring patients with meals, sharing bottled water, and disposing of waste.

Preventing Diseases by Vaccinating Patients

In Haiti, tetanus is still a major public health problem.2 In 2008, only 53% of the Haitian population was vaccinated against diphtheria, pertussis, or tetanus.2 Shortly after the earthquake, 4 cases of tetanus were diagnosed among young Haitians with relatively small and superficial wounds who had been transferred to the UMHH from other first-aid stations around Port-au-Prince. Tetanus toxoid vaccine was administered to all UMHH patients.

In the IDF field hospital, only those patients with tetanus-prone wounds received the tetanus toxoid vaccine. Initial doses of the tetanus and diphtheria vaccine were brought from Israel and the United States. Additional doses were obtained from the World Health Organization depot at Port-au-Prince. Sporadic cases of chicken pox were also diagnosed at both field hospitals.

Pest Control

Malaria, dengue, and lymphatic filariasis are all endemic in Haiti. The highest incidences of these mosquito-related infections are reported during the rainy seasons: from March through May and from October through November.2 At the UMHH, malaria and dengue were suspected on the basis of clinical presentation. Thick blood smears were available at the IDF field hospital. The interventions that were instituted to limit mosquito exposures included personal protection with the use of repellents containing N,N-diethyl-meta-tol-uamide (DEET), mosquito nets, and the elimination of open-water reservoirs at both field hospitals. The patient tents at the UMHH were air-conditioned and thus theoretically sealed, which helped to reduce the numbers of mosquitoes inside the tents.

The Israeli delegation provided their staff with zip-up tents fitted with rudimentary netting. All facilities at the IDF field hospital were sprayed 3 times daily with a chlorine-and-ternary-ammonium–based solution, and fly traps were set up around the facility. Signs of rodents were noted soon after setup. Warfarin-based bait was spread around the camp on several occasions.

Water and Human Waste Disposal

After the earthquake, piped water from municipal sources was not available. Furthermore, water reservoirs were not safe because both human and animal waste was constantly contaminating the water. At both the UMHH and the IDF field hospital, bottled water purchased abroad was provided to both healthcare workers and patients for drinking purposes. At the UMHH, hand disinfection was accomplished with the use of an alcohol-based hand sanitizer (62% ethyl alcohol; Purell). These containers of alcohol-based hand sanitizer were placed in different areas in patient-care tents (Figure 2B). Patients, patients’ family members, nonmedical volunteers, and medical personnel were instructed to use hand sanitizer before and after patient care, before food preparation, and after the use of toilets. The Israeli delegation brought a limited quantity of 70% isopropyl alcohol and 0.5% chlorhexidine gluconate (Septol; Teva Medical) hand-sanitizing fluid. These bottles were distributed to all patient-care areas. When supplies of this particular hand-sanitizing fluid were exhausted, they were replaced with commercially available, 40% ethyl alcohol-gel–based hand sanitizers (Alco-gel; Fischer Pharmaceuticals), which were less easy to use and less accepted by the staff. Water containers and soap were placed outside each tent and at the entry to the food area; however, these water containers required constant refilling.

Water for showering was initially unavailable, which forced some personnel to use bottled water. Within 21 weeks after the earthquake, the airport fire department began to pump nonpotable water (approximately 1,000 gal [3,785 L]) every night into large water tanks for showering at the UMHH. Pipes were installed connecting the water tanks to the shower system. To reduce bacterial counts, 5 mL of chlorine was added per gallon of water. After the Port-au-Prince water system was functional again, the UMHH’s water tanks were connected to the city pipes. At the IDF field hospital, a shower system was assembled on the fourth day of operations. Water originating from deep wells was provided by tanker trucks, placed in tanks approximately 1 m from the ground and subsequently chlorinated. Drainage of the shower system was built to the side of the field.

Body parts, body fluids, and contaminated medical equipment were placed in biohazard bags and were kept on the grounds of the UMHH. A large accumulation of bags occurred within the first week of operations. However, by the end of the second week, regular scheduled pickups and off-site incineration were arranged by the United Nations.

At the IDF field hospital, waste was collected in 2 locations on the hospital perimeter, allowing adequate distancing from the kitchen and from the hospital while facilitating collection. Biological waste was placed in biohazard bags (when available) and was concentrated in 1 specific location. Waste was removed once or twice daily to a closed facility, thereby deterring the local population from searching through the waste and being exposed to infections. Nonmedical garbage was gathered in a separate area and was removed to a second facility for disposal. Bodies and body parts were treated with special dignity, in accordance with Jewish tradition. Volunteers from the religious organization ZAKA (abbreviation for zihuy korbanot ason, which literally means “disaster victim identification” in Hebrew) were attached to the Israeli delegation. They were responsible for the disposal of all bodies and body parts, which were originally concentrated in a ded-
icated area of the hospital grounds, before eventually being transferred to a local cemetery or to a United Nations facility.

**FOOD AND GENERAL SUPPLIES**

One of the differences between the IDF field hospital and the UMHH was the way in which supplies and food were initially obtained. At the UMHH, supplies consisted of large amounts of random donations from all over the world. In contrast, the IDF field hospital obtained supplies from the Israeli government on the basis of the perceived needs of the Haitian population. All supplies at the UMHH were stored in an open tent within a few yards of the patient-care tents. Food and water were stored with medical supplies. Because of the lack of refrigeration, only nonperishable meals were available. Pallets were placed on the ground to support all the supplies and to avoid direct contact of the food and supplies with soil and rainwater.7

Because of severe weight limitations on the cargo aircraft and prioritization of supplies, only limited amounts of food arrived with the Israeli team. The delegation immediately started procuring supplies both locally and from the Dominican Republic, with the assistance of the Israeli Foreign Ministry and others. The kitchen was the only facility located in a permanent building, allowing adequate conditions for food storage, including refrigeration. Centrally prepared food was gradually provided by professional Israeli kitchen staff, under the continual supervision of the infection control team. Because of concerns about hygiene, cooked food was available but limited in quantity. There were also limitations on the type of food that could be prepared; for example, only vegetables that could be properly disinfected were permitted. All meals were served on disposable plates. In the last few days of the IDF field hospital, meals containing meat were provided for individual heating in microwave ovens.

**INFLUX OF PATIENTS TO INTERNATIONAL HOSPITALS**

A few hundred Haitian patients were airlifted to South Florida hospitals from both field hospitals within the first month after the earthquake. On admission to these hospitals, patients were screened for pulmonary tuberculosis by using chronic cough as a marker. If cough was present for more than 2 weeks, airborne isolation precautions were instituted. Patients were also screened for diarrhea, and if present, contact precautions were instituted. Jackson Memorial Hospital, a 1,500-bed teaching hospital affiliated with the University of Miami, Miller School of Medicine, received the highest percentage of Haitian transfer patients. All patients were screened for drug-resistant gram-negative bacteria on hospital admission by use of rectal swab cultures. These cultures showed a high prevalence of cephalosporin-resistant gram-negative bacteria starting from the first week after the earthquake. On the basis of this information, all additional transfer patients were placed under contact precautions on hospital admission until they tested negative.

**CONCLUSIONS**

Immediately after the January 12, 2010, earthquake that struck Port-au-Prince, Haiti, multiple teams from around the world responded to provide medical assistance to the thousands of injured Haitians. Among these teams, there were 2 organizations quite different in structure and composition, although united in the goal of providing emergency surgical services to the injured: the IDF emergency response hospital and the field hospital (ie, the UMHH) of Project Medishare, an affiliate of the University of Miami, Miller School of Medicine. The IDF field hospital was a unit designed for emergency relief, with a well-defined organization and structure but no prior experience in Haiti. The Project Medishare core team had been operating clinics in central Haiti and had connections in Port-au-Prince, but this team had never managed a large trauma hospital. Supported by the University of Miami, Miller School of Medicine, the Project Medishare team virtually created their hospital from scratch within days of the earthquake. It enjoyed relative proximity to its supply base in Miami, Florida, and received a relatively plentiful amount of supplies from many donors. Nevertheless, the UMHH lacked the IDF field hospital’s organization, and it was staffed entirely by short-term volunteers with limited experience in the work of a field hospital. Multiple infection control issues were encountered, especially during the first weeks of operation. These challenges are likely common to those encountered by emergency field hospitals following any disaster, and the experiences are worth sharing. Here we have described snapshots of the issues faced at both field hospitals and how the staff coped with these issues to provide safe environments in very difficult situations. Infection control problems included issues related to the placement of patients, the design of operating rooms, food and water supplies, waste disposal, toilets, and pest control before and during deployment. In Table 1, we provide a summary of our general recommendations concerning infection control issues, and these recommendations are based largely on our experience and might serve, in the event of future natural disasters, as a general guide to those working in field hospitals.

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