ABSTRACT
The tsunami of December 26, 2004, can be described as one of the worst disasters medical systems have ever had to face. This paper will describe the geophysical properties of tsunamis and their disastrous impact on human beings and infrastructure. Finally, we will present three different modes of response to the tsunami that were present in different provinces in Thailand. These three modes represent different strategies of disaster management, and analyzing each will help to begin understanding how best to respond to the next large-scale natural disaster.

Key words: tsunami, geophysical properties, modes of response

WHAT IS A TSUNAMI?
“Tsunami” is a Japanese word for “harbor waves,” and it is used by the scientific community to describe a series of waves, characterized by long wavelength (up to several hundred kilometers) moving across the ocean. These waves can attain speeds of up to 800 kilometers per hour as they travel across the ocean and are relatively flat and similar in height to normal ocean waves (0.5 to 1.0 meters). Thus, they are barely noticeable on the ocean. Such waves are capable of traveling thousands of kilometers with minimal energy loss. In shallow water, near coastlines, the tsunami slows down to speeds of tens of kilometers per hour but, in doing so, forms large destructive waves. These waves can rise up to 30 meters in height and flood the shoreline at high speed, destroying all in their path up to several kilometers inland.

Tsunamis are created by seabed movement, most commonly through ocean floor earthquakes, which abruptly deform and vertically displace the overlying water. This movement, ultimately, creates the huge tidal waves.

Tsunamis can be similarly produced by a sliding movement of the ocean floor. One of the best described processes capable of generating a tsunami is the eruption of methane gas trapped in the ocean floor. The sudden release of the gas causes landslides on the ocean floor, generating tsunamis. Worldwide earthquakes are the most common cause for tsunamis. Most of them occur near tectonic “plate boundaries,” areas prone to such large vertical movements of the earth’s crust. The Indian Ocean floor is highly prone to this seismic activity, especially around Sumatra, which is at the junction of three, large tectonic plates.

Tsunamis are relatively common in the Pacific region. In the last decade of the 20th century, the following tsunamis occurred: Nicaragua (1991), Indonesia (1992), Okushiri Island in Japan (1993), and in Papua New Guinea (1998). In Europe, tsunamis are less frequent. One of the worst ever occurred 7,200 years ago in the North Atlantic region,
caused by an extremely large underwater landslide (the Storegga Slide). The tsunami waves that flooded the Norwegian coast were as high as 20 to 35 meters above sea level, while those that flooded the English coastline reached six meters above sea level. On November 1, 1755, a strong undersea earthquake occurred 200 km off the coast of Portugal. This was one of the most devastating earthquakes in recorded history. Its magnitude is estimated at 8.5 (Richter scale), and it generated huge tsunami waves that flooded the coastline.

THE TSUNAMI DISASTER IN SOUTHEAST ASIA

On December 26, 2004 at 09:00 AM, an earthquake of 9.0 magnitude (Richter scale) struck the area off the western side of northern Sumatra, triggering massive tsunamis. The total energy released has been estimated as the equivalent of 23,000 atomic bombs of the type dropped on Hiroshima at the end of World War II. This earthquake, the strongest recorded in the last 40 years, was caused by the movement of the Indian plate under the Burma plate—a process that has been occurring for the past 1,000 years. On the day of the earthquake, a rupture 1,000 km long occurred, pushing the ocean floor above it about 10 meters horizontally and several meters vertically. This movement, of trillions of tons of rocks, generated giant waves that moved across the ocean at the speed of a jet plane, flooding coastal areas around the Indian Ocean rim, striking eight countries in Southeast Asia as well as Somalia, Tanzania, and Kenya in East Africa. The tsunami waves devastated thousands of kilometers of coastline, causing a huge number of fatalities and injuries and destruction of infrastructure. The death toll climbed steadily. One month after the disaster, it was estimated at 225,000 people. Whole villages were wiped off the face of the earth. The four countries that were most
severely hit were Indonesia, Sri Lanka, India, and Thailand. The tsunami directly affected an estimated 5,000,000 people.\textsuperscript{11,12} The estimated total number of fatalities, wounded, missing, and displaced victims is shown in Table 1.

**HAZARDOUS EFFECTS OF A TSUNAMI**

The damage caused by a tsunami is progressive. In the first stage, it hits the coastline at pressure levels of up to 10,000 kilograms per square meter, enough to destroy any structure in its path. The flooding effect of the tsunami causes most of the damage by destroying houses, roads, and infrastructure. In the second stage, the wave retreats, inflicting additional damage by washing away soil sediments, shorelines, and eroding the foundations of buildings. Tsunamis can impair water supplies in multiple ways: damaging pipelines and pumps, and contaminating wells and ground water with salt water or sewage. Tsunamis can also cause severe damage to crops and food supplies.

While most tsunamis cause little damage, some inflict massive destruction of lives and property. In areas without warning systems or located close to the
epicenter (not allowing enough time for evacuation), a large tsunami can inflict a great number of casualties, such as the hundreds of thousands in the recent Southeast Asia tsunami. Such a disaster puts a huge burden on the affected areas, which have to deal with enormous numbers of victims in a very short time.

The profile of tsunami victims is similar to that of cyclone and hurricane victims during heavy flood damage. The major causes of death are drowning and blunt trauma. The injuries sustained by the most survivors originate from complications of near drowning such as aspiration pneumonia and blunt trauma. Another common injury following a tsunami disaster is wound infection, probably due to contaminated debris. An Australian medical team that treated tsunami victims in Papua New Guinea in 1998 described 182 surgeries performed during a 15-day period. The initial medical treatment of infected wounds includes surgery and empiric antibiotic therapy until wound culture results are available. In determining a diagnosis for such patients, one must consider organisms that are prevalent in wounds exposed to sea water, such as Aeromonas Hydrophilia and Vibrio Vulnificus.

In the weeks following a tsunami, it is important to identify rapidly and monitor closely all infectious diseases, in order to identify outbreaks and treat them in a timely fashion. The World Health Organization (WHO) and other agencies link tsunamis with large outbreaks of cholera and other epidemiological forms of diarrhea. Based on previous outbreaks of diarrheal diseases, we know that the occurrence can be as high as 87,000 to 120,000 per population of 100,000. (In Goma in 1994, many of the refugees had more than one outbreak of diarrheal disease.) Such was not the case in the recent tsunami in Southeast Asia, most likely due to the speed and size of the relief effort.

**HEALTH SYSTEM RESPONSE**

Very limited data are available in the medical literature regarding the response of health systems to tsunami risks and tsunami management, and most of the available data is anecdotal and descriptive. An
important feature of tsunami disasters is selectivity. A tsunami affects some areas while sparing others at times only a few hundred meters apart. This allows both mobilization of medical staff from nearby unaffected to affected areas and evacuation of victims from the affected areas to unaffected hospitals. This is also one of the reasons for the different modes of response taken in different regions.

Multiple articles have looked at the elements which enable a system to successfully manage a crisis. Three elements were found to be crucial in managing a mass casualty natural disaster, such as a tsunami: the flow of information, overall coordination, and leadership. These three elements were found to be relevant in analyzing the Thai health system response in the recent tsunami (Figure 3).

When preparing for an unexpected emergency (such as an earthquake or a tsunami), we have to consider the role of every organization and the methods for cooperation. As Quarantelli suggests, planning should be seen as a process involving practices, interactions, and relationships.

To allow for the high level of performance required of healthcare providers in such situations, it is crucial to provide adequate support to staff and volunteers. In a study that examined support factors among Thai healthcare providers, leadership was found to be critical, as was fulfilling the basic needs of the personnel (Figure 4).

**Model I: “Field”-based and primary center-based medical aid**

A principle bottleneck in the Southeast Asia tsunami, as in other natural disasters, was the low availability of ambulances and air-based evacuation. For this reason, 70 percent of the casualties in Krabi province were primarily treated in the field or evacuated to primary clinics (tumbons), mostly by foot, by private cars, or boats. The primary clinics are regularly staffed by public health officers and a

---

Figure 3. Critical elements of the Thai Health System’s disaster response.
nurse, who is authorized to prescribe medications and supply primary care. These clinics, which have no hospitalization capabilities, were rapidly organized with mattresses and beds in order to “hospitalize” patients until their primary care was completed and their secondary triage to an established hospital (either district-secondary or provincial-tertiary) was available. In Phang Nga district, most casualties were treated in the field or in the tambons. Tambons were reinforced with manpower and medical supplies that were sent from either district or provincial medical centers. These “reaching out” teams gave advanced life support (ALS) care, triaged casualties, informed their own hospital’s operation center, and selectively evacuated patients to hospitals. For that reason, Phang Nga’s hospitals, like Takuapa’s hospitals, got “waves” of casualties (some 990 casualties until midnight) and not one mass of casualties.30,31

After the tsunami, as after other natural disasters, most patients presented to either the primary healthcare facilities or the local hospitals within a few hours.32,33

**Model II: Hospital-based response**

In other provinces (e.g., Phuket), primary care organization and reinforcement were lacking. Almost all casualties in Phuket were rapidly evacuated either by ambulances, police cars, or private cars to secondary (district) or tertiary hospitals (Figure 1). Most casualties arrived at hospitals within a few hours, creating a mass casualty incident, with hundreds of casualties—a scenario that hospital teams had never trained for. Initially, there was no coordination among hospitals, and no patient allocation or secondary diversion occurred.

The Thalang district (secondary) hospital in Phuket province admitted about 200 casualties in the first three hours of the disaster. Patong hospital, also

---

**Figure 4. Support factors that increased resilience and perceived effectiveness of medical teams.**
in Phuket province, with 48 nurses and eight general physicians, admitted 700 casualties in two hours (and only 59 more in the next 20 hours). Not surprisingly, these hospitals reinforced the primary health centers (tumbons) by the second or third day, after most of their casualties had received primary treatment.

Most victims arrived at the hospitals within six hours of the disaster. Many dead victims were brought in as well, adding to the overall burden. In some areas, the dead were diverted to temples for future identification. Reinforcement of medical crews and equipment started, in some instances, within a few hours. Most victims had lacerations, soft tissue injuries, fractures, or near drowning without significant respiratory distress. Thus, they were considered mild cases. Secondary distribution among hospitals, and evacuation to further inland tertiary hospitals, was started, in most cases, on the day after the tsunami hit. In the first two days, space and resources were severely lacking, intensive care units doubled their capacity, and operating rooms (OR) worked constantly, often with more than one patient per OR at any one time.

Model III: Mass casualty incident in a remote environment

Remote, small islands inundated by the tsunami exhibited distinctive features. One was a lack of selectivity. While in large land areas sometimes only a strip of coastline a few kilometers deep was affected, leaving a large portion of the infrastructure and manpower intact, on many of the islands the tsunami caused total flooding and destruction. This was the case on PhiPhi island in Thailand and in many of the Maldivian islands. Due to their remote location and limited accessibility, communication was very limited, and evacuation of victims and reinforcement of medical staff and equipment was very difficult. In these locations, often the leadership of a few caregivers, one physician, and a few nurses perhaps made it possible for some lives to be saved.

CONCLUSION

Tsunamis can cause large-scale disasters with hundreds of thousands of casualties and severe infrastructure damage. Early warning systems and public education can mitigate the loss of lives and injuries. As in other disasters involving flooding, most of the severely wounded victims drown. Thus, survivor injuries tend to be relatively mild. Health system preparedness prior to the event, and effective disaster management following it, are crucial for providing the necessary care for the primary injuries, while preventing and, optimally managing, secondary injuries.

During the chaos of a natural disaster, one must trust those whom one is familiar with: friends, relatives, the close-by nurse from the tumbon, or the local hospital physician. It seems useless to erect new medical systems far away and significantly different from the existing ones. It seems wise to practice different modes of response and management, in different locations, depending on the relative damage, evacuation capabilities, and medical resources in each of those locations.

Dagan Schwartz, MD, Faculty of Health Sciences, Ben Gurion University, Beer-Sheva, Israel.

Major Adi Leiba, MD, Faculty of Health Sciences, Ben Gurion University, Beer-Sheva; IDF Home Front Command, Israel.

Colonel Issac Ashkenasi, MD, MPA, MSc, Faculty of Health Sciences, Ben Gurion University, Beer-Sheva; Medical Services and Supply Center, IDF Medical Corps; IDF Medical Corps, Surgeon General Headquarters, Israel.

Captain Guy Nakash, MD, IDF Home Front Command, Israel.

Major Rami Pelts, MA, IDF Home Front Command, Israel.

Colonel (res) Avishay Goldberg, PhD, Faculty of Health Sciences, Ben Gurion University, Beer-Sheva, Israel.


Colonel Yaron Bar-Dayan, MD, MHA, Faculty of Health Sciences, Ben Gurion University, Beer-Sheva; IDF Home Front Command, Israel.

REFERENCES


