# Nephrology in Earthquakes: Sharing Experiences and Information

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**Earthquakes are the most unpredictable natural disasters and often result in many deaths and casualties as a result in part of the collapse of buildings. To restore medical facilities and activities after a large earthquake, nephrologists play critical roles not only in the restoration of dialysis facilities for regular renal replacement therapy but also in the prevention and treatment of acute kidney injury and hyperkalemia, mainly as a result of crush syndrome. For these purposes, sufficient education and establishment of functional networks among medical facilities are certainly needed. Recently, the contribution of international task forces has become more significant, especially for large-scale natural disasters. Organized detailed action plans should be prepared among regional governments and armies considering the differences in cultures and social systems.**

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## Earthquakes as Unpredictable Disasters

Contrary to our expectations and understanding, earthquakes are common natural disasters from a global point of view. As updated on the home page of the US Geological Survey Earthquake Hazards Program (http://earthquake.usgs.gov/), earthquakes with magnitude 4.0 or greater occur every day all over the world.

Thanks to the recent developments of meteorological observatory networks and technologies, the course of a storm can now be easily forecast, and even the risk for a volcanic eruption can be predicted. Warnings for such disasters help us to provide a plan for the timely evacuation of residents, except for a storm of unpredictable speed, scale, and energy. Partly as a result of global warming, the scale and the severity of storms have become more unpredictable recently (*e.g.*, hurricane Katrina, which is discussed separately in this issue [1]).

To date, earthquakes remain one of the most unpredictable natural disasters. In addition, the arrival of a tsunami as a result of an undersea earthquake can be announced only in limited areas with appropriate information systems (2,3). Another feature of earthquake damage is the collapse of many buildings, which often results in a high number of deaths and casualties. Therefore, a detailed action plan should be prepared for the rapid response to damage that results from a large earthquake.

The outcomes of several large earthquakes have been reported and discussed, including those in Japan (4,5), Turkey (6,7), Taiwan (8), Armenia (9), Iran (10), and Pakistan (11,12). Although the pattern of actions and behavior after a disaster may differ considerably depending on the locality (including the social systems, healthcare systems [13], ethnicity, and heterogeneity of the residents), the principles of action should be similar.

On the basis of our experiences in Japan, this review summarizes the common situations that nephrologists have encountered or will encounter in large earthquakes. These include restoration of medical facilities including dialysis units, transportation of patients, and prevention and treatment of acute kidney injury (AKI), mainly as a result of crush syndrome (14,15).

## You Can Never Be Too Prepared for Earthquakes: A Japanese Experience

Among the developed countries, Japan is unique in that it is regularly hit by natural disasters, such as earthquakes, volcanic eruptions, tsunamis (a word of Japanese origin), and typhoons (tropical storms in the Indian or western Pacific oceans). Officially, more than 400 earthquakes in Japan that resulted in major damage have been recorded (16). Furthermore, nearly 10 meteorological disasters with significant numbers of deaths and missing persons per year have been listed according to the Meteorological Agency in Japan. The Japanese people consider themselves to be well prepared for such disasters. Nevertheless, the disasters that occurred during the past decade were beyond the expectation and experience of any catastrophes since World War II.

In Japan, there are nearly 1000 earthquakes per year that can be felt, and more than 15 earthquakes are greater than magnitude 6.0. Accordingly, Japan is socially prepared; social frameworks including buildings and transport facilities have been designed and constructed with sufficient strength for this magnitude of earthquake. Only extremely severe earthquakes that occur rarely cause major damage to the infrastructure of cities, such as the 1923 earthquake in Tokyo and the more recent one

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in Kobe in 1995. Several large earthquakes are also expected in the near future in many areas of Japan, including Tokyo (17).

In the early morning of January 17, 1995, the Hanshin-Awaji earthquake with a magnitude of 7.2 on the Richter scale struck the area around the modern city of Kobe, Japan, with a population of more than 1 million residents. This earthquake immediately resulted in 5502 deaths (increased to 6610 in a recent report on the 12th anniversary) and 45,000 casualties as officially reported (18). Because this was a very strong local earthquake with the seismic center directly beneath the city area, modern reinforced-concrete buildings as well as traditional Japanese wooden buildings were partially or completely destroyed, including many medical facilities (4,5) (Figures 1 and 2). This was just an example of a large earthquake in a modern big city; however, we have learned a lot on the importance of cooperation among local residents, as well as those of officials and governments.

## Restoration of Medical Facilities after Large Earthquakes

Several problems need to be solved for the restoration of functional medical activity after an earthquake and its aftershocks (Table 1). Immediately after the earthquake, any medical facility will be inundated with triage and emergency treatments. In addition to the restoration of hospital rooms, medical professionals who need to be recruited during the emergency may have suffered because of the earthquake, as in other disasters. In Kobe, the telephone lines were only partially restored after the earthquake, and recruitment of medical staff was required for the rapid recovery of regular renal replacement therapy. Some voluntarily reported to the medical facilities; for communication, cellular phones were comparatively more useful than conventional phones. On the basis of these experiences, a disaster message board system was recently developed by the major carriers.

In addition to the restoration of damaged and destroyed medical facilities and equipment, restoration of lifelines, such as electricity and water, was mandatory. This was especially important for dialysis facilities that needed to accept many patients with AKI as well as long-term dialysis patients. While waiting for the restoration of electricity, many facilities temporarily used their own power plants. However, restoration of the water supply is critical for dialysis therapy; the water tanks in many facilities had been destroyed, and water had to be supplied by tank trucks or by special equipment that converts seawater into fresh water. The availability of such devices may not have been generally known either to medical facilities or to local government officers at that time. Despite such disadvantages, nearly 80% of the facilities in the Kobe area could partially restart dialysis therapy within 5 d with higher number of shifts per day to accommodate long-term dialysis patients as well as patients with AKI, and until that time, many patients had to tolerate decreased hours of dialysis per week with oral adsorbents for potassium as well as with control of diet and water.

At dialysis units, information on the safety of dialysis pa-


*Figure 1.* Severe damage after the Hanshin-Awaji earthquake. (A) Complete destruction of traditional Japanese wooden buildings. (B) Crush of the fourth floor of the city hospital (arrow) made of reinforced concrete. (C) Numbers of cracks on the wall of a dialysis clinic building. (D) Long lines for water supply. (E) Part of Nojima dislocation crossing a road and rice fields (arrows), presumably responsible for the Hanshin-Awaji earthquake. Courtesy of Dr. Jeongsoo Shin (Gojin-kai, Motomachi HD Clinic, Kobe, Japan).


*Figure 2.* Indoor chaos after the Hanshin-Awaji earthquake. (A through C) Dialysis units immediately after the earthquake. (D) Hospital laboratory immediately after earthquake. (E) Hundreds of refugees in a school gymnasium used as a temporary shelter. Courtesy of Dr. Jeongsoo Shin (Gojin-kai Motomachi HD Clinic, Kobe, Japan).

*Table 1.* Expected failures and issues to be faced in earthquakes

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|---|
| Temporary refugees for residents and patients |
| Destruction of medical facilities |
| buildings |
| medical equipment |
| shortage of medical supplies |
| Disturbed life lines |
| electricity |
| water |
| city gas |
| Disturbed networks |
| telephone access |
| Internet access |
| transportation and traffic (public or private) |

tients had to be collected. In the Kobe area, before the earthquake, approximately 2500 hemodialysis patients and 120 continuous ambulatory peritoneal dialysis patients were treated in 58 centers. Because of the tragedy, 23 patients were crushed or burned to death, and more than 80 patients were hospitalized as a result of serious injury. Although more than 2000 patients had to be referred to appropriate facilities from closed dialysis units, only a few patients died as a result of lack of access to or failure of renal replacement therapy as reported later (19). All continuous ambulatory peritoneal dialysis patients were also located and continued treatment.

## Role of Nephrologists in Earthquakes

Many patients develop various kidney problems after earthquakes (Table 2). In addition to the recovery of regular care of patients who are on maintenance dialysis, AKI is one of the major problems to be prevented and treated by nephrologists (19,20). Because the number of casualties in a large earthquake is much higher than in other natural disasters, crush syndrome has been recognized as the most important cause of AKI after an earthquake (21–25). Severe hyperkalemia by various causes is another major problem to be managed by nephrologists. As shown in the Marmana earthquake, development of hyperkalemia on admission was a significant predictor of dialysis need and mortality (26,27).

In the Hanshin-Awaji earthquake, diagnosis of crush syndrome was made in 5% of hospitalized patients (4). Most of the patients recovered and were weaned from dialysis therapy (28,29). According to Vanholder *et al.* (6,12), the ratio of dialyzed AKI per total number of fatalities varied significantly in nine recent earthquakes and may have decreased in the recent ones. Such differences may largely depend on the degree of

*Table 2.* Problems to be handled by nephrologists in earthquakes[a]

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| Prevention of AKI |
| fluid treatment |
| education of general physicians |
| Management of AKI |
| rhabdomyolysis |
| injury |
| infection |
| Management of hyperkalemia |
| Regular and acute renal replacement therapy |
| confirmation of the safety of chronic dialysis patients |
| recruitment of dialysis doctors, nurses, and technicians |
| dialysis machines and water supplies secured and operational |
| logistic plans for medical supplies |
| Transportation of patients to available or specialized medical facilities |
| within the disaster area |
| outside the disaster area |
| Follow-up of patients with chronic disease |
| chronic kidney disease |
| posttraumatic stress and depressive reactions |

[a]AKI, acute kidney injury.

building damage in the earthquake area as a result of building quality as well as on the varying corporal structure of the local population and rescue and transport possibilities; however, it is certain that prevention and treatment are better understood among nephrologists and those who are involved in emergency medicine as a result of the educational efforts of the nephrology communities and the activities of international task forces. It is expected that more intensive education of general physicians on fluid therapy (30,31) and crush syndrome will lead to earlier referral to nephrologists and better survival of patients with crush syndrome (32).

Even after the restoration of city functions, careful follow-up is required in patients with kidney diseases. After the Hanshin-Awaji earthquake, we experienced many dialysis patients who discontinued regular medical consultation for chronic kidney disease, including those with a history of hypertension or diabetes. This was partly due to their relocation to another part of the city or the closure of medical institutions that they regularly visited. Furthermore, posttraumatic stress and depressive reactions (33) may modify their symptoms and frequency of visits. Patients with various chronic diseases, therefore, should be monitored carefully after a severe natural disaster (34).

## Establishing Networks and Sharing Experiences of Earthquakes

Transportation of patients and logistics of medical supplies were other major problems in the earthquake area with many closed roads. According to a retrospective survey after the Hanshin-Awaji earthquake, patients were transferred to backup hospitals mainly by personal cars. Fewer patients used ambulances, and a minimal number of patients used helicopters (35). Thus, the emergency care system should be equipped with well-established functional transportation systems, possibly in collaboration with the army. This is only an example of the preparedness of local health care systems, the level of which has been shown to be a critical factor for the health outcomes of disaster victims (36,37). Recently, transportation and treatment of dialysis patients by a specialized hospital ship has been practiced by Kobe University, Faculty of Maritime Sciences, in collaboration with the Japanese Association of Dialysis Physicians. Nevertheless, functional coordination with a total disaster relief plan needs to be established in the near future.

In the Hanshin-Awaji earthquake, it was fortunate that the closest large city, Osaka, was mostly free from major earthquake damage, allowing many patients to be transferred and accommodated. Furthermore, the rescuers, including the government and the Japanese Self-Defense Forces, could reach the damaged area quickly despite unexpected difficulties and transfer patients to the surrounding cities when necessary.

For these arrangements, networks of dialysis facilities played an important role. The national network had already been established by the Japanese Society for Dialysis Therapy and the Japanese Association of Dialysis Physicians. This information system has become more sophisticated with practice after that major earthquake and can retrieve information on damage to the dialysis facilities in an affected area for appropriate action plans within one day. The system worked well in recent earthquakes in Japan, such as the Niigata earthquake in 2004, when a Shinkansen train derailed for the first time.

In the case of more widespread or nationwide destruction without any major backup area, the role of international task forces and collaboration between governments may become more important. International task force teams including nephrologists were developed after the Armenian earthquake in 1988 to achieve organized relief efforts (6,12,38,39). As reported in many articles, the task force has functioned well in Turkey, Iran, and recently Kashmir. A regional branch of such a task force should be established for prompt and organized relief (40). For such activities, functional collaboration between national and supranational societies and kidney foundations, as well as nongovernmental organizations such as Médecins Sans Frontières, will be needed. Also, for these efforts to work efficiently, political relationships among governments and differences in culture and social systems need to be considered. Furthermore, global coordination and an education plan should be established, possibly through the World Health Organization and the United Nations. In summary, establishment of networks at various levels is indispensable for functional action plans in big earthquakes (Table 3).

## Conclusions

Recent experiences of large earthquakes have highlighted the important role of nephrologists in the recovery of regular dialysis therapy and management of crush syndrome. Although local residents and governments may have been well prepared for regular levels of earthquakes in the area depending on their

*Table 3.* Functional networks at various levels in earthquakes

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| Local residents |
| Supporters |
| Intrahospital |
| Interhospital |
| Local governments |
| Army |
| National governments |
| International task force |

experiences, functional action plans in cases of unexpectedly more severe earthquakes should be established and drilled, on the basis of multiple simulations with the latest information technologies. In addition, early establishment of intra- and interhospital domestic and international networks seems to be mandatory for the achievement of more organized activities in disaster relief. Sharing of experiences over multiple generations should also be extremely important, because "another natural disaster comes when people forgot the last one" (an old Japanese maxim, reportedly by Torahiko Terada, PhD, 1878 to 1935, a physicist and professor at the Earthquake Research Institute, University of Tokyo).

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## Disclosures

None.

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