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Pediatric Peritoneal Dialysis During the Recent Earthquakes in Japan and Recommendations for Future Disaster Preparation

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Patients undergoing dialysis care are vulnerable to disasters, because they need a guaranteed stable and large supply of tap water and electricity. Although hemodialysis (HD) is an in-house treatment that relies largely on the infrastructure for electricity, water supply, and smooth distribution of products, among other necessities, peritoneal dialysis (PD) is a home-based treatment that is less dependent on infrastructure.[1] In pediatric patients, PD, which requires sanitary care by a family member, is a frequently selected treatment option. In the event of a catastrophe, PD might pose a serious issue for pediatric patients because access to PD-related products, including a power supply for automated peritoneal dialysis (APD) and dialysate, is critical. Because PD cancellation leads to death, ensuring electricity, water, and a hygienic environment is critical.

In the current survey, we investigated the issues that pediatric PD patients encountered during 3 recent earthquakes in Japan: namely, the Great Hanshin Awaji Earthquake Disaster (GHAED) in 1995, the Great East Japan Earthquake Disaster (GEJED) in 2011, and the 2016 Kumamoto earthquake (KE) in 2016.[2–4]

RESULTS

Comparison of 3 Earthquakes in Japan

Table 1 shows an outline of the 3 earthquakes. According to the Fire and Disaster Management Agency, the death toll from GEJED was 19,335 people, and 2600 people were missing. The death toll was high in those prefectures that were severely damaged by the tsunami, and the death toll in Iwate, Miyagi, and Fukushima Prefectures in the Tohoku region accounted for 99.6% of the total death toll. The highest death toll in Japan was 105,000 for the Taisho Great Kanto Earthquake, followed by GEJED, which was higher than those of GHAED (6434 dead and 3 missing) and KE (267 dead and 0 missing).

Impact of Earthquakes on the Contact Status

Table 2 shows the contact status for each earthquake. At the time of GHAED, many patients tried to contact the hospital by telephone; most patients were able to get in touch with the hospital within 2 days after the earthquake.

Conversely, at the time of GEJED, telephone connections were compromised because of call restrictions, so it was difficult to confirm patient safety. All patients' conditions were eventually confirmed approximately 1 week after the GEJED. At the time of KE, telephone connections were impossible for the first 4 hours, and gradually the hospital was able to contact 5 patients on the same day of the event.

Table 2 presents a summary comparison of pediatric patients with PD during the 3 earthquakes. At the time of GHAED, 6 of the 7 PD patients were able to continue APD at home. The remaining patient was at the university hospital for PD initiation at the time of the earthquake but had to be transferred to another hospital when the hospital ward closed because of the disaster. Therefore, none of the patients experienced problems in obtaining fluids and other consumables due to the GHAED. All patients who received PD at the time of GEJED had an approximate 2-week inventory of dialysates, dialysis circuits, and dialysis-related consumables at home. There were 2 automatic peritoneal reflux devices in the university hospital's pediatric ward;

Table 1. Comparison of 3 major earthquakes in Japan

	The Great Hanshin Awaji Earthquake Disaster (1995)	The Great East Japan Earthquake Disaster (2011)	The 2016 Kumamoto Earthquake (2016)
Maximum seismic intensity (magnitude)	7 (Mj 7.3)	7 (Mj 9.0)	7 (Mj 7.3)
Time of occurrence	5:46	14:46	1:25
Dead (person)	6434	19,335	267
Missing person (person)	3	2600	0
Victim (person)	43,792	6219	2804
Evacuees at peak time (person)	320,000	470,000	180,000
Fully collapsed (house)	104,906	124,690	8673
Partial destruction (house)	144,294	275,118	34,726
Partly damaged (house)	390,506	764,843	102,479
Electrical	After 6 d all restoration	95% Restoration in 1 wk	Full recovery in 1 wk
Gas	Completion of recovery after ~3 mo	Completion of recovery ~2 mo later	Completion of recovery in ~2 wk
Water supply	Completion of recovery after ~3 mo	Recovery almost completed in ~4 mo	Recovery completed in ~3.5 mo
Fixed communication	~100,000 Lines affected by the disaster	~1.9 Million lines affected by the disaster	~2100 Lines affected
Mobile communication	Approximately 145 stations stop	Approximately 29,000 stations stop	~400 Stations stop

however, the stocks of PD-related consumables were sufficient for several days. At the time of the KE, there was a 2-week inventory of dialysates, dialysis circuits, and dialysis-related consumables at the homes of all patients included in the study. In addition, there were 2 automatic peritoneal perfusion devices in the university hospital's pediatric ward. Following the KE, securing the dialysate was challenging for several days, and the dialysate was used while adjusting its use with our department and nephrology department.

Impact of the Earthquakes on the PD Methods

Evaluation of the PD methods (Table 2) revealed that all patients were receiving APD at the time of the earthquake.

At the time of the GHAED, all the patients receiving APD were in an APD session. During the earthquake, the furniture collapsed in all patients' homes, although they were unhurt and could manage the catheter clamping and tube detachment without problems during APD discontinuation. After the earthquake, 6 of the 7 patients continued APD at home, whereas 1 patient was transferred to a hospital to continue APD. At the time of the GEJED, none of the patients undergoing APD was in an APD session, and there were no serious injuries. After the earthquake, 2 patients continued daytime APD as outpatients at the hospital, 2 patients were hospitalized and continued APD, and 1 patient continued APD using a home generator. The remaining patient who received daytime APD as a hospital outpatient was initially hospitalized for APD continuation because his condition had deteriorated. At the time of the KE, 4 patients were undergoing CAPD and APD, whereas 2 patients were receiving APD alone.

Table 2. Comparison of children with PD in 3 major earthquakes in Japan

	The Great Hanshin Awaji Earthquake Disaster (1995)	The Great East Japan Earthquake Disaster (2011)	The 2016 Kumamoto Earthquake (2016)
Damage status and restoration of medical system	Temporary ward closure	Only for emergency patients Ordering system 1-d stop Oral internal stock 2–3 d	Only for emergency patients 2 Core hospital functions stopped, and transfers and sudden illness patients rushed to university hospital
Patient (person)	7 Children	6 Children	6 Children
PD method	All APD	All APD	4 CAPD+APD 2 APD
Time to make contact with patients	Almost 2 d	All >1 wk	5 Within 1 d 1 Next visit
Situation and PD method after the earthquake	6 Home (APD) 1 Transfer to other hospital (APD)	5 Hospitalized 3 In-patient (APD) 2 Out-patient (APD) 1 Home (APD)	2 Hospitalized (APD) 2 Evacuation shelters (CAPD) 1 Home (CAPD) 1 Evacuation to other prefecture (APD)
Complication			
Infection	None	None	1 Peritonitis 1 Exit-site infection
Tube trouble	None	None	None
Others	Some insomnia or weight gain, 1 hypertension	2 Poor physical condition 1 Poor drainage	None

APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; PD, peritoneal dialysis.

Table 3. Patients' opinions and experiences

Type of opinions and experiences	Patients' opinions
Method	They desire to switch from APD to CAPD with APD.
Network	They desire a system whereby they could contact medical institutions and manufacturers under any circumstances. They desire the list of hospitals that can manage patients requiring PD. They desire to establish a logistic support network.
Manual	They desire a disaster manual for PD patients.
Environment	They could not go to a hospital because the roads were interrupted. They could not be hospitalized easily because they had to take care of their siblings.
Others	They had anxieties associated with the earthquakes.

APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; PD, peritoneal dialysis.

During the earthquake, all patients were receiving APD. Their houses had partially collapsed, but there were no direct injuries to the patients. Importantly, when an APD session was discontinued, the patients were able to cope with the catheter clamping and tube separation without problems. After the earthquake, 2 patients were hospitalized and continued APD. One patient continued treatment at home by switching to CAPD because of power outages. One patient continued treatment at an evacuation shelter by switching to CAPD. One patient, who was at a shelter, continued CAPD in a car using a private power generator. One patient was evacuated outside the prefecture and continued APD.

Complications Due to the Earthquakes

As shown in Table 2, some of the patients who had experienced the GHAED frequently complained of insomnia or weight gain, and 1 patient experienced transient hypertension. However, no patient developed infections such as peritonitis. At the time of the GEJED, 2 patients were in poor physical condition, and 1 patient had poor drainage; however, no patient developed infections. During the KE, none of the patients complained of poor physical condition, poor drainage, or insomnia; however, peritonitis occurred in 1 patient, and an exit-site infection due to the PD catheter occurred subsequently in another patient.

Patients' Opinions Regarding the Impact of Earthquakes on Their Care

The patients expressed their wishes as follows: a system whereby they could contact medical institutions and manufacturers under any circumstances; a list of hospitals that could manage patients requiring PD; and a disaster manual for PD patients (Table 3). They stated that they could not be hospitalized easily because they had to care for their siblings and could not get to a hospital because the roads were blocked. The patients also expressed their desire to switch from APD only to APD with CAPD because of anxiety associated with the earthquakes.

DISCUSSION

The assessment of the aftereffects of the 3 most recent major earthquakes in Japan highlighted the importance of establishing communication methods, a list of acceptable hospitals for pediatric patients requiring PD, a disaster manual, and a network support system in the event of a disaster to address the needs of patients undergoing pediatric PD. It is critical to heed the following points while responding to a disaster.

Contact Method

Accurately confirming the patients' current status is indispensable in disaster response situations, so establishing contact with patients as soon as possible is necessary. However, the telephone will likely not function as a contact method immediately after an earthquake. This survey revealed that connecting by e-mail and text via mobile telephones was relatively easier than calls via mobile telephones and landlines; therefore, it is critical to confirm the e-mail address for the patient emergency contact at medical institutions in advance. At the time of the KE, the lines recovered relatively quickly, which facilitated contacting the patients. The KE was smaller in size than the GEJED; however, measures for emergency restoration had been strengthened to respond to a power outage or a stop wave of base stations due to a break in transmission lines after the GEJED. These precautionary measures relieved many base stations at the KE. At the same time, the manufacturers responded quickly and established disaster countermeasure headquarters immediately after the earthquake. They started securing the safety of the patients, dialysates, and other PD-related consumables. In addition, the manufacturers provided emergency deliveries for consumables, such as dialysates, and provided information to all medical institutions.

Securing PD-Related Items

There were sufficient PD-related items that could last for only several days at the hospital in the present survey; however, the supplies had to be transported to the patients' homes. As the manufacturers responded quickly, there were no shortages of PD-related items at the hospitals. Not all hospitals had the APD device of all manufacturers. In addition, several hospitals experienced cases in which the automatic peritoneal perfusion device in a home setting could not perform at the time of the patient's hospital admission, or could not be deployed to evacuation centers, and the only option was to switch to CAPD. In the current survey, PD-related supplies at the hospitals and the patients'

residences were sufficient for PD performance for at least 1 week. Furthermore, if possible, automatic peritoneal perfusion devices should store all manufacturers' products, and large in-house inventories of dialysates should be stocked within the hospital; however, this approach has several management issues, such as storage space and expiration dates. Nonetheless, adequate preparation for disasters is necessary.

Dialysis Methods in the Event of a Disaster

The dialysis methods present another issue during disasters. Continuation of APD is the safest approach if a stable power supply can be secured. In the event of a major disaster, such as the 3 recent major earthquakes in Japan, long-term power outages are possible. In such cases, a power supply might be secured by visiting a core hospital in a neighboring region to use an emergency power supply for APD. In addition, after the GEJED, nonprofit organizations provided generators to children using home ventilators. This is a good option for children receiving PD, if possible.

When securing a stable power supply becomes difficult, it may be necessary to switch from APD, which requires a power supply, to manual CAPD, which does not require a power supply. In these cases, the CAPD menu has to be set, the patient and the caregivers should receive proper training, and the consumables should be prepared in advance. In addition, if needed, the automatic connection device that requires a power supply should be fully charged to ensure that the device can be used 20 times with full charge. Those CAPD systems that do not use a power supply to connect the device are easier to operate. As a precautionary approach against earthquakes and similar disasters, the patients are instructed on CAPD use at the time of PD initiation or during the periodic peritoneal equilibrium test while they are hospitalized. In addition, the patients receive CAPD-related consumables to store at home. We suggest that this is a necessary approach for disaster preparedness, although CAPD is not usually used, and it might be difficult to operate during disasters.

The survey also revealed that, during the GHAED and KE but not the GEJED, the earthquakes required urgent APD discontinuation. Since the patients had been instructed on applying countermeasures in an emergency, all patients could stop APD without issues. This outcome highlights the significance of PD procedural guidelines when disasters occur, which should be provided to all patients.

Some of the participating patients had trouble with pediatric PD, which is usually performed by a family member. If the procedure cannot be performed by a family member because of a major disaster, medical staff should perform the PD. However, during a major disaster, a large number of patients must be handled for disaster response at medical institutions in the affected area, and some facilities may not be able to secure personnel who are familiar with PD. Furthermore, the medical staff themselves are also affected by the disaster, and they need to devote time and effort to themselves and their families. Dialysis management by the medical staff is expected to be difficult, and it may be necessary to transfer the patient to a hospital in a disaster-free area. Finally, instructing more than 1 person in a family who can manipulate APD during normal conditions is essential.

Secure Locations

In the current survey, the place of dialysis was another issue. One patient developed peritonitis after the KE. The damage due to the earthquake was relatively small, and the patient also had CAPD dialysate stocks; therefore, CAPD was enforced at home. However, it was difficult to secure clean water because of the water outage, to disinfect many times because of few PD-related goods and inventory, and to secure a clean place. The house interior had many dust particles. Ultraviolet irradiation could not be performed because the tube was detached manually due to the power outage. Peritonitis most likely occurred because of the difficulties in performing normal PD cleaning procedures. Another patient had an exit-site infection from the PD catheter. The patient was performing CAPD at an evacuation center; however, unlike performing PD at home and in hospitals, difficulties in securing clean water and space and in using ultraviolet irradiation might likely have caused the exit-site infection from the PD catheter.

In 1 situation in which there was considerable damage caused by the KE, transportation was interrupted because roads were closed. Because people could not move, 1 patient underwent CAPD in the vehicle at the family's request. The family had a private generator and used ultraviolet ray irradiation in tube separation. As the family had experience managing peritonitis contracted by their family pet, the patient's mother applied disinfection measures despite the suboptimal conditions, which might have helped them overcome obstacles during emergency conditions. Therefore, ensuring a proper environment with access to electricity, water, and clean space is critical for performing PD during disasters.

Patient Guidance

Educating the patients' families also plays an important role in emergency response. In the event of a catastrophe, communication with, and visits to, the hospital

may be impossible. Managing meals and medications may be challenging in the event of dialysis interruption. Therefore, advance training for family members is required. A disaster manual is helpful for the patient's family when responding independently during a disaster. A disaster manual for PD, including specifics for efficient correspondence with the manufacturers and various organizations at the time of the disaster, is useful.

Several patients in the survey were undergoing APD during an earthquake, and APD had to be discontinued immediately. The patients were instructed to apply countermeasures in case of emergency; therefore, all patients could stop APD without any problem. Guidance on handling PD in times of emergencies, such as disasters, was essential.

Medical Networks

In the event of a major disaster, evacuation or transfer is considered due to difficulties related to medical provisions, disaster conditions, or the living environment in certain cases. Several patients in the survey had to be evacuated. Because they wanted to relocate to a neighboring area, introduction to the medical institution was relatively smooth. However, evacuation to locations that may be unfamiliar with the patient's medical condition might hinder the selection of, or contact with, a hospital at the time of a disaster. Therefore, a list of hospitals that can accept PD patients, and a support system led by academic societies, are desirable in the event of a major disaster.

In the KE, the medical network had a functioning support system. Based on the instructions of Japan Children's PD/HD Study Group, the Japanese Society for Pediatric Nephrology and the Kyusyu Pediatric Nephrology Study Group offered to accept children, which was encouraging. However, apart from the patients who required hospitalization for peritonitis, children need to be accompanied by their parents, even if they are hospitalized for PD. However, parents should also care for other children in the family. Therefore, survey responses suggested that going to a hospital in a different prefecture was difficult.

In conclusion, we evaluated pediatric patients undergoing PD and the aftereffects in three recent major earthquakes in Japan. Based on the survey, we propose the following actions:

(i) Anytime CAPD: Prepare for CAPD at home at any time regardless of the PD method, and ensure a 2-week supply of dialysate and PD-related consumables required for CAPD.
(ii) Back-up: Establish an acceptable hospital list and support network.
(iii) Contact and cooperation: Be aware of contact methods and cooperate with community hospitals.
(iv) Disaster manual: Create a disaster manual.
(v) Environmental security: Secure a safe dialysis environment and recommend prompt management in hospital.

The survey results should provide useful information on managing pediatric patients with PD for future disasters.

DISCLOSURE

All the authors declared no competing interests.

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SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

Supplementary Methods.

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