

Practicing Internal Medicine Onboard the USNS *COMFORT* in the Aftermath of the Haitian Earthquake

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On 12 January 2010, a 7.0-magnitude earthquake devastated the island nation of Haiti, leading to the world's largest humanitarian effort in over 6 decades. The catastrophe caused massive destruction of homes and buildings and overwhelmed the Haitian health care system. The United States responded immediately with a massive relief effort, sending U.S. military forces and civilian volunteers to Haiti's aid and providing a tertiary care medical center aboard the USNS *COMFORT* hospital ship. The *COMFORT* offered sophisticated medical care to a geographically isolated population and helped to transfer resource-intensive patients from other treatment facilities. Working collaboratively with the surgical staff, ancillary

services, and nursing staff, internists aboard the *COMFORT* were integral to supporting the mission of the hospital ship and provided high-level care to the casualties. This article provides the perspective of the U.S. Navy internists who participated in the initial response to the Haitian earthquake disaster onboard the *COMFORT*.

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The earthquake in Haiti on 12 January 2010 created a tremendous medical disaster with near-total destruction of the Haitian health care system. More than 200 000 Haitians died, many of whom were crushed in unreinforced buildings. Survivors sustained severe trauma but had little access to tertiary care. Unlike the case in other recent disasters, such as earthquakes in Kashmir in 2005 and in Bam, Iran, in 2003, in-country land-based medical evacuations were rare. Whereas drowning and water-related injuries were the primary cause of immediate death in the 2004 Indonesian tsunami, initial injuries in Haiti were primarily low-velocity, high-force trauma and wound infections. These injuries created an opportunity for life-saving tertiary care. This article describes the experiences and challenges we faced as internists responding to the Haitian earthquake onboard the U.S. Navy hospital ship, the *COMFORT*.

U.S. RESPONSE: DEPLOYMENT OF THE USNS *COMFORT*

The U.S. government's robust response to the Haitian earthquake included both military and civilian government agencies (such as the U.S. Agency for International Development), in cooperation with nongovernmental organizations (NGOs) (for example, Project HOPE and the American Red Cross). The U.S. Navy is playing a vital role in the mission, termed Operation Unified Response. The USNS *COMFORT* (T-AH 20) was deployed from Baltimore, Maryland, on 15 January 2010 and started accepting casualties within 7 days of the earthquake. The *COMFORT* is a deployable hospital ship that has capabilities similar to those of U.S. tertiary care centers, with up to 1000 beds, including 75 intensive care unit (ICU) beds (Table). Ancillary services available onboard include a blood bank, hemodialysis, laboratory (chemistry, hematology,

and microbiology), pathology, morgue, physical therapy, and radiology (general, 64-slice computed tomography, and ultrasonography). The ship quickly brought tertiary care en masse to Haiti.

Most of the *COMFORT*'s 1000-plus physicians and staff are active-duty U.S. Navy personnel, augmented by physicians from other armed services and volunteers from Project Hope (Table). Once activated by order of the U.S. President, the ship was boarded with only 36 hours' notice. Staff were ordered to stay for up to 6 months. Special staff medical training is not required for *COMFORT* personnel because it functions similarly to a land-based hospital (Figures 1 and 2).

Upon the ship's arrival in Haiti, critically ill patients were transported to the *COMFORT* via U.S. helicopters. The initial influx of Haitian patients was largely referred for treatment of severe trauma. The mission concentrated on providing surgical or medical care beyond the capabilities of field hospitals, unburdening these facilities of resource-intensive patients. Many patients had more than 1 long-bone fracture, open femur fractures, pelvic fractures, gangrene, skull fractures, or spinal fractures. Appropriate patients were identified in advance by U.S. Navy triage officers, in communication with the Haitian Ministry of Health, NGOs, and U.S. military field medical facilities set up within days of the earthquake. The *COMFORT* was anchored in the harbor of Port-au-Prince but could not dock because of earthquake damage to the pier. Within 72 hours after arrival, the *COMFORT* accepted approximately 254 pa-

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Table. Physician/Staff Specialties Onboard the USNS *COMFORT* During Operation Unified Response*

Medical Staff	Surgical Specialties	Pediatrics	Miscellaneous
General internal medicine: 2	General: 2	General: 4	Anesthesia: 11
Cardiology: 1	Otolaryngology: 1	Cardiology: 1	Certified registered nurse anesthetist: 13
Critical care: 3	Neurosurgery: 2	Critical care: 2	General medicine: 2
Gastroenterology: 1	Obstetrics/gynecology: 2	Developmental: 1	Dentistry: 3
Infectious disease: 1	Oral/maxillofacial: 1	Endocrine: 1	Dermatology: 1
Nephrology: 2	Ophthalmology: 2	Emergency medicine: 1	Emergency medicine: 2
Neurology: 1	Orthopedic: 12	Infectious disease: 1	Family practice: 4
	Pediatric: 1	Neurology: 1	Nursing: 165
			Medical/surgical, ED, ICU, postanesthesia care unit, pediatrics, PICU/NICU, wound care
	Plastics: 1	Advance practice nursing: 3	Optometry: 2
	Urology: 2		Psychiatry: 1
	Vascular: 1		Psychology: 1
	Wound care: 1		Social work: 2

ED = emergency department; ICU = intensive care unit; NICU = neonatal intensive care unit; PICU = pediatric intensive care unit.

* Numbers represent peak staffing levels, including volunteers.

tients; the census then ballooned to more than 430 patients (Figure 3). Most were young adults (20 to 30 years of age), reflecting the demographic characteristics of the Haitian population. Approximately one third of patients admitted were children. This large influx of patients into a hospital that had “opened” 5 days earlier created exceptional challenges with communication, processes of care, and resource utilization.

INTERNAL MEDICINE CHALLENGES DURING THE INITIAL PHASE OF THE HAITIAN DISASTER RESPONSE

Internists on the *COMFORT* functioned as ward physicians for both surgical and medical patients. Six internists provided 24-hour coverage for more than 350 patients, allowing surgical staff to focus on needed emergency surgery.

Patients were triaged in the ship’s casualty receiving area upon arrival, registered, and given a unique patient identification number. The *COMFORT* used a paper-based medical record, with computerized laboratory and radiology reports. The initial flood of patients sometimes delayed even urgent surgery. Constant communication between internal medicine and surgical staffs was required for initial triage and retriage as the census swelled. Tracking patients’ requirements for radiographic studies, initial surgery, reexploration and washout, wound care, and discharge required a team approach among surgeons, internists, nurses, wound care specialists, and discharge planners.

Most patients arrived with no known medical history. The number of patients presenting during the initial flow precluded a comprehensive evaluation of all patients. Many patients were dehydrated and malnourished and had life- and limb-threatening injuries that required emergent operative care. Initial laboratory evaluation was limited to selected patients with severe illness. Once patients were stabilized, directed laboratory evaluation showed striking

abnormalities. A majority of patients had severe anemia. Hemoglobin values under 70 g/L were common. Hypoalbuminemia with albumin levels less than 20 g/L was routine. Severe electrolyte disorders were frequent, particularly serum potassium levels less than 2 mmol/L and greater than 7 mmol/L and sodium levels less than 130 mmol/L.

Haiti’s limited health care infrastructure complicated discharge plans. Dedicated discharge planners sought local medical facilities willing to accept stable postsurgical patients in Haiti for convalescence, wound care, and rehabilitation. These included local Haitian facilities outside the earthquake’s damage zone, as well as NGO and U.S. armed forces land-based field clinics. Few complicated patients (those with tetraplegia, paraplegia, or extensive burns) were sent by medical evacuation to the United States, with

Figure 1. Internal medicine staff of the USNS *COMFORT*.

Back row (left to right): Todd Gleeson, MD, MPH; Dolores Rhodes, MD; Chris Lewis, MD; Greg Dadekian, MD; Edward Miller, MD, PhD; Michael Monsour, MD; Thomas Hicks, MD; Dennis Amundson, DO, MS. Front row (left to right): Mill Etienne, MD, MPH; Kristina Kratovil, MD; Bret Pasiuk, MD. Not pictured: Dermot Killian, MBBS.

anticipation of their return to Haiti after treatment. The requirement of helicopter or boat transportation of patients to or from land further complicated discharges.

Intensive Care

The *COMFORT*'s ICUs are open-bay design, with state-of-the-art monitoring and mechanical ventilation capabilities. The adult, pediatric, and neonatal ICUs were initially located in the same area, but a dedicated pediatric/neonatal ICU area was formed after an unexpected number of children and infants were admitted. Frequently, dozens of patients were undergoing mechanical ventilation. The open-bay design made infection control very difficult. The main ICU quickly exceeded its 30-bed capacity (Figure 3), prompting the opening of overflow units. The patient census complicated ICU staffing (nurse-to-patient ratios approached 7 to 1) and led to rapid consumption of supplies.

The initial scope of ICU illness reflected the severe orthopedic and crush injuries created by the disaster. Severe acute renal failure (creatinine levels approaching 1768 $\mu\text{mol/L}$ [20 mg/dL]), hyperkalemia (potassium levels >8 mmol/L), and severe anemia (the lowest recorded hemoglobin value was 240 g/L in a hemodynamically stable patient) were not uncommon.

Infectious Diseases

The range and severity of infections demanded rapid responses. Extremity wounds had visible gas production by *Clostridia* species. Wounds were frequently infested with worms, insect larvae, and maggots. Patients presented with the "inexcusable disease" of tetanus, reinforcing the need for a national vaccine program for Haiti. Polymicrobial-infected wounds, bacteremia, cerebral malaria, typhoid, and bacterial and fungal meningitis necessitated large supplies of antibiotics, rapidly exhausting on-hand stores. Infection control challenges were ever-present: Screening all patients for tuberculosis is essential when patients are brought into a closed-ward, limited-ventilation ship, yet the initial rush of casualties strained the radiographic screening program. Some patients with potential tuberculosis according to chest radiography had immediate surgical needs, causing difficult risk–benefit decision analyses. Multidrug-resistant *Acinetobacter* infection appeared quickly. The presumed index patient presented from shore with meningitis. *Acinetobacter* precautions required insertion of strict infection control practices into the chaos of disaster medicine. Finally, the prevalence of HIV in the patient population affected practice by altering differential diagnoses, challenging staff to ensure follow-up care, and providing immediate care to staff members exposed to potentially infected body fluids.

Nephrology

Nephrology services were initially challenged by the rapid influx of crush injuries with renal failure, stretching dialysis capabilities and prompting a dialyzer reuse program. Until we received new filters, we cleaned designated dialysis filters between treatments and reused them for each patient. We prioritized dialysis for patients with oliguric renal

failure and stabilized hyperkalemia in the remainder of the patients by using bicarbonate-based intravenous fluids, kayexalate, calcium chloride, insulin, and glucose. Limited supplies of dual-lumen dialysis catheters required that 2 separate central venous sheaths be used for inflow and outflow, respectively. Hyperkalemia was by far the most common indication for dialysis initiation, but the ship also admitted 1 patient with end-stage renal disease that had been present before the earthquake. Placement of this patient in the now-destroyed Haitian civilian dialysis system remains problematic.

Cardiology

Initial cardiac evaluations involved noninvasive hemodynamic assessment of circulatory physiology by bedside echocardiography in the ICU. Multiple cases of cardiomyopathy were diagnosed, presumably from acute stress response; underlying severe anemia or nutritional deficiencies; or preexisting conditions, such as hypertension. Postoperative myocardial infarction was rare but did occur. Decompensated heart failure was routinely diagnosed and treated. Many patients had electrocardiographic changes and arrhythmias from electrolyte abnormalities. Presumed HIV cardiomyopathy was not uncommon; pericardial effusions were also seen, some requiring right-heart catheterization for hemodynamic evaluation. As the mission progressed, evaluation for coronary artery disease, including acute coronary syndromes, became routine.

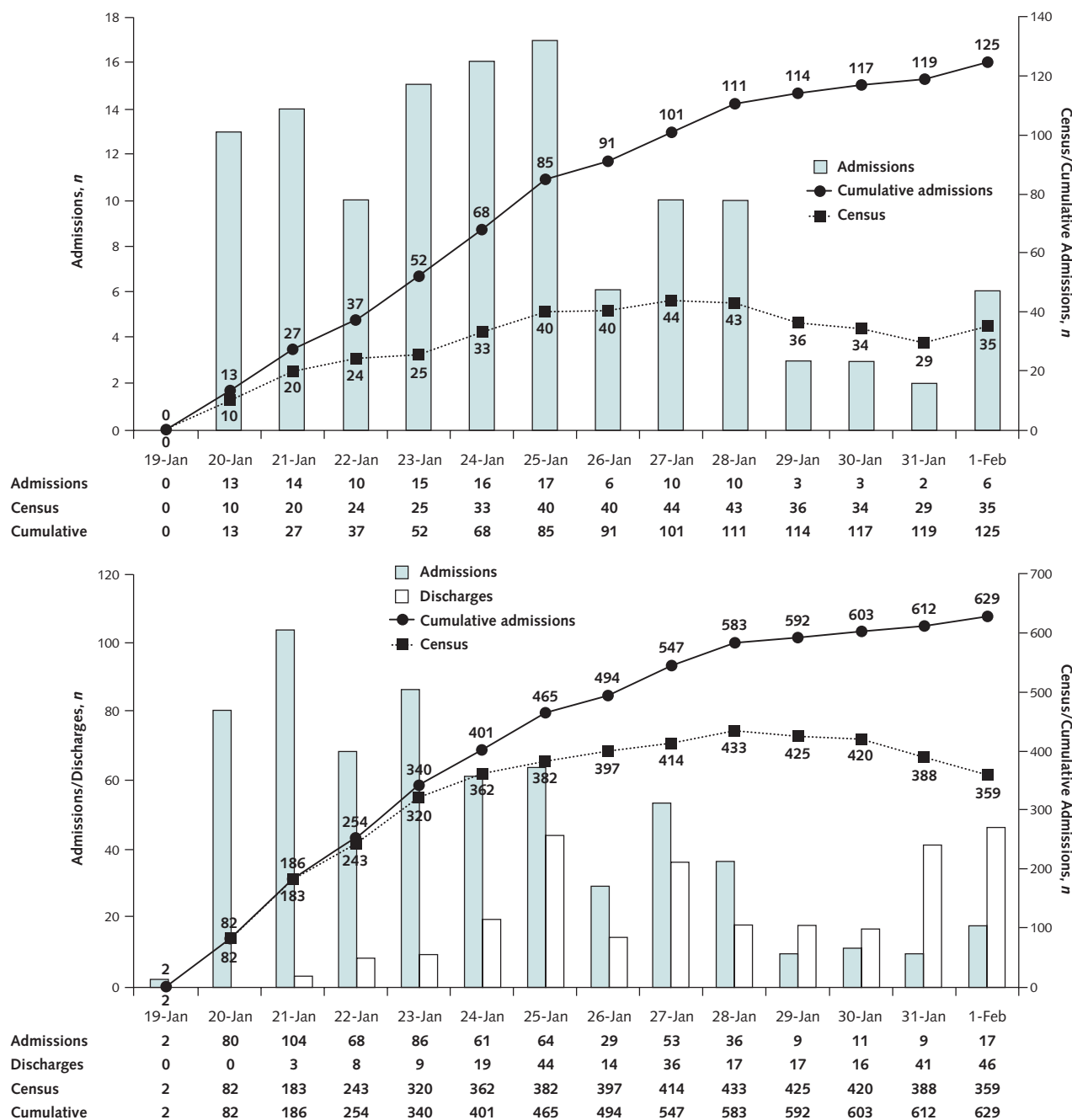
CONCLUSIONS

This article describes the unique situation of a mobile tertiary care hospital responding to a large-scale natural disaster. We do not suggest that tertiary care is required for most injuries occurring during a natural disaster, such as the Haitian earthquake. In disaster medicine, resources focused

Figure 2. Aerial view of USNS *COMFORT* in Port-au-Prince harbor.



Figure 3. USNS *COMFORT* admission numbers and census during its first 14 days in Haiti.



The total USNS *COMFORT* census includes patients on adult and pediatric wards and intensive care units. **Top.** Intensive care unit admissions per day, census, and cumulative number of intensive care unit admissions for the first 14 days of Haitian patient reception onboard the USNS *COMFORT* during Operation Unified Response. The peak number of intensive care unit admissions ($n = 17$) occurred on 25 January 2010, and the peak total census ($n = 44$) occurred on 27 January 2010. **Bottom.** Total USNS *COMFORT* admissions and discharges per day, census, and cumulative number of admissions during the same period depicted in the top part of the figure. The peak number of admissions was 104 on 21 January 2010, and peak total patient census (excluding patient escorts) was 433 on 28 January 2010.

on helping the greatest numbers of minimally to moderately injured patients, as well as preventing disease and providing shelter and nutrition, are of the most benefit. Critics may claim that the resources and care provided by the *COMFORT* are beyond the local standard of care and

therefore inappropriate. However, the ability of the *COMFORT* to function as a tertiary care “clearing house” significantly multiplied the capabilities of other agencies on the ground, enhancing their ability to manage minimally to moderately injured patients. This allowed time to begin

the reconstruction of the Haitian health care system. Hundreds of Haitians are alive today directly because of the care they received on the *COMFORT*. Applying the “multiplier” analogy, the role of the *COMFORT* in this disaster saved countless more lives.

The Haitian earthquake provided a unique scenario in which a fully functional, high-volume mobile tertiary care hospital was brought to a disaster site quickly as the de facto tertiary care referral medical center for the region. This role was important to the U.S. and international community’s medical response by unburdening other groups and facilities of their sickest patients, allowing them to focus limited resources on greater numbers of patients.

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