Renal Replacement Therapy

REVIEW

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Earthquake, volcanic eruption, flood, and CBRNE: How can we prepare for disasters?

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Abstract

It has long been known that dialysis treatment is susceptible to disasters. In fact, the Great Hanshin earthquake in 1995 and the Great East Japan Earthquake Disaster in 2011 severely affected dialysis treatment; however, in the previous disasters, dialysis treatment has been continued through cooperation among dialysis facilities. In addition to earthquakes, tsunamis, and floods, unprecedented disasters such as volcanic eruptions and CBRNE are expected in Japan, necessitating preparation for dialysis treatment. It is well known that power outages are easier to fix after an earthquake than water outages. Therefore, it is important to be prepared for water outages to continue dialysis treatment. If a disaster restricts access to dialysis treatment, dialysis patients must be transferred to a facility where treatment is available. In addition, when dialysis facilities experience a water outage or power outage, the assistance of the local government may be required. Therefore, in the event of a disaster, it is important to share information about the damage among dialysis facilities and between the facilities and the government. The Japanese Association of Dialysis Physicians (JADP) has promoted information sharing among dialysis facilities and with governments, including the establishment of the Disaster Information Network in 2000. Furthermore, JADP chapters are established in each prefecture, and regional organizations such as JADP chapters work with local governments to build local disaster preparedness. The Japan Hemodialysis Assistance Team was established in 2015 and is tasked with disseminating information from the afflicted area during the acute phase of a disaster as well as providing human and material support during the subacute phase of a disaster. Preparation during normal times is imperative as various forms of disasters are expected to occur in the future.

Keywords Earthquake, Volcanic eruption, Information sharing, Water outage, Power outage

Introduction

Although Japan covers only 0.28% of the world's land area, 20.5% of all earthquakes of magnitude 6 or greater worldwide occur in Japan, and 7.0% of all active volcanoes in the world are in this country according to the Cabinet Office [1]. Japan accounts for 17.5% of the total amount of damage caused by disasters worldwide. In the other words, Japan is one of the most disaster-prone countries in the world.

Hemodialysis therapy requires large volumes of water and electricity to run specialized equipment. Therefore, the vulnerability of dialysis therapy to disasters has been recognized in this country for a long time. If a disaster prevents dialysis treatment, dialysis patients must be transferred to a facility where treatment is available.

We have experienced major earthquakes such as the Great Hanshin-Awaji earthquake and the Great East Japan Earthquake Disaster (GEJED) and have learned how to secure dialysis treatment in times of disaster. However, dialysis treatment could also be affected by various potential disasters, similar to the Nankai Trough

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earthquake with a huge tsunami, a major eruption of an active volcano such as Mt Fuji, as well as missile attacks and terrorist attacks based on international conflicts.

This manuscript describes what dialysis professionals in Japan have learned from the disasters they have experienced and how we can prepare for possible disasters.

Characteristics of disasters and their impact on dialysis treatment

Earthquake

In Japan, earthquakes are the most frequent disaster that affects dialysis treatment. Large earthquakes often destroy buildings, scatter household goods, cause fires, landslides, etc., and are also responsible for human casualties. Power outages occur when an earthquake damages power lines and underground cables because of the collapse of transmission towers and poles or liquefaction of the ground. If major transmission lines or power stations are damaged in an earthquake, widespread blackouts may occur. Earthquakes can disrupt transport services as a result of power outages, damage to equipment, or landslides. Consequently, earthquakes can cause staff shortages as well as shortages of medicines and supplies to healthcare facilities. It may also interfere with dialysis patients' access to hospitals.

In recent years, the Great Hanshin-Awaji earthquake and the Great East Japan earthquake are often cited as earthquakes that caused major damage; however, the characteristics of these two earthquakes are very different.

In the 1960s, the theory of plate tectonics was proposed, which states that the Earth's lithosphere comprises several large tectonic plates that have been moving slowly [2]. Plate boundaries—where two plates meet and subduct into each other—are called trenches, and earthquakes that occur at these plate boundaries are called interplate earthquakes.

Japan is a region where four plates collide: The Pacific Plate, the Philippine Sea Plate, the Eurasian Plate, and the North American Plate. In 2011, the earthquake off the Pacific coast of Tohoku that caused GEJED was an interplate earthquake that occurred at the plate boundary between the Pacific Plate and the North American Plate. The 1923 Great Kanto earthquake was also an interplate earthquake with its epicenter in the Sagami Trough at the boundary between the Philippine Sea Plate and the North American Plate.

On the other hand, the Great Hanshin earthquake had its epicenter inside a plate and is referred to as an intraplate earthquake. This earthquake caused extensive damage because its epicenter was near an urban area and was relatively shallow; however, the magnitude of the earthquake itself was weak than that of an interplate earthquake, and the area of damage caused was relatively small. The Kumamoto earthquake in 2016 was also an intraplate earthquake.

The Nankai Trough earthquakes, which are predicted to occur in the near future, are interplate earthquakes with their epicenter in the Nankai Trough, where the Eurasian plate meets the Philippine Sea plate.

It is known empirically that interplate earthquakes occur in cycles, with the M8-class earthquakes occurring in cycles of 100–200 years. The Nankai Trough earthquake is of particular concern because it has been 80 to 170 years since the most recent earthquake occurred with an epicenter in the Nankai Trough [3]. Incidentally, intraplate earthquakes can occur anywhere in Japan and are impossible to predict.

Volcanic eruption

Scientists currently consider volcanoes to be active if it has erupted within the last 10,000 years. There are approximately 1,400 active volcanoes in the world, of which 111 are in Japan. Active volcanoes are most common in Hokkaido, and Kyushu, while Kinki, Chugoku, and Shikoku have few. Despite the large number of volcanoes in Japan, there have not been any recent volcanic disasters that have claimed more than 100 fatalities. However, a major volcanic eruption could have a large impact on society, and on dialysis treatment, which depends heavily on social infrastructure.

The following phenomena are all brought on by volcanic eruptions.

1. *Volcanic cinders* are rock masses formed when the dispersing part of the lava that has been ejected becomes cool. The 2014 eruption of Mt. Ontake killed 58 people, and many of these victims were directly hit by volcanic cinders flying from the crater. Fortunately, the cinders do not travel tens of kilometers, but they only reach up to 4 km from the crater at most. However, there is no time to evacuate, and the risk of being in the vicinity of the crater is extremely high.
2. *Lavas*, which are hot liquid rocks that flow from a volcano, can reach tens of kilometers from the crater depending on conditions. When the speed of the lava flow is low evacuation becomes easy, however, because of high temperatures, structures that come in contact with the lava flow catch fire and are destroyed.
3. *Pyroclastic flows*, which are dense, destructive masses of very hot ash, lava fragments, and gases ejected explosively from a volcano, are one of the most dangerous volcanic hazards. Pyroclastic flows can reach speeds in excess of 100 km/hour and can

reach ranges of 100 km or more and even cross the ocean. The pyroclastic flow from the 1991 eruption of Mt. Unzen-Fugendake in Nagasaki, Japan, killed 44 people, mostly journalists, who were covering the eruption. The ancient Italian city of Pompeii was destroyed in A.D. 79 by a pyroclastic flow from the eruption of Vesuvius, about 10 km away.

4. *Volcanic ash* is a piece of magma less than 2 mm in diameter, and despite its name, volcanic ash is fundamentally different from the ash that forms when paper or wood is burned and causes much more troublesome problems than common ash. Volcanic ash is the most far-reaching of all volcanic hazards, and in large eruptions, ashfall can reach hundreds of kilometers away.

Volcanic ash directly affects the human body by damaging the throat, airways, lungs, and mucous membranes of the eyes and nose.

Because of the heavy nature of volcanic ash when it contains water, ash accumulated on buildings can cause buildings to collapse after rainfall and can also cause rivers to overflow and mudslides to occur.

Although the above phenomena occurred before the Edo period, the impact of volcanic ash in modern society is more serious in the sense that it causes significant damage to infrastructure. Roads become impassable with a few millimeters of ashfall causing the risk of slipping, and railroads experience system failures due to poor electrical conduction caused by ashfall. Furthermore, airplanes cannot operate in the presence of when volcanic ash in the air because it causes serious engine damage.

The water supply system becomes unusable when the inflow of volcanic ash exceeds the treatment capacity of the water purification plant, and the sewage system becomes blocked when a large amount of volcanic ash flows into the system. Volcanic ash is conductive when it contains water, causing electrical leakage and power outages. Volcanic ash can also cause malfunctioning of precision equipment and seriously affect agriculture and forestry.

As described above, the impact of volcanic ash has a significant influence on the infrastructure of modern society, which means that volcanic disasters are an extremely serious threat to dialysis treatment, which relies heavily on infrastructure.

Typhoon and heavy rainfall

Typhoons are a strong low-pressure system that are born in the northwestern Pacific Ocean and often strike Japan and East Asia in the summers and during the fall. Strong typhoons bring heavy rainfall, flooding, windstorms, high waves, storm surges, river floods, and landslides.

Typhoons can cause power outages by damaging power transmission facilities such as poles, wires, and transmission towers due to their strong winds. Power outages can also cause communication problems due to the paralysis of relay station functions and water outages due to pumping station outages.

The 2019 Typhoon No. 15 was a very strong typhoon that made landfall on September 9 and caused damage to the extensive power grid, leaving 930,000 homes without power. The power outage caused by this typhoon was difficult to restore and lasted about two weeks.

Besides a typhoon, very heavy rainfall in a short period of time can cause river floods, landslides, as well as power and water outages. The torrential rains that hit western Japan in July 2018 caused landslides and flooding, closed many roads, cut off water in many areas, and greatly affected the continuity of medical care in those areas.

Snowfall

In northern Japan, heavy snowfall can cause significant damage. Rail and road traffic might become blocked when heavy snowfall occurs all at once. The weight of the snowfall could also cause houses to collapse. Power outages could happen when power lines get severed when snow accumulates on them. The biggest problem for dialysis treatment during heavy snowfall disasters is that patients have difficulty getting to hospitals.

CBRNE

CBRNE is an acronym for Chemical, Biological, Radiological, Nuclear, Explosive, and is a concept of risk assumed by the threat of terrorism, which has increased since the end of the Cold War. Recently, human-caused disasters such as accidents at nuclear power plants are also being considered as CBRNE disasters.

Zoning is the foundation for coping with CBRNE. Wearing protective clothing is necessary when hazardous materials are present (hot zones). Decontamination of contaminated people and objects is done outside, where there are no hazardous materials apart from people and objects that have been contaminated by hazardous materials (warm zone). Outside of the warm zone (cold zone), a command center and first aid station are located, and general medical care is offered there.

Following the Fukushima Daiichi nuclear power plant accident caused by GEJED in 2011, no dialysis patients experienced any direct health effects from radiation exposure; however, a significant number of dialysis patients who lived near the plant were forced to receive dialysis treatment in more distant cities because of medical collapse brought on by psychological panic [4].

General disaster response in dialysis therapy

If a disaster prevents dialysis treatment, dialysis patients must be transferred to a facility where treatment is available. However, transferring patients to other facilities requires significant resources and places a heavy psychological burden on patients. Therefore, we have the following policies for dialysis facilities in the event of a catastrophe.

1. The first goal is to continue treatment at your facility or, if impossible, at a facility within the patient's living area.
2. Out-of-area transport is chosen when hemodialysis patients are unable to receive hemodialysis treatment within their living area or, if possible, when it would interfere with the provision of medical care, or when inadequate treatment would be severely detrimental to the patient.

The following conditions must be met for hemodialysis treatment to continue in the event of a disaster:

1) The building and equipment are not damaged.
2) Electricity is available (external power supply or in-house power generation).
3) Water supply (tap water or water supply by water truck) is available for hemodialysis treatment.
4) Supplies, medicine, and food are available.
5) Doctors and medical staff are available.

If any of these five conditions are not met, dialysis treatment cannot continue. Buildings that comply with the new earthquake resistance standards established in 1981 should be able to withstand tremors of up to magnitude six or higher.

Assuming that the building will not collapse, Akatsuka devised four countermeasures, which are displayed in Table 1, to prevent damage to the infrastructure of dialysis rooms against tremors of up to the Japanese seismic intensity scale's upper limit of six [5].

Of these measures, (1) and (2) require no cost at all, while (3) and (4) require some cost; however, the effectiveness of these four measures was proven in a survey conducted after the Great East Japan earthquake [4].

It is known that the speed of restoration differs greatly between power outages and water outages. After the Great Hanshin-Awaji Earthquake, power outages were fully restored in six days, and after the Great East Japan Earthquake, 95% of power outages were restored in one week, despite the damage to multiple power plants.

In contrast, water outages take longer to restore than power outages, and in the two earthquakes mentioned above, about 80% of the water was restored only after two to three weeks; in the 2016 Kumamoto earthquake, 30 facilities were unable to provide dialysis, but only six of the 30 facilities were affected by the power outages [6].

These facts imply that after a disaster, it is easy to have a situation in which there is no power outage but there is a water cutoff. For the continuity of dialysis treatment, it is crucial to be prepared for water interruptions. Specifically, it is recommended that dialysis facilities install water storage tanks of sufficient capacity and verify procedures to ensure uninterrupted water supply from water trucks in the event of a water outage.

Information sharing in the event of a disaster

Hemodialysis treatment is deeply dependent on infrastructure, and it is difficult to continue treatment because of infrastructure damage caused by catastrophic disasters. In such cases, "support dialysis" at facilities that can provide dialysis services becomes necessary. In addition, facilities that are unable to provide dialysis treatment due to water or power outages may be able to continue treatment with the assistance of water trucks or power trucks. Therefore, in the event of a disaster, it is important that dialysis facilities share information among themselves and between facilities and the governments.

In the 1995 Great Hanshin-Awaji earthquake, "support dialysis" was performed by self-mobilization of patients and some inter-facility cooperation; however, there were few organized activities related to "support dialysis".

The Japanese Association of Dialysis Physicians (JADP), comprising dialysis doctors in Japan, launched the disaster information network in 2000 as a tool for sharing information in the event of a disaster. The disaster information network of JADP is made up of two internet-based information-sharing tools: a web-based disaster information network created for quickly sharing precise information among affected areas, support

Table 1 Four recommended measures in preparation for earthquakes in dialysis facilities by Akatsuka [5]

1.	Un-lock the casters of floor-type dialysis monitors
2.	Lock the casters of dialysis beds
3.	Fasten dialysis fluid delivery systems and reverse osmosis (RO) systems to the floor with anchor bolts or place those devices on a base isolation stand
4.	Use flexible tubes for the connection of dialysis fluid delivery systems and RO systems to the wall of a machine room

areas, and governments in times of disasters (http://www.saigai-touseki.net/) and a crisis-management mailing list that was created as a nationwide information-sharing tool in 2003. This disaster information network functioned well during GEJED, enabling the construction of a dialysis support system around an affected area or in a broader area as reported by Masakane [4].

JADP chapters are established in each prefecture, and regional organizations such as JADP chapters work with local governments to build local disaster preparedness.

The disaster information network of JADP is based on the premise of information sharing via the Internet and was effectively utilized during the 2016 Kumamoto earthquake when there were no communication failures. However, in situations like GEJED where there were communication failures due to widespread power outages, other information gathering methods such as personal connections with medical professionals in the affected areas and information from sales representatives of medical-related manufacturers in the affected areas were also very much needed.

In December 2015, JHAT (Japan Hemodialysis Assistance Team) was established by JADP, the Japan Academy of Nephrology Nursing, the Japan Association of Clinical Engineers, and the Japanese Society for Technology of Blood purification as an organization of dialysis medical professionals who provide support in disaster areas. JHAT has the role of entering the affected area during the acute phase of a disaster and disseminating information from the affected area in addition to providing human and material support to the affected facilities after the subacute phase of a disaster. Their role is expected in disasters with widespread communication failures.

Cooperation with the governments

A response to a large-scale disaster may not be sufficient for a single medical facility or even several medical facilities alone. Responses to power outages and water outages often require administrative support. In particular, when dialysis treatment is performed during water outage conditions, the water trucks owned by the local government are often insufficient to supply the large volume of water needed, and water trucks from the Self-Defense Forces are often required.

Administrative assistance is also needed to transport large numbers of patients for "support dialysis," as most medical facilities do not have the capacity to transport large numbers of patients. A huge earthquake with a tsunami may require transporting dialysis patients by air from isolated areas.

Cooperation with the governments is important both at the national level and at the local level. JADP works closely with the competent departments of the Ministry of Health, Labour and Welfare, and information is shared in the event of a disaster. In GEJED, JADP requested the government to transport patients, and the Self-Defense Force aircraft transported 80 dialysis patients from Miyagi to Chitose [7].

Of particular importance in the request to the local government is the response to power and water outages. As mentioned above, in situations where there is no power outage and water is cut off, there is a good chance that dialysis treatment can continue with the assistance of water trucks. The conditions for such a response are correct and prompt sharing of information about dialysis facilities and close coordination between the local government department and the local dialysis facility organization. It is desirable that the transportation of many patients in the event of a disaster be discussed in advance with the local government and the dialysis facility organization.

Conclusion

Japan is a very disaster-prone country, and we have experienced many disasters. Dialysis treatment is vulnerable to disasters; however, through cooperation among dialysis facilities, we have been able to cope well with disasters. For major disasters, government support is necessary, and we believe that cooperation with the governments is the way forward. Since various forms of disasters are expected to occur in the future, preparation during normal times is necessary.

Abbreviations

CBRNE	Chemical, biological, radiological, nuclear, explosive
GEJED	The Great East Japan Earthquake Disaster
JADP	Japanese Association of Dialysis Physicians
JHAT	Japan Hemodialysis Assistance Team

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I declare that I have no competing interests.

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References

1. White paper on disaster management in Japan 2006. https://www.bousai.go.jp/kaigirep/hakusho/h18/index.htm. Accessed 6 Sep 2022 (**in Japanese**).
2. Dietz RS. Continent and ocean basin evolution by spreading of the sea floor. Nature. 1961;190:854–7. https://doi.org/10.1038/190854a0.
3. Long-term evaluation of earthquakes along the Nankai Trough. 2nd ed. https://www.jishin.go.jp/main/chousa/kaikou_pdf/hyuganada_2.pdf. p. 2013. Accessed 6 Sep 2022 (**in Japanese**).
4. Masakane I, Akatsuka T, Yamakawa T, Tsubakihara Y, Ando R, Akizawa T, et al. Survey of dialysis therapy during the Great East Japan Earthquake Disaster and recommendations for dialysis therapy preparation in case of future disasters. Ren Replace Ther. 2016;2:48. https://doi.org/10.1186/s41100-016-0060-0.
5. Akatsuka T. Disaster response manual for dialysis rooms. Osaka: Medicus Shuppan Publisher Co, Ltd; 2008. (**in Japanese**).
6. Akatsuka T, Shimojo T, Yamada Y, Kugiyama A, Yamakawa T. The record of the Kumamoto earthquake. From the questionaries' survey that was carried out to all dialysis facilities in Kumamoto Prefectures. J Jpn Ass Dial Phys. 2016;31:547 (**in Japanese**).
7. Working group for survey of dialysis therapy during the great East Japan earthquake disaster, Japanese society for dialysis therapy. Survey of dialysis therapy during the Great East Japan Earthquake Disaster and recommendations for dialysis therapy preparation in case of future disasters. Tokyo: Igakutosho-shuppan Ltd; 2013 (**in Japanese**).

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