Survey of Preventable Disaster Deaths at Medical Institutions in Areas Affected by the Great East Japan Earthquake: Retrospective Survey of Medical Institutions in Miyagi Prefecture

Satoshi Yamanouchi, MD, PhD;[1] Hiroyuki Sasaki, MD, PhD;[2] Hisayoshi Kondo, MD, PhD;[3] Tomohiko Mase, MD, PhD;[4] Yasuhiro Otomo, MD, PhD;[5] Yuichi Koido, MD, PhD;[3] Shigeki Kushimoto, MD, PhD[6]

1. Emergency Center, Osaki Citizen Hospital, Osaki, Japan
2. Division of International Cooperation for Disaster Medicine, International Research Institute of Disaster Science, Tohoku University, Sendai, Japan
3. Institute for Clinical Research, National Disaster Medical Center, Tokyo, Japan
4. Center for Research and Training on Community Health Services During Disaster, Iwate Medical University, Shiwa-gun, Japan
5. Department of Acute Critical Care and Disaster Medicine, Tokyo Medical and Dental University, Tokyo, Japan
6. Division of Emergency and Critical Care Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan

Correspondence:
Satoshi Yamanouchi, MD, PhD
Emergency Center, Osaki Citizen Hospital
3-8-1 Honami, Furukawa, Osaki 989-6183, Japan
E-mail: y-3104@yc4.so-net.ne.jp

Conflicts of interest: This study was supported by a Ministry of Health, Labour, and Welfare (Tokyo, Japan) Grant-in-Aid for Scientific Research (Research on Regional Medicine) and medical research funding support from the Gonryo Foundation (Sendai, Japan) for the Promotion of Medical Science. The authors declare no conflicts of interest.

Keywords: disaster medicine; disaster-relief planning; disaster victims; earthquake; tsunami

Abbreviations:
BCP: business continuity plan
DBH: disaster base hospital
MHLW: Ministry of Health, Labour, and Welfare
PDD: preventable disaster death

Abstract

Introduction: In 2015, the authors reported the results of a preliminary investigation of preventable disaster deaths (PDDs) at medical institutions in areas affected by the Great East Japan Earthquake (2011). This initial survey considered only disaster base hospitals (DBHs) and hospitals that had experienced at least 20 patient deaths in Miyagi Prefecture (Japan); therefore, hospitals that experienced fewer than 20 patient deaths were not investigated. This was an additional study to the previous survey to better reflect PDD at hospitals across the entire prefecture.

Method: Of the 147 hospitals in Miyagi Prefecture, the 14 DBHs and 82 non-DBHs that agreed to participate were included in an on-site survey. A database was created based on the medical records of 1,243 patient deaths that occurred between March 11, 2011 and April 1, 2011, followed by determination of their status as PDDs.

Results: A total of 125 cases of PDD were identified among the patients surveyed. The rate of PDD was significantly higher at coastal hospitals than inland hospitals (17.3% versus 6.3%; $P < .001$). Preventable disaster deaths in non-DBHs were most numerous in facilities with few general beds, especially among patients hospitalized before the disaster in hospitals with fewer than 100 beds. Categorized by area, the most frequent causes of PDD were: insufficient medical resources, disrupted lifelines, delayed medical intervention, and deteriorated environmental conditions in homes and emergency shelters in coastal areas; and were delayed medical intervention and disrupted lifelines in inland areas. Categorized by hospital function, the most frequent causes were: delayed medical intervention, deteriorated environmental conditions in homes and emergency shelters, and insufficient medical resources at DBHs; while those at non-DBHs were disrupted lifelines, insufficient medical resources, delayed medical intervention, and lack of capacity for transport within the area.

Conclusion: Preventable disaster death at medical institutions in areas affected by the Great East Japan Earthquake occurred mainly at coastal hospitals with insufficient medical resources, disrupted lifelines, delayed medical intervention, and deteriorated environmental conditions in homes and emergency shelters constituting the main contributing factors. Preventing PDD, in addition to strengthening organizational support and functional enhancement of DBHs, calls for the development of business continuity plans (BCPs) for medical facilities in directly affected areas, including non-DBHs.

Yamanouchi S, Sasaki H, Kondo H, Mase T, Otomo Y, Koido Y, Kushimoto S. Survey of preventable disaster deaths at medical institutions in areas affected by the Great East Japan Earthquake: retrospective survey of medical institutions in Miyagi Prefecture. *Prehosp Disaster Med*. 2017;32(5):1-8.

Received: August 30, 2016
Accepted: December 1, 2016

doi:10.1017/S1049023X17006501

Introduction

The Great East Japan Earthquake that occurred on March 11, 2011 was a magnitude (M) 9.0 earthquake, which together with a massive tsunami resulted in widespread devastation that left approximately 18,500 people dead or missing,[1] with more than 90% of these deaths caused by drowning in the tsunami.[2]

In comparison with reports of earthquake damage from large-scale earthquake disasters that have occurred globally since 2000 (eg, the 2004 Indian Ocean Earthquake, a M9.1 earthquake that occurred off the coast of Sumatra in which approximately 286,000 people perished, over 283,000 of whom died in the resulting tsunami;[3] the 2008 Sichuan Earthquake, a M8.0 earthquake that occurred in China's Sichuan Province, claiming over 69,000 lives, 60,000 of whom died by being crushed under falling buildings;[4] and the 2010 Haiti Earthquake, a M7.0 earthquake that occurred in the Republic of Haiti, claiming between 10,000 and 31,600 lives, the majority of whom died by being crushed under falling buildings[5]), a characteristic of the Great East Japan Earthquake was that it occurred during winter in a cold region and was accompanied with extensive tsunami damage.[6]

In addition, with regard to preventable disaster deaths (PDDs), the authors previously reported the results of a retrospective preliminary investigation of Miyagi Prefecture (Japan), which experienced the highest numbers of dead or missing people during the Great East Japan Earthquake.[6] Preventable disaster deaths were defined as "deaths occurring during a disaster that would have been preventable under normal regional and hospital environmental conditions and medical systems," and the 25 hospitals selected for inclusion in the study were either disaster base hospitals (DBHs) or those that had experienced at least 20 patient deaths between March 11, 2011 and April 1, 2011. Preventable disaster deaths at medical institutions in areas affected by the Great East Japan Earthquake occurred mainly at coastal hospitals, with delayed medical intervention and a lack of resources in the medical facilities constituting the major potential contributing factors.[6] A limitation of this previous report was that because medical institutions that experienced fewer than 20 patient deaths were not considered in the survey, the possibility remained that important factors for PDD may have been hidden in such institutions, and that the results might not reflect PDD at hospitals across the entire prefecture.[6]

The aim of this study, therefore, was to clarify the incidence and causes of PDD at medical institutions in Miyagi Prefecture, which was the worst-hit of the prefectures affected by the Great East Japan Earthquake, by conducting an additional survey of hospitals that experienced fewer than 20 patient deaths. In addition, a survey of the number of beds at the time of the earthquake in the participating hospitals was conducted, and the results were examined in conjunction with the previous survey results in order to improve disaster medical systems.

Methods

In 2012, a preliminary study to lay the groundwork for a field survey of PDDs in Miyagi Prefecture resulting from the Great East Japan Earthquake was conducted. A questionnaire survey regarding the number of in-hospital patient deaths between March 11, 2011 and April 1, 2011 was administered to all 147 hospitals in Miyagi Prefecture, with responses obtained from 121 hospitals (a collection rate of 82.3%).[7] In 2014, an on-site survey was conducted with the participation of 25 hospitals that either served as DBHs or experienced at least 20 patient deaths between March 11, 2011 and April 1, 2011. A database was created based on the medical records of 868 patient deaths, followed by the determination of their status as PDDs.[6] Disaster base hospitals are hospitals that are equipped to play a central role in regional medical activities in times of disaster, such as by dispatching medical teams and accepting and transporting seriously sick and injured patients within the disaster area.[8] Designations have taken place in Miyagi Prefecture since 1997, and 14 hospitals had been designated as DBHs at the time of the Great East Japan Earthquake.

In 2015, a request to participate in an on-site survey was sent to 82 hospitals consisting of: (1) 75 hospitals that had yet to participate in the survey out of the 100 hospitals reporting patient deaths from among the 121 hospitals from which questionnaire responses were collected at the time of the previous survey; and (2) a further seven hospitals that had not responded to the questionnaire. On-site surveys were conducted with the 50 hospitals from which consent was obtained (45 hospitals from which questionnaire responses had been collected and five hospitals from which questionnaire responses had not yet been collected), and determination of PDD with regard to patient deaths (375 patients) was carried out. At the same time, 21 hospitals reporting zero patient deaths on the previous questionnaire were added, bringing the total number of hospitals considered in this additional survey to 71.

The number of in-hospital patient deaths identified to have occurred in Miyagi Prefecture in the wake of the disaster up to April 1, 2011 was 1,408 (data from 126 hospitals, including five hospitals from which questionnaire responses were not collected). Combining the results of the surveys conducted in 2014 and 2015, the total 1,243 responses (data from 96 hospitals) were considered to be pertinent to this survey (868 from the 2014 survey + 375 from the 2015 survey/1,408 deaths = 88.3%). A database of medical records for all patient deaths during the same period was prepared based on on-site surveys. Participating hospitals were classified as "coastal" or "inland" based on their positional relationship with the tsunami inundation area (Figure 1). Database items comprised: sex; age; inpatient or outpatient death; date of hospitalization (inpatient deaths) or date of outpatient visits (outpatient deaths); date and time of death; diagnosis on initial examination; diagnosis at death; course from hospitalization to death; relationship between cause of death and disaster; whether the case was PDD; and, if so, the cause of PDD. With regard to PDD, cases were classified as "PDD," "high possibility of PDD," "cannot rule out PDD," or "not PDD." The "PDD" and "high possibility of PDD" cases were totaled to provide the overall number of PDD cases. Evaluation of cases as PDD was determined in discussion with two disaster health care professionals responsible for the hospital surveys.

Final determination of PDD classification was carried out based on the created database in consultation with 10 disaster health care professionals (in 2014) and eight disaster health care professionals (in 2015). Preventable disaster death cases were further classified based on origin of the cause of PDD (prehospital, in-hospital, or post-hospital) and by cause (Table 1). The cause categories, as well, were classified by keywords, including the wording listed in the database based on the discussions carried out with 10 disaster health care professionals in 2014.

In addition, the number of beds at each hospital at the time of the disaster (ie, of general beds, long-term care beds, psychiatric beds, infectious disease beds, tuberculosis beds, and total beds) was surveyed. Here, "general beds" refers to beds primarily for patients

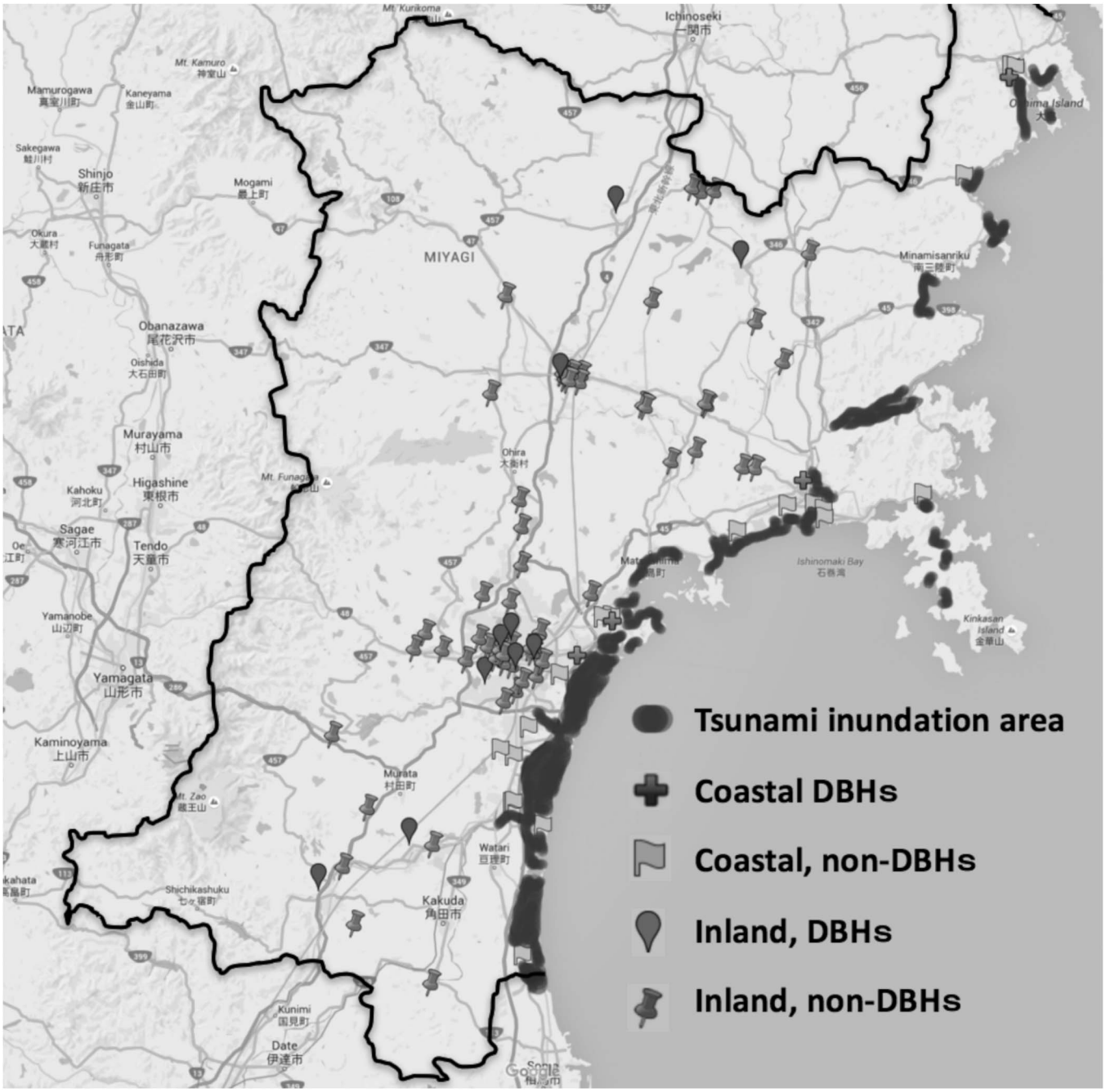

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Figure 1. Location of Participating Hospitals in the Miyagi Prefecture Tsunami Inundation Area.
Abbreviation: DBH, disaster base hospital.

suffering from acute diseases, and, by the Medical Service Act designation, those other than long-term care beds, psychiatric beds, infectious disease beds, and tuberculosis beds.[9]

The present study was carried out with Ethics Committee approval of the individual participating hospitals and the Tohoku University School of Medicine (Sendai, Japan).

Analysis of contingency tables was performed using either Pearson's chi-square test or Fisher's exact test, while the Mann-Whitney U test was used as a non-parametric test for two independent groups. Statistical analysis was performed using GraphPad Prism 7.0a (GraphPad Software; San Diego, California USA) with the level of significance at $P < .05$. The number of beds and age groups are represented as medians (interquartile range).

Results

By medical institution, the number of beds at the time of the earthquake is shown in Table 2 and e-Table 1 (e-Tables available online only). General beds and total beds were significantly more numerous in DBHs than in non-DBHs ($P < .001$), while no significant difference was observed in terms of the number of beds between coastal and inland hospitals (Table 2). Psychiatric beds

Origin	Cause
Prehospital	Delayed medical intervention.
	Deteriorated environmental conditions in homes and emergency shelters.
	Insufficient support for vulnerable people (those requiring evacuation assistance).
	Cessation of treatment for chronic disorders (chronic renal failure, respiratory failure, etc).
	Delayed decision by health care professional regarding the need for hospitalization.
	Delayed rescue.
	Lack of prevention and education.
	Cessation of regular medication.
	Lack of means of transport (for patients requiring hospitalization).
In-hospital	Insufficient medical resources.
	Disrupted lifelines.
	Scaled down life-sustaining treatment.
	Shortage of human resources.
	Inadequate medical care.
Post-hospital	Lack of capacity for transport within the area.
	Lack of capacity for transport out of the area.

Table 1. Causes of PDD
Abbreviation: PDD, preventable disaster death.

	Total Beds		General Beds	
	Hospitals	Beds	Hospitals	Beds
DBHs	14	426.5	14	426.5
		[312.8-532][a]		[312.8-532][b]
Non-DBHs	82	120.5	60	80
		[80-200]		[50-139.5]
Coastal	23	200	20	160
		[120-357]		[64.5-376.5]
Inland	73	123	54	92
		[81-279.5]		[52.3-300]

Table 2. Number of Beds by Medical Institution
Abbreviation: DBH, disaster base hospital.
[a] $P < .001$ vs total non-DBH beds.
[b] $P < .001$ vs general non-DBH beds.

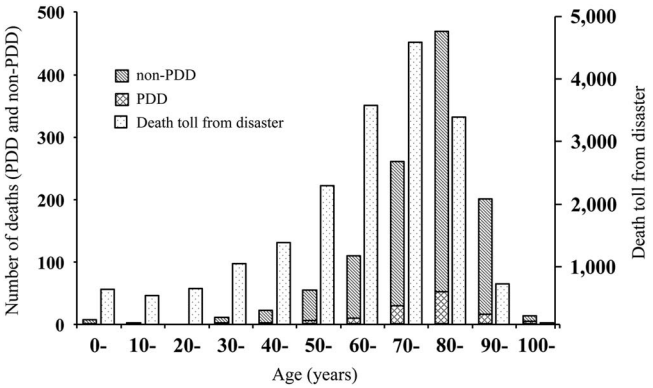

Figure 2. Age Distribution of PDDs, Disaster-Related Deaths, and Patient Deaths in Miyagi Prefecture.
Abbreviation: PDD, preventable disaster death.

were significantly more numerous in non-DBHs than in DBHs ($P = .0056$; e-Table 1 [e-Tables available online only]).

The 1,243 patient deaths at the participating hospitals included 658 men, 584 women, and one patient whose sex could not be identified. The median age (inter-quartile range) of patients who died in-hospital, excluding six cases whose ages were not identified, was 82 years (74-88 years), with the peak age group being made up of 80 to 89-year-olds, and those aged ≥60 years accounting for 91.8% of all deaths, those aged ≥70 years accounting for 82.3%, and those aged ≥80 years accounting for 59.6% (Figure 2). The median age of PDD cases, excluding one case whose age was not identified, was 82 years (76-87 years), with the peak age group being made up of 80 to 89-year-olds, and those aged ≥60 years accounting for 93.5% of all deaths, those aged ≥70 years accounting for 85.4%, and those aged ≥80 years accounting for 60.5% (Figure 2).

Table 3 shows the number of patient deaths and PDD by medical institution according to location (coastal or inland) and function (DBHs or non-DBHs). Of 1,243 patient deaths, 125 (10.1%) were determined to be PDD.

PDD by Function and Location of Medical Institution

Analysis of the relationship between type of medical institution and PDD showed a significantly higher rate of PDD at coastal hospitals compared to inland hospitals (17.3% versus 6.3%; $P < .001$; Table 4), while no difference was observed in overall PDD incidence between DBHs and non-DBHs.

PDD in Non-DBHs by Number and Classification of Beds

In non-DBHs, categories were created for number of general beds and compared for incidence of PDD. The proportion of deaths accounting for PDD was found to correlate inversely with the number of general beds ($P = .03$; Table 5). While analysis of the proportion of PDD in relation to the presence or absence of long-term care beds found that the proportion of PDD was significantly higher ($P = .0035$) in hospitals equipped with long-term care beds, no clear relationship was found with respect to the number of beds (e-Table 2; e-Tables available online only). Analysis of the proportion of PDD in relation to the presence or absence of psychiatric beds did not discern any significant difference in the proportion of PDD for psychiatric beds (e-Table 3; e-Tables available online only).

Timing of Hospitalization (Outpatient Visits) in PDD Cases

At DBHs, post-disaster hospitalization was prevalent at both coastal and inland DBHs (91.4% and 96.3%, respectively),

				PDD			
		No. of Hospitals	No. of Patient Deaths	Definitely PDD	High Possibility of PDD	PDDs n (%)	Cannot Rule Out PDD
Coastal	DBHs	4	205	15	20	35 (17.1%)	12
	Non-DBHs	19	217	15	23	38 (17.5%)	9
Inland	DBHs	10	347	15	12	27 (7.8%)	5
	Non-DBHs	63	474	11	14	25 (5.3%)	17
Total		96	1,243			125 (10.1%)	

Table 3. Number of PDDs by Function and Location of Medical Institution
Abbreviations: DBH, disaster base hospital; PDD, preventable disaster death.

	Patient Deaths	PDD, n (%)
Coastal	422	73 (17.3)[a]
Inland	821	52 (6.3)
DBHs	552	62 (11.2)
Non-DBHs	691	63 (9.1)

Table 4. PDD by Function and Location of Medical Institution
Abbreviations: DBH, disaster base hospital; PDD, preventable disaster death.
[a] P < .001 vs inland.

Beds	Hospitals	Patient Deaths	PDD, n (%)
300-	7	183	8 (4.4)
200-299	3	51	4 (7.8)
100-199	14	116	10 (8.6)
1-99	36	286	37 (12.9)
0	22	55	4 (7.3)

Table 5. PDD in Non-DBHs by Number of General Beds
Abbreviations: DBH, disaster base hospital; PDD, preventable disaster death.

while a higher proportion of cases at non-DBHs involved pre-disaster hospitalization (57.9% and 36.0%, respectively; Table 6). At non-DBHs, while the number of general beds was not found to be associated with the proportion of cases involving pre-disaster hospitalization, more victims had been hospitalized prior to the disaster in hospitals with fewer than 100 general beds (Table 6). In terms of the timing of hospitalization (outpatient visits) for PDD cases in non-DBHs with long-term care beds, more victims had been hospitalized prior to the disaster (e-Table 4; e-Tables available online only).

		Pre-Disaster	Post-Disaster	Proportion Pre-Disaster (%)
Coastal	DBHs	3	32	8.6[a]
	Non-DBHs	22	16	57.9
Inland	DBHs	1	26	3.7[b]
	Non-DBHs	9	16	36.0

Table 6a. Timing of Hospitalization (Outpatient Visits) in PDD Cases
Abbreviations: DBH, disaster base hospital; PDD, preventable disaster death.
[a] P < .001 vs coastal non-DBHs.
[b] P = .004 vs inland non-DBHs.

Beds	Pre-Disaster	Post-Disaster	Proportion Pre-Disaster (%)
300-	1	7	12.5
200-299	2	2	50
100-199	4	6	40
1-99	23	14	62.2

Table 6b. Timing of Hospitalization (Outpatient Visits) in PDD Cases by Number of General Beds in Non-DBHs
Abbreviations: DBH, disaster base hospital; PDD, preventable disaster death.

Origin of Cause of PDD

In DBHs, the cause of PDD originated in the prehospital setting in the majority of cases, while in non-DBHs, the cause most frequently originated in an in-hospital setting (P < .001; Table 7). Among non-DBHs, the proportion of causes of

		Origin of Cause of PDD			
		Prehospital	In-Hospital	Post-Hospital	Total
Coastal	DBHs	25	13	2	40
	Non-DBHs	11	26	8	47
Inland	DBHs	21	8	3	32
	Non-DBHs	14	15	10	37
DBHs		46	21	5	72
Non-DBHs		25	41	18	84

Table 7a. Origin of Cause of PDD (Some Overlap)
Abbreviations: DBH, disaster base hospital; PDD, preventable disaster death.

	Origin of Cause of PDD			
Beds	Prehospital	In-Hospital	Post-Hospital	Total
300-	8	3	1	12
200-299	2	2	2	6
100-199	6	4	3	13
1-99	8	28	9	45

Table 7b. Origin of Cause of PDD in Non-DBHs by Number of General Beds (Some Overlap)
Abbreviations: DBH, disaster base hospital; PDD, preventable disaster death.

PDD originating in-hospital was highest in hospitals with fewer than 100 general beds and hospitals with long-term care beds (Table 7; e-Table 5 [e-Tables available online only]).

Causes of PDD

With regard to prehospital settings, the primary causes listed were delayed medical intervention (46 cases) and deteriorated environmental conditions in homes and emergency shelters (24 cases); with regard to in-hospital settings, disrupted lifelines (40 cases) and insufficient medical resources (37 cases) were listed; and with regard to post-hospital settings, a lack of capacity for transport within the area (14 cases) was listed (Table 8).

Categorized by area, insufficient medical resources (28 cases), disrupted lifelines (25 cases), delayed medical intervention (23 cases), and deteriorated environmental conditions in homes and emergency shelters (14 cases) were most prevalent in coastal areas, while delayed medical intervention (23 cases) and disrupted lifelines (15 cases) were most prevalent in inland areas (Table 8).

Categorized by hospital function, delayed medical intervention (30 cases), deteriorated environmental conditions in homes and emergency shelters (16 cases), and insufficient medical resources (12 cases) were most prevalent among DBHs, while the most prevalent causes among non-DBHs included disrupted lifelines (31 cases), insufficient medical resources (25 cases), delayed medical intervention (16 cases), and a lack of capacity for transport within the area (14 cases; Table 8). Examining the cause of PDD in non-DBHs categorized by number of general beds showed that the most prevalent causes in hospitals with fewer than 100 general beds consisted of disrupted lifelines (20 cases), insufficient medical resources (18 cases), and scaled down life-sustaining treatment (10 cases; e-Table 6 [e-Tables available online only]). Even in hospitals with long-term care beds, the most prevalent causes were similar, consisting of disrupted lifelines (20 cases), insufficient medical resources (19 cases), and scaled down life-sustaining treatment (10 cases; e-Table 7 [e-Tables available online only]).

Discussion

According to data from the Ministry of Health, Labour, and Welfare (MHLW; Tokyo, Japan),[10] the peak age group for deaths in Miyagi Prefecture in the Great East Japan Earthquake was 70-79 years old, with 65.7% of victims aged ≥60 years, 46.7% aged ≥70 years, and 22.1% aged ≥80 years (Figure 2). The ages of cases of in-hospital patient deaths and PDD identified in the present study were higher than those reported by the MHLW. Rather than local citizens who died as a result of the tsunami, for example, this is thought to be due to the deaths of many already hospitalized elderly patients who were more "susceptible to disaster."

In terms of the causes of PDD, prehospital and in-hospital factors were more prevalent in coastal areas, while prehospital factors were most prevalent in inland areas (Table 8). Taking a closer look at hospital function shows that prehospital factors were more prevalent at DBHs and in-hospital factors more prevalent at non-DBHs. In addition to the fact that the coastal region suffered more widespread damage than the inland region due to the impact of the tsunami, this strongly suggests the possibility that non-DBHs are more vulnerable to disaster. In particular, the proportion of PDD was higher in hospitals equipped with long-term care beds and hospitals with fewer general beds. Many patients in these hospitals were elderly, and in some cases, the presence of dementia, being bedridden, and family background would also have made inter-hospital transfer difficult. A deeper discussion of means of providing medical support for such vulnerable patients in times of disaster is necessary as a matter of concern for society as a whole. There is also a need for the medical personnel who carry out disaster relief to perform preparatory activities with these issues in mind, and to consider the allocation of human and material resources and support in accordance with local circumstances.

In addition, the fact that prehospital factors represent the most prevalent origin of the cause of PDD in DBHs suggests the possibility that large numbers of patients may have been transported in a concentrated manner in a poor state of health due to delayed medical intervention and deteriorated environmental conditions in homes and emergency shelters. To prevent PDD, it will be necessary for health care professionals, working together with public administration bodies, health care centers, fire departments, and the Japan Self-Defense Forces, to prevent the deterioration of environmental conditions in homes and emergency shelters and provide medical intervention in a timely manner.

A previous study found that at the time of the Great East Japan Earthquake, reserves at DBHs were insufficient and requests for supplies had to be made to the Miyagi Prefecture Disaster Medicine Headquarters.[11] As the chief in-hospital causal factors

		Coastal		Inland		
Origin	Cause	DBHs	Non-DBHs	DBHs	Non-DBHs	Total
Prehospital	Delayed medical intervention.	16	7	14	9	46
	Deteriorated environmental conditions in homes and emergency shelters.	10	4	6	4	24
	Insufficient support for vulnerable people.	3	2	3	4	12
	Cessation of treatment for chronic disorders.	3	2	1	4	10
	Delayed decision by health care professional regarding the need for hospitalization.	2	2	0	2	6
	Lack of prevention and education.	1	1	0	1	3
	Delayed rescue.	0	0	1	1	2
	Cessation of regular medication.	2	0	0	0	2
	Lack of means of transport (for patients requiring hospitalization).	1	0	0	0	1
In-Hospital	Disrupted lifelines.	4	21	5	10	40
	Insufficient medical resources.	9	19	3	6	37
	Scaled down life-sustaining treatment.	1	9	0	0	10
	Shortage of human resources.	6	1	1	0	8
	Inadequate medical care.	1	0	1	3	5
Post-Hospital	Lack of capacity for transport within the area.	0	6	0	8	14
	Lack of capacity for transport out of the area.	1	3	3	3	10
Total						230

Table 8. Causes of PDD
Abbreviations: DBH, disaster base hospital; PDD, preventable disaster death.

for PDD, disrupted lifelines, insufficient medical resources, and shortages of human resources, along with the post-hospital factor, a lack of capacity for transport within the area, are factors that should be incorporated into a business continuity plan (BCP), accounting as they do for 43.0% of the causes of PDD (99/230 cases; Table 8). The formulation of BCPs that include such preparations will be necessary not only for DBHs, but especially for non-DBHs with few general beds and hospitals equipped with long-term care beds.

Limitations

The present study had the following limitations:

1. Many of the PDD case patients may not have been transported to the hospital, meaning that patients transported to the hospital may represent only a portion of the overall PDD cases;
2. When investigating differences between regions and facilities, no adjustments were made for the severity of patients' conditions, comorbidities due to pre-existing conditions or chronic illness, or differences in daily living standards, nor was any investigation performed with regard to structural elements such as quake-resistant or quake-absorbing structures; and
3. As there is no authorized definition of PDD, determination of its incidence in the present study was based on discussions among experts. However, the findings may vary under different definitions of PDD.

Conclusion

Over 120 cases of PDD were identified at medical facilities in Miyagi Prefecture during the Great East Japan Earthquake. In disasters such as this, involving widespread tsunami devastation, the incidence of PDD will differ between coastal and inland hospitals. At coastal hospitals, the main causes of PDD were insufficient medical resources, disrupted lifelines, delayed medical intervention, and deteriorated environmental conditions in homes and emergency shelters, and it seems possible that the lack of physical health care resources was particularly problematic in the case of hospitals with long-term care beds and non-DBHs with fewer than 100 general beds. The prevention of PDD, in addition to the strengthening of organizational support and functional enhancement of DBHs, calls for the development of BCPs for medical facilities in directly affected areas, including non-DBHs.

Acknowledgements

In bringing this manuscript to completion, the authors would like to extend their sincere gratitude to the many officials at the various hospitals that agreed to cooperate in this survey, as well as Dr. Yoshitaka Kohayagawa and Dr. Miho Tsuruwa of the Clinical Research Institute at the National Disaster Medical Center, Tokyo, Japan.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1049023X17006501

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