

# Patients who cannot Receive Hemodialysis in Neighborhood Dialysis Facilities: Report from the Area Near the Fukushima Nuclear Power Plants

Takaaki Koshiba<sup>1,2\*</sup>,  
Aki Ishida<sup>3</sup>,  
Masayuki Hayashi<sup>4,5</sup>, and  
You Shishido<sup>3</sup>

## Abstract

**Background:** The Sousou area (Sousou) of Fukushima Prefecture, in which the Fukushima nuclear power plant is located, has a general population of 100,000, and approximately 200 hemodialysis (HD) patients. A substantial number of these patients are unable to receive HD at their local HD centers due to the serious shortage of medical staff worsened by the Great East Japan Earthquake and tsunami, and nuclear power plant accident. To receive HD, they must go to the Midorinosato Clinic (MC), a HD center in Miyagi Prefecture, located approximately 30-50 km north of Sousou. The number of such patients is now constantly increasing.

**Methods and findings:** We collected detailed information on 30 consecutive HD patients living in Sousou who were referred to the MC between December 22, 2014 and October 31, 2016. Of them, 10 patients who received HD  $53.7 \pm 18.5$  times on an outpatient basis at the MC were accepted by HD centers in Sousou when spaces became available (Group A). However, no fewer than 12 patients were still receiving HD at the MC as of the end of October 2016 (Group B). In three patients, chronic kidney disease (CKD) was conservatively managed with a view to introduce HD at the MC (Group C). Five patients followed different clinical courses (Group D). Group D included patients who were referred to but could not go to the MC to receive HD for medical reasons such as severe cardiac failure and visual impairment.

**Conclusions:** A solution to the ongoing situation in Sousou where patients cannot receive HD at local facilities has yet to be found.

**Keywords:** Hemodialysis; Nuclear power plant; Dialysis; Chronic kidney disease

**Abbreviations:** CKD: Chronic Kidney Disease; D: Days; DS: Dialysis Session; HD: Hemodialysis; MC: Midorinosato Clinic; Sousou: the Sousou area

- 1 Department of Disaster and Comprehensive Medicine, Fukushima Medical University, Fukushima, Fukushima, Japan
- 2 Department of Nephrology, Dialysis and Vascular Access, Iwai Kyoritsu General Hospital, Iwaki, Fukushima, Japan
- 3 Midorinosato Clinic, Iwanuma, Miyagi, Japan
- 4 Department of Epidemiology, Fukushima Medical University, Fukushima, Fukushima, Japan
- 5 Iwaki Meisei University, Iwaki, Fukushima, Japan

\*Corresponding author: Dr. Takaaki Koshiba

✉ tkoshiba@fmu.ac.jp

Department of Disaster and Comprehensive Medicine, Fukushima Medical University, 1 Hikarigaoka, Fukushima, Fukushima, 960-1295, Japan.

Tel: +81-24-547-1013

Fax: +81-24-547-1991

**Citation:** Koshiba T, Ishida A, Hayashi M, Shishido Y (2017) Patients who cannot Receive Hemodialysis in Neighborhood Dialysis Facilities: Report from the Area Near the Fukushima Nuclear Power Plants. J Clin Exp Nephrol Vol 2 No 4:46.

Received: July 01, 2017, Accepted: July 27, 2017, Published: August 05, 2017

## Introduction

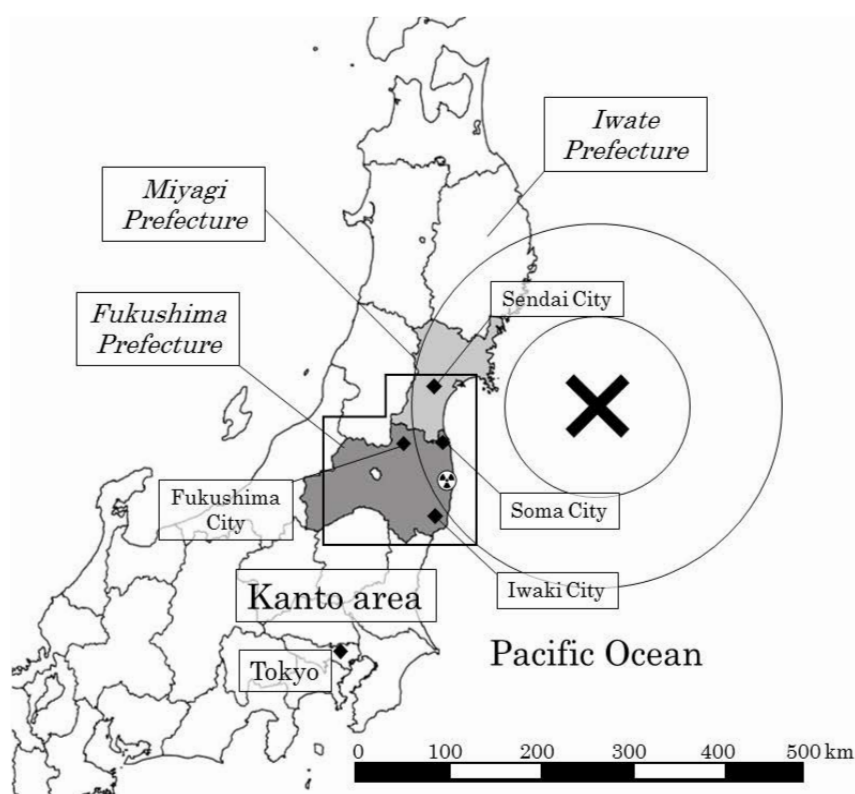
The Sousou area (Sousou) of Fukushima Prefecture, the site of the Fukushima nuclear power plants, is located on the eastern coast of Japan, and is isolated from other districts of Fukushima by the Abukuma mountain range (Figures 1A and 1B) [1]. Due to such geographical restrictions, there has historically been a shortage of medical staff in this area [2]. On March 11, 2011, the Great

East Japan Earthquake and its resulting tsunami struck the coast of Tohoku, subsequently causing the Fukushima nuclear power plant accident [3]. The tsunami caused severe damage to houses on the coast, many residents of which are still living in temporary housing in surprisingly bad conditions [4]. The tsunami also caused transport disruption; the railway link between Sousou and Sendai City was destroyed and the railway link between Sousou and the Kanto area was closed. Now, only the link

between Sousou and Sendai City has been reopened but not the link between Sousou and the Kanto area due to risk of exposure to high doses of radiation [5]. Though it is unlikely that residents near the damaged plant have been severely contaminated by radioactivity, there are still doubts as to the safety of living in Sousou [6,7]. All those disadvantageous conditions have made living in Sousou more difficult than before the disaster. Thus, the previously mentioned issue of medical staff shortage has become even worse. In particular, the shortage of nurses appears to be the most critical [8]. Fukushima Prefecture has reported that the number of nurses working in Sousou was 1188 before the disaster, but this number was reduced to 737 due to the many nurses included in the evacuation that immediately followed the disaster. Since the nurses who evacuated have no desire to return to Sousou, where life has become more difficult as mentioned above, the number of nurses remains low even now [8]. According to the latest report of Fukushima Prefecture, as of

November 1, 2016, five years and eight months after the disaster, no more than 711 nurses were working in Sousou [9].

Before the disaster, approximately 200,000 people lived in Sousou [10]. Six hemodialysis (HD) centers were in operation and approximately 400 patients were on dialysis [11]. About one month after the Fukushima nuclear power plant accident, Japanese authorities declared an area of 20 km surrounding the plant to be an evacuation zone which could only be entered under government supervision (**Figure 1B**) [12]. Because this meant that people could not live in the evacuation zone, two HD centers within the zone had to close (**H-5, 6. Figure 1B**), and the remaining four HD centers became responsible for the care of all HD patients in the area (**H-1, 2, 3, 4. Figure 1B**). Currently, those four HD centers can only take care of an approximate total of 200 patients, and approximately 100,000 people live within the medical districts of those four HD centers [10]. Although



**Figure 1** A Geographic details of Fukushima Prefecture, Sousou and the Midorinosato Clinic (MC) in Iwanuma City

Fukushima Prefecture, indicated in dark grey, is located southwest of the epicenter of the 2011 Great East Japan Earthquake, which is indicated by the "X". Concentric circles show 100 km intervals. Miyagi Prefecture indicated in light grey is located north of Fukushima Prefecture (A). Sousou is located on the coast of the Pacific Ocean. Fukushima City, the capital of Fukushima Prefecture, is 50–60 km west of Sousou. Sousou is isolated from other areas of Fukushima Prefecture including Fukushima City by the Abukuma mountain range indicated by light grey double line and "M" (B). The damaged nuclear power plant indicated by a "hazard mark" is located between a relatively populated region of Sousou including Soma City and Minamisoma City, and Iwaki City. A concentric circles shows 20 km interval (A, B). Hemodialysis (HD) centers in Sousou are indicated by "■" (H-1, 2, 3, 4). Two HD centers are in operation in Soma City (H-1, 2) and Minamisoma City (H-3, 4), respectively. Two hundred patients are on dialysis in those four HD centers in total.

The defunct two HD centers in the evacuation zone are indicated by "■" (H-5, 6). The Midorinosato Clinic (MC) is indicated by "□" and it is highlighted by means of an arrow. The MC is located in Iwanuma City in Miyagi Prefecture indicated in light grey. It is 30–40 km north of Soma City and 50–60 km of Minamisoma City. It takes 60 to 90 min from Soma City and Minamisoma City to the MC by car (B).

the remaining four HD centers had to take on the patients of the defunct centers in the evacuation zone, the total number of patients immediately following the disaster was still within capacity due to the evacuation of several dialysis patients [11].

However, the number of patients on HD in the remaining four centers of Sousou has been constantly increasing since the disaster, though the reason for this remains unclear. The number of patients has increased by no less than 25% compared to that before the disaster in one of those four centers which has experienced the most drastic increase [11]. Thus, HD centers in Sousou have been experiencing an unprecedented imbalance between its increasing number of HD patients and ongoing medical staff shortage [11]. At the end of 2014, the four HD centers finally reached maximum capacity while their operation rate decreased due to the shortage of medical staff. Then, they were forced to stop accepting new patients [11,13]. As a consequence, any new HD patients living in Sousou had to travel outside the area for HD treatment. Currently, most new dialysis patients in Sousou are referred to the Midorinosato Clinic (MC), a HD center in Iwanuma City, near Sendai City in Miyagi Prefecture, approximately 60-90 min north of Sousou by car (**Figure 1B**) [14]. The MC specializes in nephrology, HD, and gastroenterology, but does not have a cardiovascular department. The center treats 240-250 HD patients [15]. New HD patients in Sousou must travel to this center three times a week for HD until vacancies arise in their local centers (**H-1, 2, 3, 4. Figure 1B**). Typically, patients drive themselves to the MC, or are driven by their families, because there is little public transportation. This places a burden on the

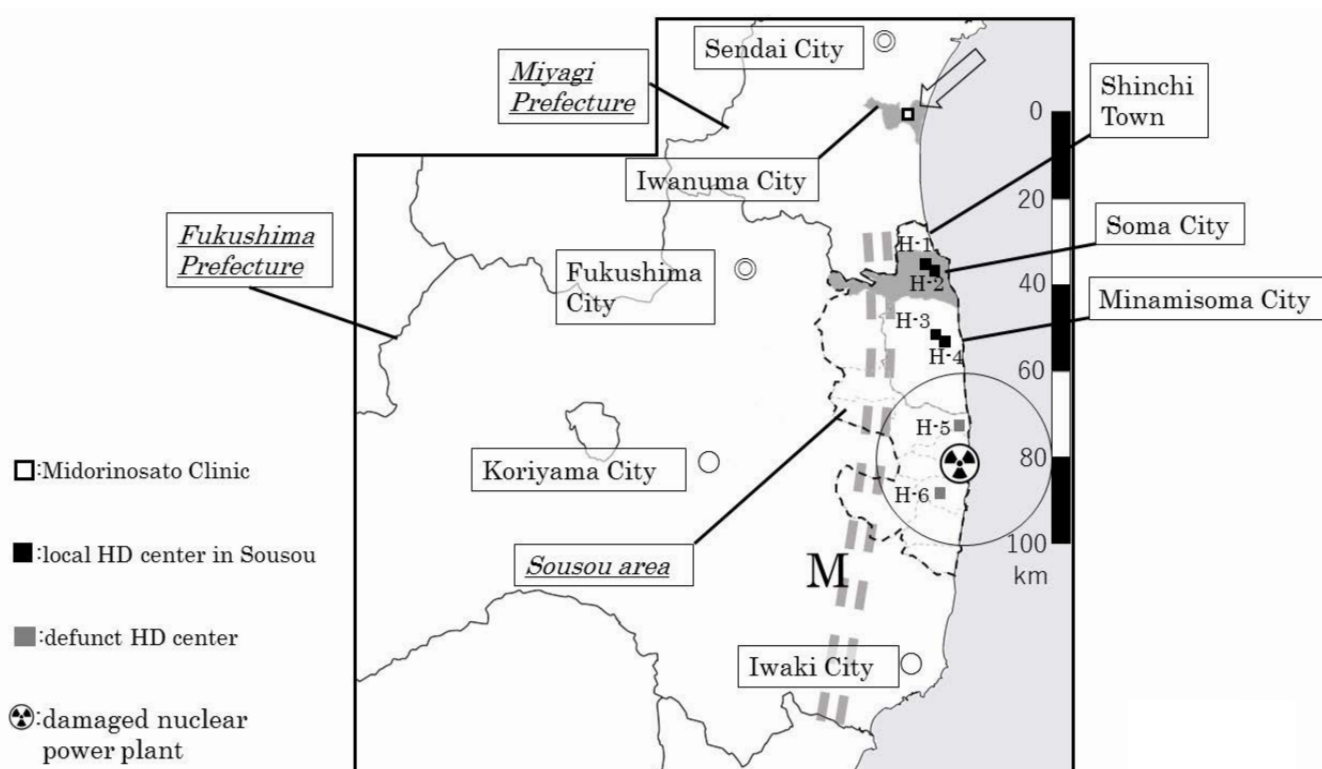
patients, and often their families also. At the time of writing, the number of patients in Sousou who receive HD at the MC is continually increasing. It has doubled roughly every one year. Therefore, there is a growing concern as to the possibility that the MC may also have to stop accepting patients from Sousou in order to keep spaces for their own patients. Should such an action be taken, the situation of the HD patients in Sousou will become even more serious.

To our knowledge, this is the first report on patients who could not receive HD at adjacent HD centers in Sousou due to serious medical staff shortage worsened by the Great East Japan Earthquake, tsunami, and nuclear power plant accident.

## Methods

We collected detailed information on 30 consecutive HD patients living in Sousou who were referred to the MC between December 22, 2014 and October 31, 2016. Information was retrieved from the patients' medical records and letters that were exchanged between the MC and patients' original hospitals. The information obtained included the following: gender, residential address, primary disease, comorbid disorder, date of the first visit to the MC, age at the time of the first visit, dates of the first and the last HD sessions at the MC, the hospitals that sent the patient to the MC, laboratory data, and current HD treatment. We also interviewed patients in order to obtain undocumented information.

This study was approved by the ethics committee of Fukushima Medical University (issue#2560).



**Figure 1B** Geographic details of Fukushima Prefecture, Sousou and the Midorinosato Clinic (MC) in Iwanuma City.

## Results

### Cases

A total of 30 patients living in Sousou were referred to the MC. The mean age at first visit was  $67.4 \pm 11.4$  years, and ranged from 40 to 82 years. They consisted of 19 men and 11 women, and among all patients, 11 were aged 75 years and older. The causes of the primary disease were diabetic nephropathy alone (n=12), combined diabetic nephropathy and nephrosclerosis (n=3), nephrosclerosis alone (n=2), chronic glomerulonephritis alone (n=3), combined chronic glomerulonephritis and nephrosclerosis (n=1), polycystic kidney disease (n=2), IgA nephropathy (n=2), floating kidney (n=1), and unknown (n=4) (**Figure 2**).

### Resident areas of patients

As shown in **Figure 1B**, the MC in Iwanuma City is approximately 30-40 km north of Shinchi Town and Soma City, and 50-60 km north of Minamisoma City [14]. By car it takes approximately one hour from Shinchi Town and Soma City and one hour and a half from Minamisoma City. Minamisoma City is located directly north of the Fukushima nuclear power plant that was damaged by the disaster [14]. In Minamisoma City, there are two centers where approximately 100 patients receive HD in total (**H-3, 4. Figure 1B**) [11]. The population of Minamisoma City is 64197 [10]. Along the coast, Soma City is located north of Minamisoma City. Two centers are in operation in Soma City and treat an approximate total of 100 HD patients (**H-1, 2. Figure 1B**) [11]. The Population of Soma City is 35632 [10]. Further north, Shinchi Town is on the border with Miyagi Prefecture. There is no HD center in this small town. The population of Shinchi Town is 7729 [10], and two centers in Soma City are also responsible for the HD patients living in Shinchi Town (**H-1, 2. Figure 1B**). Of the 30 patients referred

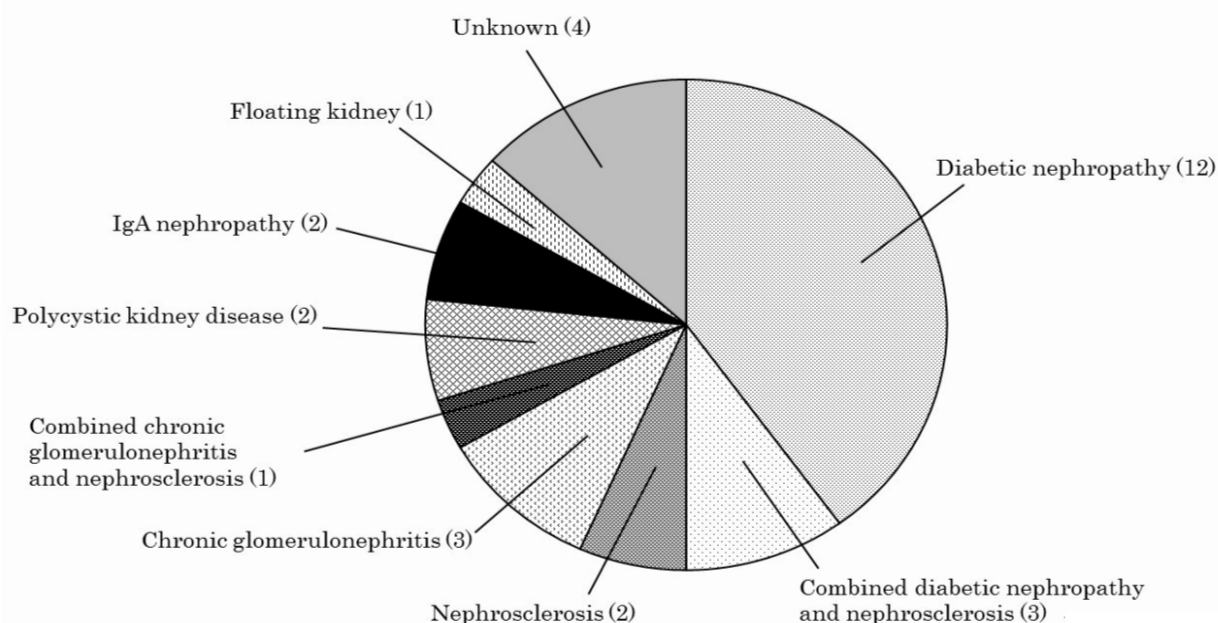
to the MC, five, seven, and 18 patients came from Shinchi Town, Minamisoma City, and Soma City, respectively (**Figure 3**).

### Hospitals that sent patients to the MC

Patients living in Sousou were sent to the MC from several hospitals. Most patients were referred to the MC before construction of vascular access and introduction of HD. 22 patients were sent from Public Soma General Hospital in Soma City (**H-1. Figure 1B**) [16]. Before patients were referred to the MC, HD had been introduced in a patient with chronic kidney disease (CKD) there. It became impossible due to medical staff shortage. University hospitals in Fukushima City (Fukushima Medical University) [17] and Sendai City (Tohoku University Hospital) [18] sent two patients and one patient, respectively, after construction of vascular access. A hospital specializing in renal diseases in Sendai City (Sendai Hospital) [19] sent one patient who had undergone renal transplant, and required HD due to graft loss. Two patients were sent from Soma Central Hospital, a private hospital in Soma City (**H-2. Figure 1B**) [20]. This hospital mainly accepted patients who had already started HD in other hospitals. Kashima Kosei Hospital [21] and National Hospital Organization Miyagi National Hospital [22] each sent one patient. The former hospital is located in Sousou and the latter is in Miyagi Prefecture, but near Sousou. Neither hospital has a HD center (**Figure 4**).

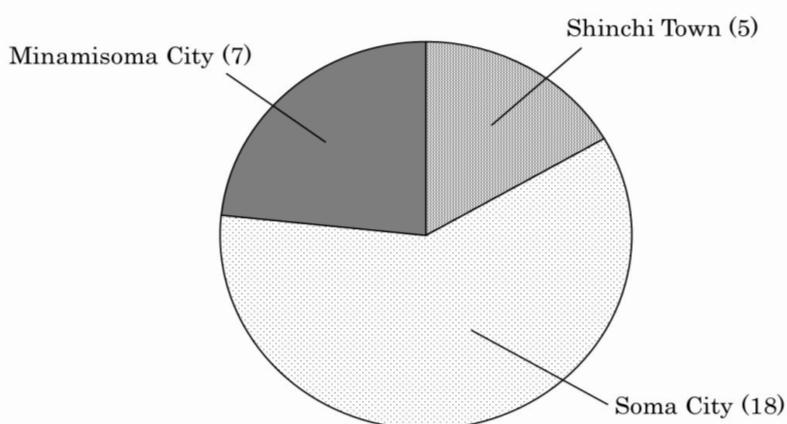
### Individual patient's situation

As of October 31, 2016, 10 of the 30 patients were already accepted by HD centers in Sousou after receiving HD at the MC until the transfer to each center (Group A). 12 patients still continued to receive HD at the MC three times a week on an outpatient basis (Group B). In three patients, CKD was managed

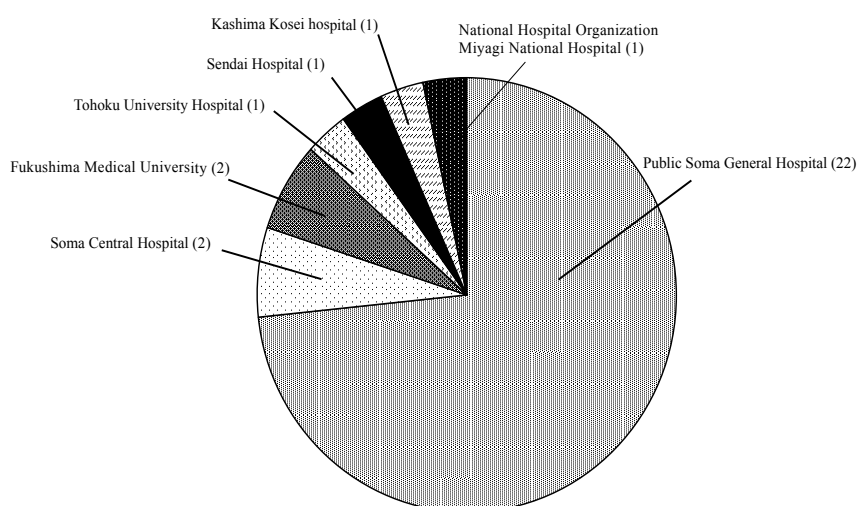


**Figure 2** Resident area of patients with chronic kidney disease (CKD) referred to the Midrinato Clinic (MC)





**Figure 3** Resident area of patients with chronic kidney disease (CKD) referred to the Midrinosato Clinic (MC)



**Figure 4** Hospitals that sent 30 patients with chronic kidney disease (CKD) to the Midrinosato Clinic (MC).

conservatively at the MC with a view to receive HD there (Group C). Another 5 patients followed different clinical courses (Group D). Detail descriptions of each group are shown below (**Figure 5**).

#### Group A Patients accepted by centers in Sousou after receiving HD at the MC

10 patients who could not receive HD in Sousou were treated at the MC on an outpatient basis for  $125.4 \pm 43.3$  days (D) (ranging from 78 to 188 days (D)) and received HD three times a week with a total mean of  $53.7 \pm 18.5$  dialysis sessions (DS). They were accepted by HD centers in Sousou when a vacancy arose due to the death or transfer of a patient. One of the 10 patients was hospitalized for the treatment of renal cell carcinoma for 28 days at a hospital in Sendai specializing in renal diseases [19]. During this period, he did not receive his HD treatment at the MC but at this hospital (Case A-6).

Six of the 10 patients were 75 years and older (Case A-1, 2, 3, 6,

9, 10). All 10 patients travelled to the MC by car. Of them, four patients drove themselves, five were driven by a family member, and one patient was driven by a family member for the first month, but drove himself for the remaining two months.

Of the 10 patients, eight were accepted by Soma Central Hospital (**H-2. Figure 1B**) [20] and two patients were accepted by Public Soma General Hospital (**H-1. Figure 1B**) [16].

#### Group B Patients commuting between Sousou and the MC to receive HD

At the time of writing, 12 patients still continued to commute between Sousou and the MC to receive HD on an outpatient basis. Three patients were 75 years and older (Case B-2, 7, 9). Of the 12 patients, 10 patients expected a vacancy in Sousou whereas two did not because of personal reasons (Case B-11, 12).

Of these 10 patients, to commute to the MC, six patients drove themselves while four patients were driven by family members.

By October 31, 2016, those 10 patients had been on HD three times a week with a total mean of  $59.7 \pm 36.6$  DS over a period of  $139.2 \pm 85.4$  D (ranging from 19 to 308 D). One of the 10 patients was admitted to a general hospital in Sendai for the treatment of gastric cancer after the introduction of HD at the MC. He was hospitalized for 35 days and received HD at this hospital during this period (Case B-2).

Case B-11, one of the remaining two patients, was a 66-year-old male. He started receiving HD at the MC as there was no vacancy available in Sousou. Although Iwanuma City was not close to where he lived, he considered it an advantage because he was able to conceal the fact that he was on dialysis from his neighbors. Then, he decided to continue HD at the MC. He was driven to the MC by a family member and underwent 276 DS during the period of 645 D.

Case B-12, the other of the remaining two patients, was a 43-year-old male. He had started HD 26 years previously. He had previously been receiving nocturnal dialysis at a HD center in Sousou. After the disaster in 2011, his center stopped nocturnal dialysis due to a shortage of medical staff and he received HD during the daytime. In August, 2015, he was referred to the MC for nocturnal dialysis because he had to work during the daytime. He commuted three times a week between Sousou and the MC, and received 130 DS during the period of 303 D. In June 2016, he found a job in Iwanuma City near the MC and moved there to receive his nocturnal dialysis. He drove back to his family home in Sousou twice a week after moving. For as long as there is no HD center in Sousou at which he can receive nocturnal dialysis, it is the patient's intention to remain living in Iwanuma so that he can receive nocturnal dialysis at the MC with minimum inconvenience.

### Group C CKD patients managed conservatively

Three patients with CKD (Case C-1, 2, 3) regularly visited the MC. Their CKDs were conservatively managed with a view to introduce HD. Their serum creatinine levels were 4.26 mg/dl, 4.59 mg/dl, and 6.34 mg/dl, respectively. In Case C-1, vascular access had already been constructed. A 73-year-old female patient with diabetic nephropathy was referred to the MC from a hospital specializing in neurological diseases in Miyagi Prefecture near Sousou [22]. Of note, she had Parkinson's disease, and was completely blind due to retinitis pigmentosa (Case C-2).

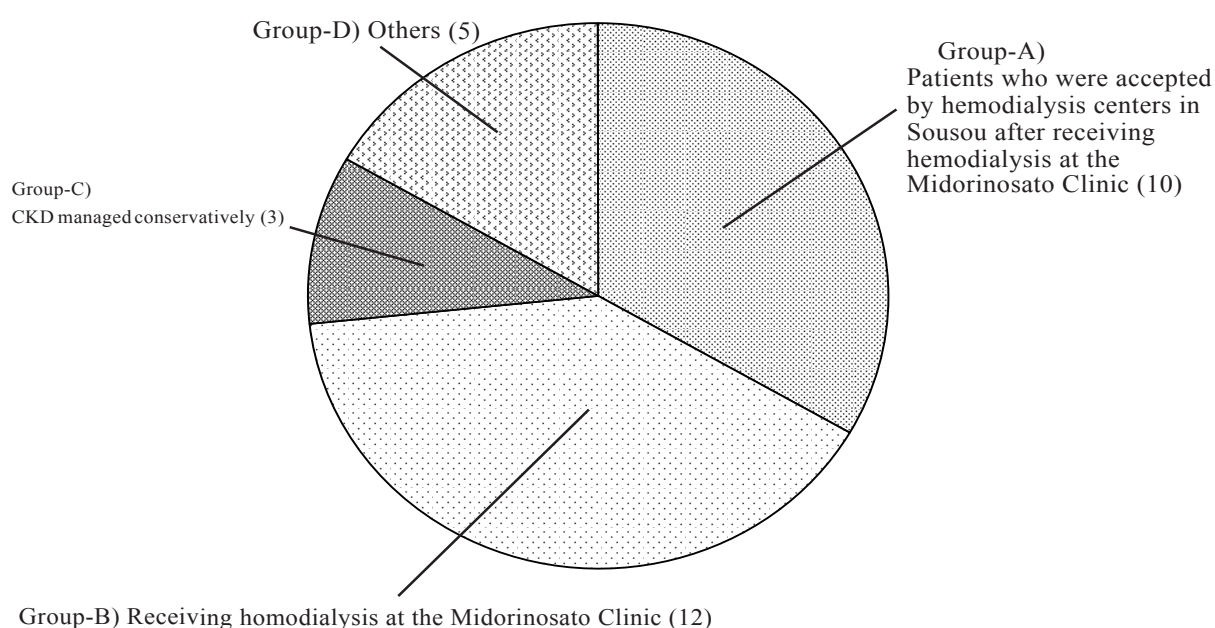
### Group D Patients with different clinical courses

Case D-1, a 78-year-old male patient was hospitalized in the MC to start HD. During hospitalization, he developed cerebral infarction and died of urinary tract infection before receiving HD on an outpatient basis.

Case D-2, a 40-year-old female patient was started on HD at the MC; however, shortly after introduction, breast cancer with lung metastasis was suspected. Therefore, HD at the MC was discontinued and she was transferred to Public Soma General Hospital (H-1, Figure 1B) [16] for examination for malignancy as well as for HD treatment.

In Cases D-3 and D-4, vascular access was constructed in a 51-year-old female patient (D-3) and a 73-year-old male patient (D-4) with a view to begin HD at the MC. However, both patients were admitted to cardiovascular departments of general hospitals in Sousou [16,23] due to heart failure before starting dialysis at the MC. They were scheduled to start HD in these hospitals and treated by cardiovascular specialists.

Case D-5, 73-year-old female patient, was referred to the



**Figure 5** Individual patient's situation  
30 patients with chronic kidney disease were divided into 4 different groups depending on their individual situations.

MC from Public Soma General Hospital (**H-1. Figure 1B**) [16]. However, since she was diabetic and almost completely blind, a discussion was held among the patient, her family, the MC, and the general hospital. Following the conclusion of this discussion, she was scheduled to start HD at the general hospital.

### Increase in the number of patients commuting between Sousou and the MC

Quarterly changes in the number of patients commuting between Sousou and the MC to receive HD. This figure also shows the number of patients who were accepted by the centers in Sousou before October 31, 2016 (Group A) (indicated by white bars), and the number of those who still received HD at the MC at the same date (Group B) (indicated by black bars). At the end of January, 2015, the total number of patients was just two. A constant increase was observed in the total number of patients thereafter until the end of October, 2016, when it reached 12. As for Group B, only one patient received HD at the end of January 2015. A striking increase in the number of patients in Group B was observed at the end of July, 2016, when the number reached 10. Three months earlier, at the end of April, 2016, that number was just four.

## Discussion

As described above, the chronic shortage of medical staff had existed in Sousou, the site of the Fukushima nuclear power plants, which is the most geographically disadvantageous area in Fukushima Prefecture (**Figures 1A and 1B**) [1,2]. Since the Great East Japan Earthquake in 2011 made living in Sousou more difficult, the shortage of medical staff, especially nurses, has become even worse [8,9]. In addition, the two HD centers nearest to the damaged nuclear power plant were forced to close due to the risk of exposure to high levels of radiation (**H-5, 6. Figure 1B**) [11]. Thus, the capacity to accept HD patients in Sousou declined from approximately 400 patients to 200 patients [11]. Since both patients and medical staff were among those who evacuated at the time of disaster, the number of patients immediately following the disaster was actually within the upper limit. However, from that point on, the number of patients requiring HD in the remaining four centers began to continually increase (**H-1, 2, 3, 4. Figure 1B**). Among those four centers, one in Soma City (**H-2 in Figure 1B**) experienced the most drastic increase in the number of patients which increased by no less than 25% compared to before the disaster [11]. It resulted in an unprecedented imbalance between the increasing number of patients and shortage of medical staff. Finally, HD centers in Sousou became unable to respond to the persistently increasing demand and, at the end of 2014, had to stop accepting new patients [11]. New patients on HD in Sousou currently have no choice but to go to the MC, a HD center in Iwanuma City near Sendai in Miyagi Prefecture, approximately 30-50km north of Sousou (**Figure 1B**) [14]. Since there is little public transport in Sousou, patients must shuttle to and from the MC by car. It takes 60 to 90 min each way [14]. Patients either drive themselves or are driven by family members. This places a burden on the patients and/or their family.

### Why a community problem cannot be solved within Fukushima Prefecture?

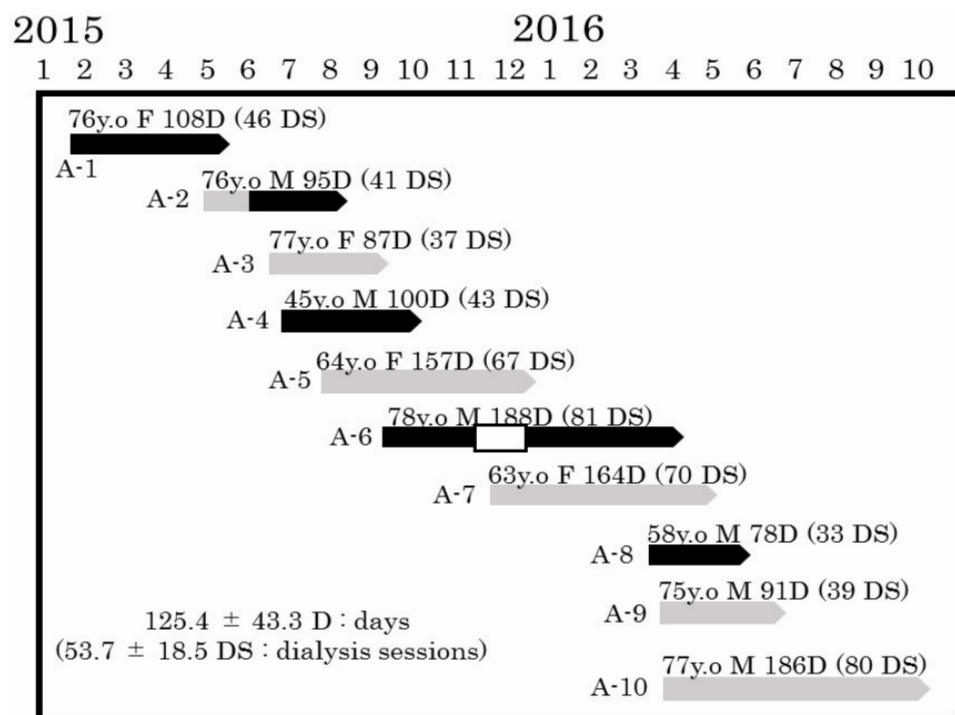
One may question why such a community problem cannot be solved within Fukushima Prefecture. Fukushima City is 50-60 km west of Sousou (**Figures 1A and 1B**) [24]. When patients go to Fukushima City, they must cross the Abukuma mountain range by car. The roads have many twists and turns in the midst of the mountains and often become icy during winter. Due to such extremely hazardous road conditions, it is not realistic for patients to shuttle between Fukushima City and Sousou three times a week, especially if they are driving themselves. In addition, Iwaki City is 80-100 km south of Sousou (**Figures 1A and 1B**) [25]. An expressway has recently been built and shuttling between Iwaki City and Sousou has therefore become much easier [26]. However, the expressway passes close to the damaged Fukushima nuclear power plant, so it is not surprising for patients to hesitate to go to HD centers in Iwaki City frequently. As a reality, the vast majority of patients who required HD were referred to the MC in Iwanuma City, Miyagi Prefecture, not centers in Fukushima City or Iwaki City.

### Potential risks of driving a great distance, across the border between Fukushima and Miyagi prefectures

As mentioned above, it is much more convenient and realistic for patients to travel to the MC in Iwanuma City than it is to travel to centers in Fukushima City or Iwaki City. However, there are still several potential risks of driving a great distance, and across the border, between the two prefectures three times a week for HD.

One of the potential risks is associated with traffic accident. It was not uncommon that patients who went to the MC for HD had to drive themselves despite their old age (75 years and older) (**Case A-1, 2, 6. Figure 6, Case B-2, 7. Figure 7**). Recently, car accidents caused by senior drivers become a significant social issue in Japan [27]. A 75-year-old year male patient (**Case B-7. Figure 7**) crashed into a car in front of him when he was travelling home following a HD session. Dialysis-induced hypotension may increase the risk of car accidents after HD. The risk could be higher especially in aged patients. As described above, the railway link between Sousou and Sendai was destroyed by tsunami at the disaster. A new railway track has been recently built and the railway link was reopened [5]. Iwanuma City has therefore become accessible by train from Sousou. However, the frequency of the trains is only once or twice an hour [28]. In addition, the MC is not within walking distance of Iwanuma Station [15]. It is unlikely that patients will regularly use trains to go to the MC instead of cars. Thus, the worry of further car accidents on the roads between Sousou and Iwanuma involving HD patients, especially elderly patients, remains.

Another potential risk is associated with health emergency. Without doctor's consultation, it is not presently permitted by law for an ambulance to transport a patient from one prefecture to another prefecture. An 80-year-old female patient who was undergoing HD sessions at the MC experienced chest discomfort at home at an early hour (**Case B-9. Figure 7**). She called an



**Figure 6** Patients accepted by centers in Sousou after receiving hemodialysis (HD) at the Midorinosato Clinic (MC) (Group-A)

Each bar indicates when hemodialysis (HD) was initiated and terminated at the Midorinosato Clinic (MC) in Iwanuma City. The black bar represents patients who drove themselves to the MC, and the gray bar represents patients who were driven to the MC by family members. Each bar is accompanied by age, and gender. 10 patients from Sousou were treated at the MC on an outpatient basis for  $125.4 \pm 43.3$  days (D) (ranging from 78 to 188 days(D)) and received HD three times a week with a total mean of  $53.7 \pm 18.5$  dialysis sessions (DS). D and DS of each patient are also shown. The abscissa axis starts from the beginning of January 2015 and terminates at the end of October 2016, and the scale resolution is one month. The white blank on the black bar of patient A-6 indicates discontinuation of HD at the MC due to hospitalization in Sendai Hospital for the treatment of renal cell carcinoma.

ambulance and asked them to take her to the MC. However, because of the above situation, she was taken to a hospital in Sousou which did not have an HD unit. Fortunately, her condition did not require emergent HD and she received a diagnosis of acute diverticulitis. If she had been in a condition which required emergent HD, such as hyperkalemia or heart failure, she could have failed to receive prompt medical attention. To avoid such a scenario from occurring, we believe that an agreement should be made between the two prefectures, allowed for inter-prefectural transport of patients in cases where emergent treatment is required.

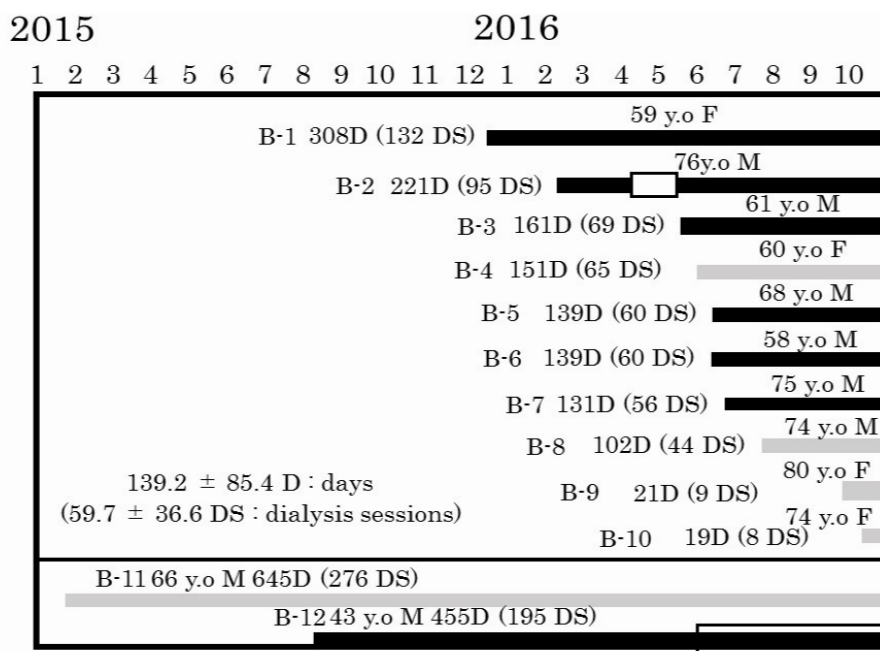
Disasters including the weather can also be a risk factor. Tohoku district was hit by powerful Typhoon No. 10 this past autumn [29]. Since Fukushima and Miyagi Prefectures were located in the path of the typhoon, both medical staff at the MC and patients from Sousou had to carefully prepare for the approaching typhoon. There was a concern about the possibility that the typhoon might interfere with transportation between the MC and Sousou, and at worst patients would not be able to come to the MC to receive HD. Iwate Prefecture, 150 km north of Sousou (Figure 1A),

was severely damaged by the typhoon and at least 11 people were killed [30]. Fukushima Prefecture and Miyagi prefecture were not affected by the typhoon in such a devastating way. The HD patients were able to travel to the MC as usual. From this experience, we learned that preparation is necessary for HD patients who become unable to travel to the MC due to unforeseen circumstances. One possible solution is receiving such patients at HD centers in Sousou at least temporarily. We believe that a discussion should be held in order to establish a system for such circumstances.

### A principle of equality in a medical setting and a priority based on medical reasons

The patients who had received HD at the MC were accepted by centers in Sousou in the order of initiation of HD according to a principle of equality in a medical setting (Figure 6). It is of paramount importance to abide by such a principle. Nonetheless, we realized that not all patients referred to the MC could receive HD there for several medical reasons. For instance, an almost blind patient was referred to the MC, but her disability prevented





**Figure 7** Patients still shuttling between Sousou and the Midorinosato Clinic (MC) (Group-B)

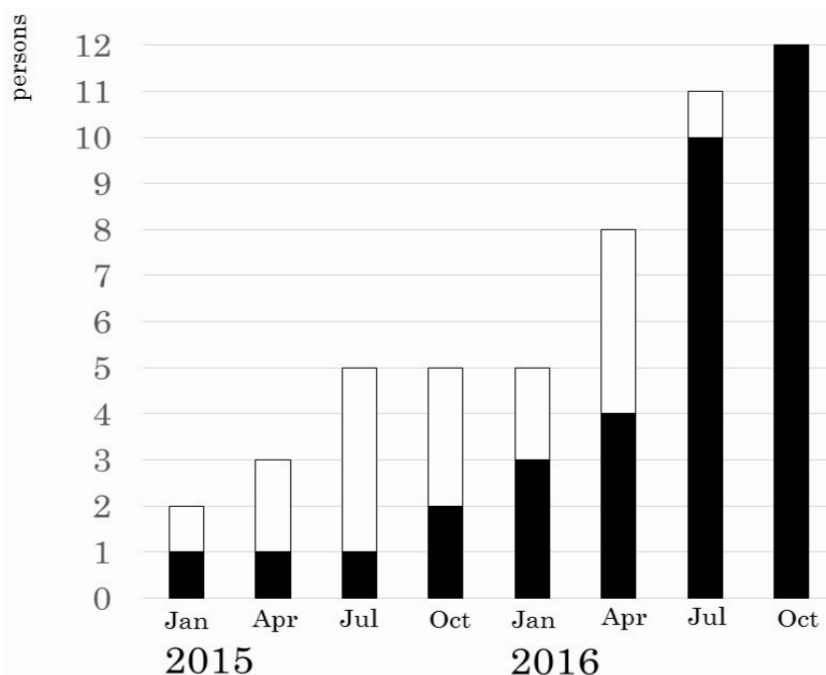
Each bar indicates when hemodialysis (HD) was started at the Midorinosato Clinic (MC) in Iwanuma City. All patients were on HD as of the end of October 2016. The black bar represents patients who drove themselves to the MC, and the gray bar represents patients who were driven to the MC by family members. Each bar is accompanied by age, and gender. 10 patients (Case B-1,2,3,4,5,6,7,8,9,10) had been on HD three times a week with a total mean of  $59.7 \pm 36.6$  dialysis sessions (DS) over a period of  $139.2 \pm 85.4$  days (D) (ranging from 19 to 308 days (D)). D and DS of each patient are also shown. The abscissa axis starts from the beginning of January 2015 and terminates at the end of October 2016, and the scale resolution is one month. Those 10 patients were commuting between Sousou and the MC to receive HD, but expected a vacancy in Sousou. A white blank on the black bar of patient B-2 indicates discontinuation of HD at the MC due to hospitalization in a general hospital for the treatment of gastric cancer. Patients B-11 and B-12 were particular cases. Patient B-11 decided to continue HD at the MC regardless of whether vacancies become available in Sousou. Patient B-12 had an intention of continuing nocturnal dialysis at the MC as no center had resumed providing nocturnal dialysis in Sousou. The white blank on the black bar of patient B-12 indicates the period during which he moved to Iwanuma City to live, returning to his family home in Sousou for visits twice a week.

her from going to the MC for her HD treatment since there was little public transportation between Sousou and the MC. Patients with severe heart dysfunction were also referred to the MC. Careful discussion between the doctors in Sousou and the MC led to the conclusion that those high risk patients must be treated by both dialysis doctors and cardiovascular specialists in a general hospital. According to the conclusion, they were scheduled to start and continue HD in the general hospital of Sousou. Regardless of a principle of equality in a medical setting, such a priority must be carefully considered based on medical reasons.

### The capacity of the MC

At present, an approximate total of 240-250 patients are on dialysis at the MC [15]. The number of patients on dialysis from Sousou was only two at the beginning of 2015. However, it

constantly increased with time and reached no fewer than 12 at the end of October 2016. In particular, at the end of July 2016, a conspicuous increase was observed in the number of patients on dialysis who had not been accepted by centers in Sousou yet (belonging to Group-B) (Figure 8). At the same time, the waiting period before being accepted in centers in Sousou increased. The waiting period in seven (Case B-1, 2, 3, 4, 5, 6, 7. Figure 7) out of 10 patients who were on dialysis but were not accepted by centers in Sousou was longer than the average waiting period required for the 10 patients who had been already accepted by centers in Sousou (125.4 days) (Figure 6). In addition, doctors in Sousou cannot manage all the vascular access problems in their patients and referred their patients to the MC for vascular access treatment. At the MC, the same doctor and medical staff perform both vascular access and HD treatments for a patient.



**Figure 8** Quarterly changes in the number of patients receiving hemodialysis (HD) at the Midorinosato Clinic (MC)

At the end of January 2015, the number of patients shuttling between Sousou and the MC to receive HD was only two. It constantly increased and reached 12 at the end of October 2016. At each time point, the white bar indicates patients who were accepted by centers in Sousou before the end of October 2016. The black bar indicates patients who were still on HD at the end of October 2016. At the end of July 2016, a notable change was seen in the number of patients who were still on HD compared to the end of April 2016 (four at the end of April 2016 vs. 10 at the end of July 2016).

Moreover, their own patients with CKD are treated at the MC. Fifteen patients exhibited serum creatinine level  $>4.0$  mg/dl. Of them, five patients underwent construction of vascular access. In 18 patients, serum creatinine levels were between 3.0 and 4.0 mg/dl. Altogether, demands from Sousou have resulted in the MC almost reaching its maximum capacity. If the demands exceed the maximum capacity of the MC, patients with CKD from Sousou must go further afield, and the situation regarding HD in Sousou will become more serious.

### What are practical solutions?

In this context, practical solutions for this extremely difficult situation are needed. Renal transplantation and peritoneal dialysis are possible solutions. However, the problems in Sousou require urgent solutions since the current demands are resulting in the MC almost reaching maximum capacity. It remains a matter of debate whether the current systems in the Sousou HD centers can be modified to enable the care of a larger number of patients by limited number of medical staff. The introduction of medical clerks and fully automatic consoles may be a prompt and effective solution.

However, a long-term solution is required in addition to these short-term and partial potential solutions. The future situation

in Sousou regarding CKD treatment is unpredictable. For the purpose of estimating the number of HD patients in the very near future, the current number of patients with advanced CKD (for instance, serum creatinine level  $>3.0$  mg/dl) must be determined. In addition, we are currently carefully collecting data to answer the following questions with hopes that we will discover significant clues that will help us to reach a fundamental solution. Why did the imbalance between the numbers of HD patients and medical staff become so serious after the disaster? Was it merely a result of the decrease in the number of HD centers in Sousou caused by the disaster? Did the incidence of CKD increase in Sousou after the disaster? Did the number of HD patients per 100,000 population increase? If so, what is the cause? Is it a natural effect of a rapidly aging society in Sousou? Alternatively, did the disaster affect the health conditions of inhabitants of Sousou in a powerful way?

In conclusion, this is the first report on an extremely serious problem facing HD patients in Sousou, the area surrounding the Fukushima nuclear power plants. A substantial number of patients cannot receive HD at local HD centers due to a serious shortage of medical staff worsened by the Great East Japan Earthquake, tsunami, and nuclear power plant accident. To receive HD, these patients must go to a HD center in Miyagi Prefecture, 30-50km

north of Sousou. The number of patients required to do this is constantly increasing. Despite improvement of infrastructures such as expressway and rail access, the lives of HD patients in Sousou remain very difficult. A solution to this serious situation has yet to be found.

## References

- 1 SOSO BUREAU (2015) Aiba area is like this. Available: <http://sosobureau.yumesoso.jp/aboutsoso>
- 2 Nishikawa Y, Fukuda Y, Tsubokura M, Kato S, Nomura S, et al.(2015) Managing type 2 diabetes mellitus through periodical hospital visits in the aftermath of the Great East Japan Earthquake Disaster: A retrospective case series. PLoS One 10: e0125632.
- 3 Editorial (2012) Lessons of a triple disaster. Nature 483: 123.
- 4 "Records of the Great East Japan Earthquake in March 11, 2011-The second interim report by the detailed version" Soma City.
- 5 The Japan Times (2016) Section of East Japan Railways' Joban Line, suspended since 2011 quake, partially reopens.
- 6 Distribution Map of Radiation Dose. Available: <http://ramap.jmc.or.jp/map/>
- 7 Kazuhiro AKIMOTO (2014) Resuspension and Transfer of Radioactive Particulate Matter and Subsequent Secondary Contamination. Jpn J Health Phys 49: 17-28.
- 8 Fukushima Minpo (2015) 24 August 2015. p1 (in Japanese).
- 9 Official Website for Revitalization in Fukushima. Available: <https://www.pref.fukushima.lg.jp/sec/21045d/kansenkangokango144.html>.
- 10 Fukushimaken gennju jinkou chousa nennpou (2017). Available: <https://www.pref.fukushima.lg.jp/sec/11045b/16890.html>.
- 11 Koshiha T, Nishiuchi T, Akaiha H, Haga N, Kojima Y, et al.(2016) Evaluating the imbalance between increasing hemodialysis patients and medical staff shortage after the Great East Japan Earthquake: Report from a hemodialysis center near the Fukushima nuclear power plants. Ther Apher Dial 20: 127-134.
- 12 McCurry J (2011) Anxiety over radiation exposure remains high in Japan. Lancet 378: 1061-1062.
- 13 Fukushima Minyu (2015) 6 September 2015. p2 (in Japanese).
- 14 Japan AB. Miyagiken Iwanumashi kara Fukushimaken no toshie. Available: <http://www.japanab.com/from/24-11591710-08>.
- 15 Midorinosato Clinic (2017) Available: <http://www.midorino-sato.com/>.
- 16 Public Soma General Hospital (2017). Available: <http://www.bb.soma.or.jp/~psghjim1/index.html>.
- 17 Fukushima Medical University (2017). Available: <https://www.fmu.ac.jp/univ/en/>.
- 18 Tohoku University Hospital (2017). Available: <http://www.hosp.tohoku.ac.jp/en/>.
- 19 Sendai Hospital (2017) Available: <http://sendai.jcho.go.jp/>.
- 20 Soma Central Hospital (2017) Available: <http://www.tachiya.or.jp/>.
- 21 Kashima Kosei Hospital (2017) Available: <http://www.ja-fkosei.or.jp/kashima/index.html>.
- 22 National Hospital Organization Miyagi National Hospital (2017) Available: <http://www.mnh.go.jp/>
- 23 Minamisoma General Hospital (2017) Available: <https://www.city.minamisoma.lg.jp/index.cfm/30,33591,203,494,html>.
- 24 Fukushimaken Fukushima-shi kara Fukushimaken no toshie. Available: <http://www.japanab.com/from/08-11606572-08>.
- 25 Fukushimaken Iwakishi kara Fukushimaken no toshi e. Available: <http://www.japanab.com/from/08-11616251-08>.
- 26 The Japan Times (2015) Completion of Joban Expressway stirs Tohoku reconstruction hopes. Available: <http://www.japantimes.co.jp/news/2015/03/02/national/completion-joban-expressway-stirs-tohoku-reconstruction-hopes/#.WRHW3NG1upo>.
- 27 The Japan Times (2016) Safe driving by senior citizens. Available: <http://www.japantimes.co.jp/opinion/2016/11/26/editorials/safe-driving-senior-citizens/#.WRHZ2tG1upo>.
- 28 Ekikarajikokuhyou (2017) Available: <http://ekikara.jp/newdata/line/1301241.htm>.
- 29 The Japan Times (2016) Strong Typhoon Lionrock lashes Tohoku.
- 30 The Japan Times (2016) Typhoon Lionrock leaves 11 dead, three missing in flooded North Japan.

## Acknowledgements

We thank Mr. H Hasegawa and Mr. S Okabe, core members of Fukushima Prefecture Association of Kidney Disease Patients, for helpful discussion.

## Conflict of Interest

There is no conflict of interest to disclose.