Table 1 – Characteristics of 5 tsunami victims who developed scedosporiosis.

Authors year	Age/ Sex	Clinical findings	Pathological CNS Other sites	Diagnosis Culture specimen Time to diagnosis after near-drowning	Antifungal therapy Empirical treatment Etiological treatment on identification	Treatment	Outcome
Garzoni et al. 2005 [6]	59/M	Fever, cough, back pain	–	*S. apiospermum* paravertebral collection 108 days Re-identification in 2008 *P. boydii*	– VRCZ	Chest drainage, lobectomy, spinal drainage	Survival
Garzoni et al. 2005 [6]	51/F	Fever, altered consciousness	Brain abscess Hydrocephalus	*S. apiospermum* brain abscess 61 days Re-identification in 2008 *S. aurantiacum*	– VRCZ	Brain abscess aspiration	Survival
Nakamura et al. 2011 [1]	59/F	Fever	Brain abscess Lung abscess	*S. apiospermum* BAL/PCR+Sequencing, 102 days	MCFG, VRCZ+L-AMB	–	Survival
Nakadate et al. 2012 [2]	33/F	Respiratory failure Septic shock	– Pneumonia	*S. apiospermum* *S. prolificans* BAL/PCR+Sequencing 102 days	FLC –	PMX-DHP	Death (16 days)
Present case	68/F	fever, double hemiplesia	Brain abscess Hydrocephalus Pneumonia	*S. aurantiacum* BAL/PCR+Sequencing 102 days	MCFG VRCZ+L-AMB	VRCZ administered intrathecally	Survival

M: male, F: female, CNS: central nervous system, BAL: bronchoalveolar lavage, PCR: polymerase chain reaction, VRCZ: voriconazole, MCFG: micafungin, L-AMB: liposomal amphotericin B, FLC: fluconazole, PMX-DHP: polymyxin B-immobilized fiber column direct hemoperfusion.

present as pulmonary and/or disseminated scedosporiosis after near-drowning accidents. CNS infections often manifest as either multicenter or solitary brain abscesses [8]. In immunocompetent patients, CNS infection is generally preceded by near-drowning or trauma and is characterized by localized involvement. In contrast, CNS infection in immunocompromised patients presents as rapidly progressive disseminated lesions at varying degrees of evolution [9]. Katragkou et al. comprehensively reviewed all previously reported cases of *S. apiospermum* infection after near-drowning incidents, but were unable to determine the origin of scedosporiosis after these events [8]. They reported that the median time till diagnosis of *S. apiospermum* infection was 28 days, and after accounting for delay in diagnosis, it remained unclear whether the *Scedosporium* was actually acquired during the immersion episode or during the hospitalization. Three cases of *Scedosporium* infection were reported around the same time a tsunami occurred in Japan, and both events were recorded simultaneously in the same hospital. Therefore, one can speculate that these cases of *Scedosporium* infection with subsequent brain abscesses are attributable to near-drowning-related pneumonia that it was induced by the aspiration of water contaminated with *Scedosporium* and that treatment of these infections could be extremely difficult. Of the 5 reports of *Scedosporium* infection following a near-drowning due to a tsunami, the 4 surviving patients were eventually treated with voriconazole and recovered (Table 1). Our patient was treated with intrathecal voriconazole; however, voriconazole has only been shown to penetrate into the CSF and to not contribute to higher concentrations detected in brain tissue as compared with those detected in the CSF or blood. To our knowledge, intrathecal voriconazole therapy has been reported in only 1 case [10]. The critical clinical course observed in this case called for emergency intrathecal treatment with continuous vital sign and electrocardiographic monitoring. We cannot be certain that our treatment protocol was responsible for the decrease in (1→3)-β-D-glucan levels. The accumulation of clinical cases using intrathecal voriconazole therapy for intraventricular abscesses is warranted to determine the association between CSF drug concentration, treatment efficacy, and adverse effects.

Owing to the length of time necessary to achieve a diagnosis, there was an extreme risk of severe complications. In our case, the devastation caused by the massive earthquake and tsunami led to chaos in our society, which tremendously hampered the functioning of clinical laboratories, thereby causing a delay in the identification of the fungi. Thus, these cases highlight the need for a rapid and reliable etiological diagnosis to improve patient outcome.

Conflict of interest

The authors have no conflicts of interest.

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Original article

The impact of a large-scale natural disaster on patients with chronic obstructive pulmonary disease: The aftermath of the 2011 Great East Japan Earthquake

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ABSTRACT

Background: A large-scale natural disaster may exacerbate chronic respiratory diseases, such as chronic obstructive pulmonary disease (COPD). The aftermath of a natural disaster can include poor access to medication, medical equipment, and medical supplies. Little is known about the impact on patients with COPD.

Methods: A retrospective cohort study was conducted at a regional medical center in Ishinomaki, the area affected most severely by the Great East Japan Earthquake in 2011. The study was performed 6 months after the disaster. The characteristics, clinical courses, and outcomes of COPD patients hospitalized after emergency visits during the study period were investigated and compared.

Results: One hundred patients (112 episodes) were identified. Within a few days after the disaster, patients undergoing oxygen therapy at home came to the hospital to receive oxygen. In the subacute phase (from the third to the fifth week), the number of hospitalizations due to COPD exacerbations was significantly increased compared to the numbers observed before the earthquake ($p<0.05$). On admission, COPD patients reported significantly reduced participation in the activities of daily living (ADLs) after as compared to before the disaster. The incidence of cases of exacerbated COPD normalized 6 weeks after the earthquake.

Conclusions: The large-scale natural disaster that hit Japan in 2011 had a serious negative impact on the clinical outcomes of COPD patients in the disaster-affected area.

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Abbreviations: ADL, activities of daily living; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; GOLD, Global Initiative for Chronic Obstructive Lung Disease; NPPV, noninvasive positive pressure ventilation

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1. Introduction

Large-scale natural disasters, such as earthquakes or tsunamis, destroy buildings, vital infrastructure, communication technology, and transportation facilities, often resulting in many deaths and traumatic injuries. Medical resources and public health services are also often severely impaired. These disasters may exacerbate chronic respiratory diseases, such as chronic obstructive pulmonary disease (COPD). In the aftermath of the disaster, COPD patients often endure limited access to medication, medical equipment, and/or medical supplies. However, no systematic investigation has examined the impact of natural disasters on patients with COPD.

An earthquake of magnitude 9.0 occurred in Japan on March 11, 2011, most severely affecting the Tohoku region on the northeast coast of the country. A devastating tsunami followed the earthquake and caused widespread damage on Japan's eastern coast. Approximately 20,000 people were killed or went missing, and over 380,000 houses were destroyed [1]. In the aftermath of this catastrophe, we dealt with respiratory emergencies at a regional medical center set up in Ishinomaki to deal with the disaster's aftermath. We conducted a retrospective cohort study to evaluate the impact of the disaster on clinical outcomes among COPD patients.

2. Material and methods

2.1. *Study design*

We conducted a retrospective cohort study at the Japanese Red Cross Ishinomaki Hospital in Ishinomaki, Japan. The institution is a 402-bed tertiary hospital, which provides medical services to over 220,000 people in Ishinomaki and the surrounding cities. Ishinomaki is a port town located in the coastal area of Tohoku region and was one of the most affected cities by this disaster. The Japanese Red Cross Ishinomaki Hospital was designated as the region's primary medical center after this disaster. Although other medical facilities in Ishinomaki were either destroyed or damaged by the tsunami, the Japanese Red Cross Ishinomaki Hospital continued to operate at full capacity [2]. Remarkably, the electronic medical record system remained functional as well. Clinical laboratory and radiology services were also available. In the first 7 days after the disaster, we were able to treat 3938 emergency patients at the hospital.

This study was carried out in accordance with the Declaration of Helsinki and was approved by the Ethics Committee at the Japanese Red Cross Ishinomaki Hospital (December 5, 2011).

2.2. *Inclusion and exclusion criteria*

We reviewed the medical records of patients who made an emergency visit and required a hospital stay during the period from March 11 to September 10, 2011, and identified patients diagnosed with COPD in accordance with the GOLD criteria [3]. Each patient presenting with aggravated symptoms underwent a comprehensive assessment that included a physical examination, pulse oximetry, chest radiography, and electrocardiography. COPD exacerbation was defined as a sudden worsening of symptoms such as increased breathlessness, coughing, or sputum production, thereby requiring additional treatments [3]. Patients with symptoms exacerbated by congestive heart failure were excluded from the study. Patients with advanced cancer whose disease stabilization could not be achieved were also excluded. Patients who had received oxygen therapy at home and required emergency visits were included. We reviewed the medical records of COPD patients hospitalized due to exacerbations in the corresponding periods of 2009 and 2010 as controls.

2.3. *Data collection*

Sociodemographic characteristics, smoking status, and maintenance treatments at baseline were recorded for each patient. The presence of comorbidities, including congestive heart failure, ischemic heart disease, chronic liver disease, chronic renal disease, diabetes, and cancer was also assessed [4]. Pulmonary function tests were performed under stable conditions within a year before the emergency visit or after recovery from the symptoms induced by the disaster. The severity of COPD was defined in accordance with the GOLD criteria [3]. The ADLs of patients upon admission and before the earthquake were evaluated by interviewing patients or their caregivers. ADLs were classified as "good" if they could live without support, "fair" if they could not leave their residence without support or "poor" if they spent days in bed or in a chair and had lost the ability to move independently. Data relating to symptom exacerbation including the final diagnosis, treatment, and length of hospital stay were collected as well.

Patients were followed up at the outpatient clinic for over 3 months after discharge. If a patient was referred to another hospital, we contacted the institution and inquired about the patient's clinical course.

2.4. *Statistical analyses*

Individual comparisons were performed using the Wilcoxon signed-rank test. The non-parametric Wilcoxon rank sum test was used for the comparisons of categorical variables. Simple regression analysis was performed using the least squares method. P values less than 0.05 were considered significant. All analyses were performed using JMP software (SAS Institute Inc., NC).

3. Results

We identified 100 COPD patients (112 episodes) who presented at the emergency department and required hospitalization within 6 months after the disaster. The characteristics of the patients are shown in Table 1. The diagnosis and clinical course of each patient is presented in Tables 2 and 3. The details are provided below.

Table 1 – Patient characteristics.

Age (years)	78 (10)
Sex, male/female	89/11
Residence	
Home	84
Community evacuation center	12
Nursing home	3
Other hospital	1
Smoking history, pack-year[a]	55 (40)
Pulmonary function test[b]	
FEV1, L	0.93 (0.75)
%FEV1 (%)	45.1 (29.3)
FEV1/FVC	0.41 (0.18)
GOLD stage[b]	
Stage I/II/III/IV	6/29/20/29
Comorbidities	
Congestive heart failure	14
Ischemic heart disease	3
Chronic liver disease	4
Chronic renal disease	1
Diabetes	7
Cancer	10
Long-term oxygen therapy	46

Each data-point is presented as a number or median (interquartile range).
FEV1: forced expiratory volume in 1 s, %FEV1: percentage of predicted FEV1.
[a] Smoking history was not available in 11 patients.
[b] Pulmonary function testing was not available for 16 patients.

Table 2 – Diagnoses and clinical courses of 112 episodes.

Diagnosis	
Exacerbations of COPD	68
Oxygen-dependent evacuee	36[a]
Pneumothorax	8
Pulmonary embolism	0
Introduction of ventilator support	
NPPV	7
IMV	2
Length of hospital stay (days)	10 (8)
Prognosis	
In-hospital death	6
Death within 90 days[b]	10

Each data-point is presented as a number or median (interquartile range).
NPPV: noninvasive positive pressure ventilation, IMV: invasive mechanical ventilation.
[a] One patient who lost his oxygen equipment visited after closure of the temporary evacuation center.
[b] At 90 days, 10 patients were lost to follow-up.

3.1. *Patients receiving oxygen therapy*

During the period from March 11 to 17, 35 COPD patients who received long-term oxygen therapy at home (including 3 patients using NPPV) presented at the hospital after loss of a stable oxygen supply due to power failure or equipment damage (Fig. 1). Only 12 of these patients were treated at our hospital, with the remaining patients receiving regular treatment by general practitioners ($n=14$) or at other hospitals ($n=9$). These patients were triaged and then transferred to a temporary evacuation center established inside the hospital [5]. None of them showed exacerbated symptoms upon presentation to the hospital, but 20% (7/35) experienced exacerbations requiring additional treatment during their time at the evacuation center. These patients showed exacerbated symptoms on March 15 ($n=4$), 16 ($n=2$), and 17 ($n=1$). Rapid diagnostic tests were used to confirm that none of the patients had influenza. There was no difference between the exacerbated group and the non-exacerbated group in terms of age or gender. Since we could not obtain the results of pulmonary function tests for patients treated at other hospitals, differences in pulmonary function were not evaluated. Patients who were stable returned home when their local-area electricity was restored or were sent to rearward hospitals if they had lost their houses or means of survival. The median length of hospital stay was 9 days; the evacuation center was closed on March 26.

3.2. *Exacerbations of COPD*

During the 6-month study period, 63 patients with exacerbations (68 episodes) presented at the emergency department requiring hospitalization. Five patients were hospitalized twice during the study period. The number of patients hospitalized due to COPD exacerbations each week is shown in Fig. 2. The total number increased 1.5- and 1.3-fold compared to the corresponding periods in 2010 and 2009, respectively.

The number of patients increased during the period from 3 to 5 weeks after the earthquake and then decreased. We classified the patients into 3 groups in terms of the time of hospitalization after the disaster: the acute phase (first 2 weeks after the earthquake), the subacute phase (from weeks 3 to 5), and the chronic phase (from 6 weeks to 6 months). The number of patients admitted while in the subacute phase significantly increased compared to the corresponding periods in 2010 and 2009 ($p<0.05$). There were no significant differences between the patients in the acute plus subacute phase group as compared to those in the chronic phase group in terms of age, FEV1, percentage of predicted FEV1, regular medication, or long-term oxygen therapy. However, the deterioration in ADL upon admission was significantly different between the groups. The ADLs of patients were significantly decreased compared to that before the earthquake in the acute phase and subacute phase group ($p<0.01$) (Fig. 3a). In contrast, no reduction in ADL was observed during the chronic phase (Fig. 3b).

All patients with exacerbations were treated in accordance with the consensus guidelines [3]. Mechanical ventilation was required in 7 patients with NPPV and 1 patient with invasive mechanical ventilation. The in-hospital and 90-day mortalities of patients with exacerbations of COPD were 5.9% (4/68) and 13.6% (8/59), respectively. At 90 days, 9 patients had been lost to follow-up .

3.3. *Other pulmonary complications*

Eight patients with pneumothorax were identified during the study. None of these cases were associated with chest

Table 3 – The characteristics and clinical courses of patients with exacerbated COPD symptoms.

	All (n=68)	Acute and subacute phases (n=36)	Chronic phase (n=32)
Age (years)	77.5 (8.8)	77.0 (12.3)	78.0 (7.0)
Sex, male/female	61/7	31/5	30/2
Residence			
Home	52	25	27
Community evacuation center	12	9	2
Nursing home	3	0	3
Other hospital	1	1	0
Smoking history, pack-year	50 (39)	52.5 (39)	41.9 (40)
Pulmonary function test[a]			
FEV1, L	0.96 (0.67)	0.96 (0.42)	0.99 (0.92)
%FEV1 (%)	49.0 (28.5)	47.4 (26.6)	50.4 (30.1)
FEV1/FVC	0.44 (0.22)	0.42 (0.17)	0.49 (0.23)
GOLD stage[a]			
Stage I/II/III/IV	6/24/18/13	2/13/10/8	4/11/8/5
Comorbidities			
Congestive heart failure	14	8	7
Ischemic heart disease	4	4	0
Chronic liver disease	2	1	1
Chronic renal disease	1	1	0
Diabetes	6	3	3
Cancer	11	6	5
Regular treatment			
Anticholinergic	46	24	22
Long-acting beta agonist	44	26	18
Inhaled corticosteroid	23	15	8
Theophylline	16	13	3
Macrolide	5	5	0
Oral prednisolone	5	4	1
Long-term oxygen therapy	15	7	8
Chest infiltrate	36	18	18
Length of stay (days)	11 (11.5)	9 (11.3)	13 (14)
Prognosis			
In-hospital death	4	1	3
Death within 90-days[b]	8	4	4

Each data-point is presented as a number or median (interquartile range).
FEV1: forced expiratory volume in 1 s, %FEV1: percentage of predicted FEV1.
[a] Pulmonary function testing was not available in 7 patients.
[b] At 90 days, 9 patients had been lost to follow-up.

trauma. Six patients were treated conservatively, and 2 patients underwent thoracoscopic surgeries. Seven patients were cured, but 1 patient with very severe COPD required invasive mechanical ventilation and died due to complicating pneumonia. Six and 7 patients with pneumothorax were identified in the years 2009 and 2010, respectively. No patient included in the study experienced a pulmonary embolism.

4. Discussion

The findings of our study indicate that the Great East Japan Earthquake had a strong negative impact on clinical outcomes among COPD patients. In the acute phase of the disaster, patients with very severe COPD sought refuge in our hospital and were provided with oxygen therapy. A population 3 times as big was admitted due to exacerbated symptoms. During the chronic phase, the frequency of admission due to exacerbations returned to baseline levels.

During the acute phase, most of the COPD patients who presented at the hospital were seeking oxygen therapy. In Japan, home oxygen therapy is widely used for patients with chronic respiratory failure and is covered by the national healthcare insurance system [6]. Since the Hanshin–Awaji earthquake in 1995, medical personnel and oxygen-service providers have recognized the importance of managing oxygen-dependent patients during a disaster and have established emergency operation measures. The wide-scale disaster of 2011, however, was more catastrophic than predicted in even the most pessimistic scenarios. Fortunately, we were able to accept many oxygen-dependent patients who were normally treated at other clinics in addition to our own outpatients.

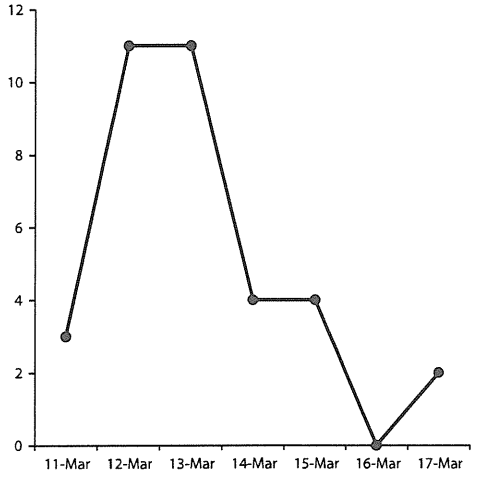

Fig. 1 – Number of oxygen-dependent patients who visited the hospital after the earthquake.

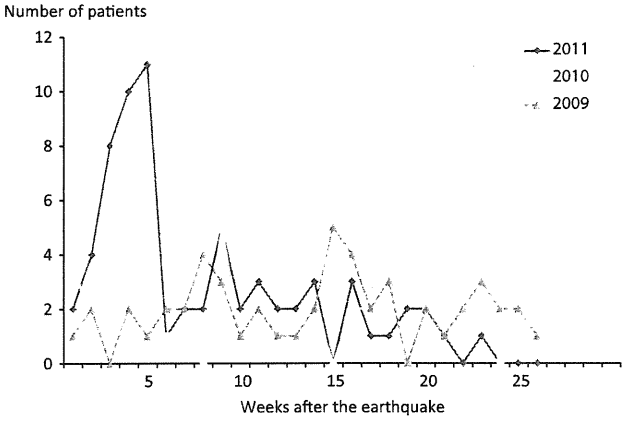

Fig. 2 – Numbers of patients hospitalized due to COPD exacerbations per week for 6 months after the disaster, and during the corresponding periods in 2010 and 2009.

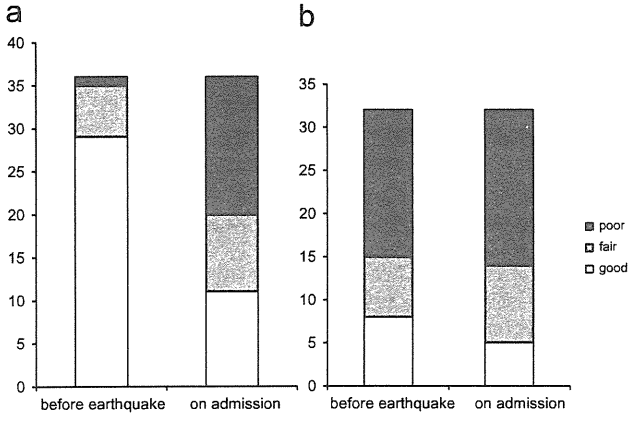

Fig. 3 – Comparison of patient ADL values prior to the earthquake, upon admission in the acute plus subacute phases group (a) and in the chronic phase group (b). ADL was classified as good, fair, or poor (see the text for more detail).

The evacuees were not hospitalized because all of the hospital beds were occupied by casualties who were seriously ill. Instead, each COPD patient was provided with a continuous oxygen supply via the central gas piping system in the outpatient ward. The unexpectedly high number of patients exceeded the facility's capacity for sound care. Therefore, on March 14, we established a temporary oxygen therapy center inside the hospital using electric oxygen concentrators. This area had been used as a rehabilitation center before the disaster and lacked an oxygen piping system [5]. Trained nurses in the Respiratory Medicine Department were assigned to the evacuation center to provide medical care, and respiratory physicians visited each outpatient every day. Nevertheless, there was a high incidence of symptom exacerbation among those patients staying at the evacuation center. Symptom severity was likely exacerbated by the facility's poor insulation [7,8] and the interruption of regular treatment [9]. Some patients had been drenched by the tsunami, while others, prior to their hospital visit, stayed in houses or shelters that not only lacked oxygen supplies but also lacked heating systems or water supplies. Some patients were also deprived of their prescribed drugs, and this interruption of regular treatment may have partly contributed to the worsening of symptoms.

The symptoms of many patients worsened during the subacute phase. The number of patients hospitalized due to exacerbated symptoms was 3 times higher than those hospitalized during the corresponding period in 2009 or 2010. First, interruption of regular treatment may have resulted in increase in exacerbations of COPD [9]. In addition to the factors cited above, tracheobronchial infections may be associated with worsened COPD symptoms. Previous reports demonstrated that respiratory infections increased in the aftermath of a massive earthquake [10,11]. In Ishinomaki and the surrounding areas, habitants suffered insufficient fuel supplies, power failures, water and food shortages, and an inability to maintain the appropriate level of personal hygiene. These conditions were compounded by cold winter temperatures and damaged houses or emergency shelters [2]. Such unfavorable conditions are likely to result in the increased occurrence of respiratory infections. The inhalation of dust and fine particles from rubble and tsunami-sludge also make breathing difficult. It has been reported that air pollution is an important risk factor for the exacerbation of COPD [12,13]. Many buildings in Ishinomaki were destroyed by the tsunami, and the entire area was covered by a thick layer of mud. Thus, chemicals, particulates, and biological materials from debris and tsunami-sludge may have contributed to the worsening of respiratory symptoms among COPD patients in the area hit by the tsunami.

The deterioration of ADLs in the acute and subacute phases after the disaster resulted in increased number of hospitalizations (Fig. 3a). It was previously reported that physical disability was an independent risk factor for death after the Hanshin–Awaji earthquake [14] and the 1999 Taiwan earthquake [15]. However, those reports investigated mortality in the acute phase, but not hospitalizations in the subacute or chronic phases. Recent reports have also demonstrated that physical inactivity is a risk factor for symptom aggravation and mortality in COPD [16,17]. After the earthquake and

tsunami in the Ishinomaki region, over 40,000 evacuees stayed at crowded emergency shelters, where they had to lie down on the floor without beds. Elderly patients with COPD were largely sedentary, which led to ADL deterioration. Furthermore, impaired ADLs and poor oral hygiene induced swallowing dysfunction, which can in turn exacerbate COPD [18].

The number of patients presenting with COPD exacerbations declined in the chronic phase as compared to the subacute phase. The recovery of water and food supplies, the restoration of vital infrastructure and medical services, and the improvement in living conditions may have contributed to this phenomenon. In Ishinomaki and the surrounding cities, medical relief teams circulated around community evacuation centers and prescribed medications for patients with chronic disease [2]. These efforts minimized the interruption of treatment during the chronic phase.

Diagnoses of pneumothorax [19] and pulmonary embolism [20] should be considered in COPD patients reporting exacerbated symptoms, even in the aftermath of natural disasters. In this study, we identified 8 patients with pneumothorax, and none with pulmonary embolism. Patients whose symptoms had worsened underwent comprehensive evaluation, including chest radiography, which led to the detection of pneumothorax in several patients.

The major limitation of our study is its single-center, retrospective design. The Japanese Red Cross Ishinomaki Hospital is the only regional respiratory center in the Ishinomaki medical-care zone. In 2009, we established a regional medical liaison system to provide patients with comprehensive care in Ishinomaki and the surrounding region. This collaboration involved general practitioners, pharmacies, rehabilitation clinics, and home-visit nursing stations. The system was set up so that our hospital accepted all COPD patients with respiratory emergencies who were located in the Ishinomaki medical care-zone and required hospital management. Therefore, the results of our study will accurately reflect the impact of the disaster on COPD symptoms.

Another limitation of this study was that some data were not available due to disruptions caused by the disaster. We had to exclude some patients who had chronic respiratory symptoms and emphysema as diagnosed by chest radiography, but did not confirm the diagnosis with a pulmonary function test. Although we tried to contact the hospital to ascertain patient outcomes, some patients that were referred to rearward hospitals could not be followed up.

To our knowledge, this is the first retrospective study to determine outcomes in patients with COPD who experienced a large-scale natural disaster in a developed nation with an aging population. Although pulmonary complications, such as chest trauma or respiratory infection, are commonly recognized after natural disasters [21,22], the impact on the outcomes of COPD patients had not previously been clarified [23]. The results of our study indicate that patients with COPD will suffer substantially in the aftermath of natural disasters.

In conclusion, the present study demonstrates that large-scale natural disasters have a negative impact on clinical outcomes among COPD patients in the affected area. Further studies are required to determine how various types of natural disasters influence clinical outcomes. Our results suggest that respiratory physicians, in cooperation with disaster specialists, should develop strategies for the management of COPD patients in the aftermath of natural disasters.

Conflict of interest

The authors have no potential conflict of interest.

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The impact of the 2011 Great East Japan Earthquake on hospitalisation for respiratory disease in a rapidly aging society: a retrospective descriptive and cross-sectional study at the disaster base hospital in Ishinomaki

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ABSTRACT

Objective: To investigate the impact in an aging society of the 2011 Great East Japan earthquake on hospitalisation for respiratory disease at the disaster base hospital.

Design: Descriptive and cross-sectional study.

Setting: Emergency care in Japanese Red Cross Ishinomaki Hospital, a regional disaster base hospital in Miyagi, Japan.

Participants: 322 emergency patients who were hospitalised for respiratory disease from 11 March to 9 May 2011, and 99 and 105 emergency patients who were hospitalised in the corresponding periods in 2009 and 2010, respectively.

Main outcome measures: Description and comparison of patient characteristics and disease distribution in terms of age, time after the disaster and activities of daily living (ADL).

Results: 1769 emergency patients were admitted to our hospital during the study period (compared to 850 in 2009 and 1030 in 2010), among whom 322 were hospitalised for respiratory disease (compared to 99 in 2009 and 105 in 2010). Pneumonia (n=190, 59.0%) was the most frequent cause of admission for pulmonary disease, followed by acute exacerbation of chronic obstructive pulmonary disease (AE-COPD) (n=53, 16.5%), asthma attacks (n=27, 8.4%) and progression of lung cancer (n=22, 6.8%). Compared with the corresponding periods in 2009 and 2010, the increase in the absolute numbers of admissions was highest for pneumonia, followed by AE-COPD and asthma attacks. At hospitalisation, 195 patients were 'dependent' and 54 patients were 'partially dependent'. Respiratory admissions accompanied by deterioration of ADL after the disaster were more frequent in elderly and female patients.

Conclusions: After the Great East Japan Earthquake, admissions for pneumonia and exacerbation of chronic respiratory disease in the elderly increased at the disaster base hospital.

ARTICLE SUMMARY

Article focus

- The Great East Japan Earthquake affected one of the most rapidly aging societies in the world.
- We describe how the disaster affected respiratory diseases in the worst affected area, which has one of the highest ratios of elderly people in Japan.
- The study provides lessons for use after natural disasters in an aging society.

Key messages

- After the earthquake and tsunami, admissions for pneumonia and exacerbation of chronic respiratory disease increased among the elderly.
- Harsh conditions and poor activities of daily living status after the disaster may be associated with increased hospitalisation for respiratory diseases in elderly people.

Strengths and limitations of this study

- We were able to obtain detailed patient data after a disaster.
- We only studied hospitalised patients, but there were also numerous outpatients, many of whom died.

INTRODUCTION

On 11 March 2011, at 14:46 h Japanese time, the Pacific coast of Japan's Tohoku (north-eastern) region was struck by a huge earthquake (The Great East Japan Earthquake) measuring 9.0 on the Richter scale.[1] The earthquake triggered a devastating tsunami which destroyed many towns and villages close to the sea. The epicentre was estimated to be about 130 km east of Oshika Peninsula in Miyagi Prefecture. Officially, over 19 000

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people were killed or are missing and there were more than 550 000 refugees.[2]

Ishinomaki city, located on the Pacific coast of Honshu Island, lost the most victims in the disaster, with 3280 people killed and 669 still missing. A huge number of casualties, more than 10 000 patients in the first 30 days, were treated at Japanese Red Cross Ishinomaki Hospital, a regional disaster base hospital in Ishinomaki which preserved its hospital function during and after the catastrophe.

Japan is one of the most rapidly aging societies in the world. In 2010, 23% of Japanese citizens were aged 65 or over,[3] while 26.6% of people living in Ishinomaki city in the Tohoku region were aged 65 or over. Although several reports showed a significant association between age and death following the earthquake and tsunami,[4–8] few reports have investigated the impact of a huge disaster on the elderly in an aging society.[9 10]

As respiratory diseases are common in the elderly, investigating the impact of the disaster on respiratory health will help elucidate the problems of an aging society. Thus, we carried out a retrospective descriptive and cross-sectional analysis of the medical and epidemiological data of patients requiring hospitalisation for respiratory disease after the Great East Japan Earthquake and subsequent tsunami.

METHODS

This study was a retrospective descriptive and cross-sectional analysis of data obtained from the medical records at Japanese Red Cross Ishinomaki Hospital. We reviewed the medical records of patients admitted to the hospital for respiratory diseases during the first 60 days after the Great East Japan Earthquake, when the hospital only accepted emergency patients. We also reviewed the medical records of patients who required unscheduled hospitalisation for respiratory disease in the corresponding periods in 2009 and 2010.

Japanese Red Cross Ishinomaki Hospital has 402 inpatient beds and is located 4.5 km inland from the Pacific. It serves approximately 220 000 people (Ishinomaki City, Onagawa Town and Higashi-matsushima City) and was designated a regional disaster base hospital. It normally accepts most emergency respiratory patients in the region because it has a respiratory department and employs pulmonary specialists.

Information on date of admission, age, sex, diagnosis and place of residence was extracted from the medical records for the 2011 study period. We also investigated activities of daily living (ADL) before the earthquake and at hospitalisation. The number of unscheduled hospitalisations during the corresponding periods in 2009 and 2010 were counted for comparison.

Pneumonia was defined as the presence of infiltrates on chest radiograph together with one or more of the following signs or symptoms: fever, cough, sputum production, breathlessness, pleuritic chest pain or signs consistent with pneumonia on auscultation.

Chronic obstructive pulmonary disease (COPD) and bronchial asthma were determined according to spirometric data, patient self-report or physician diagnosis based on patient history, physical examination and radiological findings. An acute exacerbation of COPD (AE-COPD) was defined as an increase in or new onset of more than one symptom of COPD (cough, sputum, wheezing, dyspnoea or chest tightness) without pneumonia or pneumothorax. An attack of asthma was defined as wheeze or severe cough in asthma patients without pneumonia. Progression of lung cancer was defined as a requirement for admission for a lung cancer-associated condition such as dehydration, respiratory failure or uncontrolled pain. Obstructive pneumonia due to lung cancer was considered to be progression of lung cancer. Chest trauma and traumatopnea were deemed to be chest injury rather than respiratory disease.

ADL was assessed based on information provided by the patient, the patient's family or the patient's caregiver, and the patient classified into one of three categories: 'independent'(living without particular support), 'partially dependent' (unable to leave home without support), 'dependent' (spending the day in bed or in a wheelchair and unable to move about independently). To investigate the impact of the disaster on ADL, we defined as 'originally dependent' those who were dependent or partially dependent before the disaster, and as 'newly dependent' those who became dependent or partially dependent after the disaster.

Data analysis

All data were entered into a personal computer and analysed using Microsoft Excel software. Statistical analysis was performed using JMP9 (SAS Institute, Cary, North Carolina, USA). A missing value in a medical record was treated as 'unknown'. Results were given as means±SD for numerical variables and as proportions for categorical variables. To analyse sequential changes in the effects of the disaster, we divided the 60 days of the study period into six groups of 10-day bins. To investigate the risk of hospitalisation for respiratory disease after the earthquake and tsunami, we compared patient characteristics for the 2011 study period with the combined data for the corresponding periods in 2009 and 2010. We used a two-sided Student t test for numerical variables and the χ^2 test for categorical variables. Statistical significance was set at $p<0.05$.

RESULTS

For the first 60 days following the earthquake, all scheduled admissions to Japanese Red Cross Ishinomaki Hospital were cancelled and only emergency admissions were accepted. During this period, 1769 patients were admitted to the hospital, 322 of whom were hospitalised for respiratory disease. In the corresponding periods in 2009 and 2010, there were 850 (99 for respiratory disease) and 1030 (105 for respiratory disease)

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unscheduled admissions, respectively. Patients hospitalised for respiratory disease accounted for 18.2% of total admissions during the 2011 study period. This proportion was significantly higher than that in 2009 (11.6%; p<0.001) or 2010 (10.2%; p<0.001). While the number of admissions in 2011 was approximately twice that in 2009 or 2010, hospitalisation for respiratory disease in 2011 was three or more times greater than in 2009 or 2010. The overall number of hospitalisations peaked during the first 10 days, while the number of admissions for respiratory disease continued to increase for the first 20 days (figure 1A,B).

We compared the numbers and proportions of patients hospitalised for respiratory disease between 2011, 2010 and 2009 (figure 2). Pneumonia was the most frequent disease (n=190, 59.0%), followed by AE-COPD (n=53, 16.5%), asthma attacks (n=27, 8.4%) and progression of lung cancer (n=22, 6.8%). One case of AE-COPD and seven cases of asthma attacks were physician diagnoses. The category 'others' included pneumothorax, restrictive thoracic disease, pleural effusion, influenza, drowning, primary pulmonary hypertension, requirement for mechanical ventilation for neuromuscular disease, etc. One patient diagnosed with pneumonia who also had an asthma attack, and two patients with COPD exacerbated by pneumonia were treated for both conditions and counted as pneumonia. In comparison with the previous 2 years, the increase in the number of hospitalisations was greatest for pneumonia, followed by AE-COPD and asthma attacks. The numbers of hospitalisation for progression of lung cancer and for 'others' were similar to those in the previous 2 years. In 2011, 39.4% of patients were hospitalised from emergency shelters.

To investigate the disease-specific effect of the earthquake, the age and sex of each patient with a particular disease were compared between the study period in 2011 and the corresponding periods in the previous 2 years. The mean age of patients hospitalised for respiratory disease was significantly higher in 2011 than in the preceding 2 years (75.7±12.5 vs 73.2±13.4 years old; p=0.03). There were fewer males in 2011 compared to the previous 2 years (59.6% in 2011, 67.2% in 2010 and 2009; p=0.08). Specifically, pneumonia patients and AE-COPD patients were significantly older in 2011 compared to 2010 and 2009 (pneumonia patients were 77.6±11.8 vs 74.3±12.8 years old; p=0.03, while AE-COPD patients were

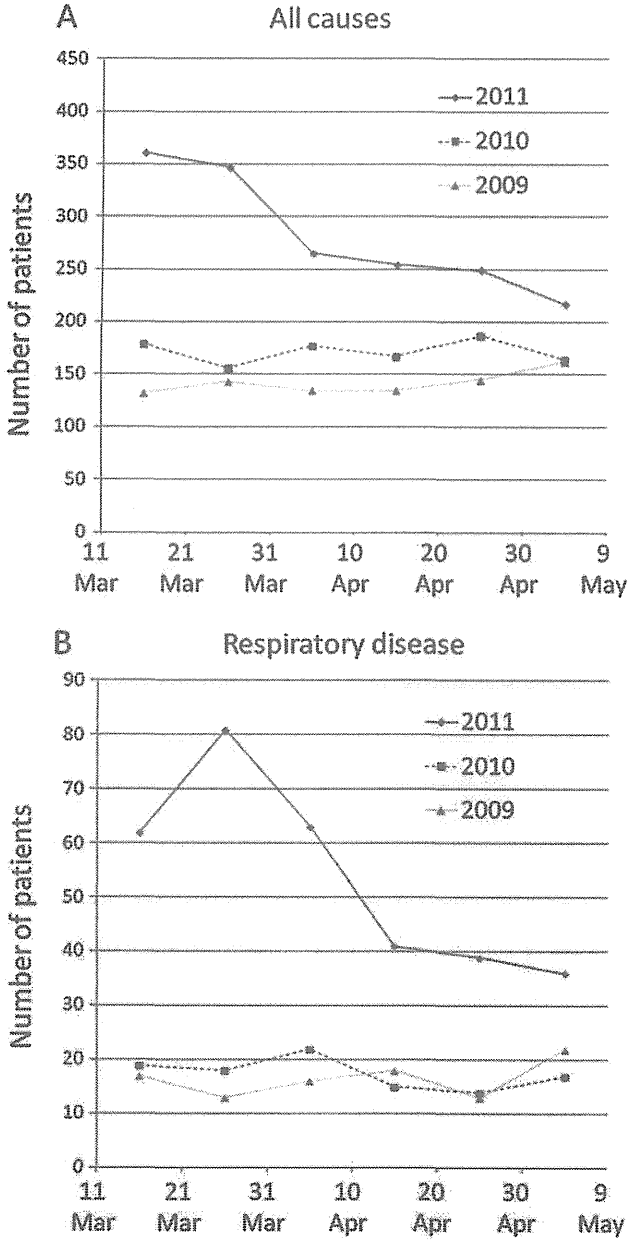

Figure 1 Number of unscheduled admissions for all causes (A) and for respiratory disease (B) from 11 March to 9 May in 2009, 2010 and 2011, presented in 10-day bins.

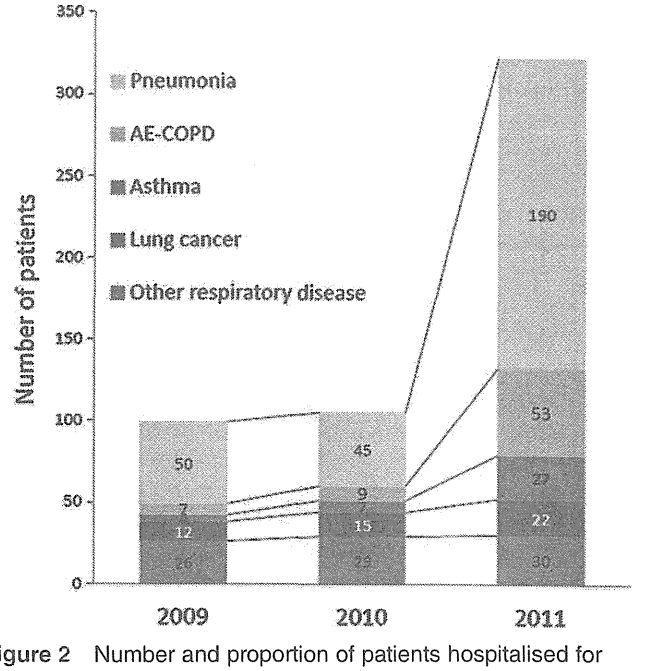

Figure 2 Number and proportion of patients hospitalised for respiratory disease pooled from 11 March to 9 May in 2009, 2010 and 2011. AE-COPD, acute exacerbation of chronic obstructive pulmonary disease.

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76.0±8.7 vs 69.5±15.9 years old; p=0.03). Significantly more males had AE-COPD (81.1% vs 50.0%; p=0.01), but significantly fewer had asthma attacks in 2011 compared with 2010 and 2009 (18.5% vs 54.6%; p=0.03).

The numbers of admissions for the main respiratory diseases for each 10-day bin during the study period are shown in figure 3. Pneumonia peaked during the second 10-day bin, AE-COPD and asthma attacks peaked during the third 10-day bin and progression of lung cancer peaked in the fifth 10-day bin.

Next, we investigated ADL status at hospitalisation and before the disaster among patients admitted during the 2011 study period. Because of the confused situation after the disaster, ADL status was not recorded in 11 patients. At hospitalisation, 195 patients (60.5%) were 'dependent' and 54 patients (16.7%) were 'partially dependent'. However, before the earthquake, only 86 patients (26.7%) were 'dependent' and 51 patients (15.8%) were 'partially dependent'. To investigate the impact of ADL status and its deterioration on time of admission for pulmonary disease after the disaster, we counted the number of patients who were 'originally dependent', 'newly dependent' or 'independent throughout' in each of the 10-day bins (figure 4). Throughout the study period, the majority of patients were dependent or partially dependent. In the first 20 days, the majority of admissions were for 'originally dependent' patients. After 3 weeks, there was a sharp increase in 'newly dependent' patients, as assessed by ADL status. Independent patients were mainly hospitalised during the first 20 days.

Table 1 shows the relationship between ADL category ('independent throughout', 'newly dependent' and 'originally dependent') and patient age, sex and diagnosis. The ratio of each disease was calculated for each category. Eleven patients whose ADL status was not completely recorded were excluded from the analysis. Young and male patients were more frequent in the order 'independent', 'newly dependent' and 'originally dependent'. In regard to patient diagnosis, proportion of pneumonia and progression of lung cancer increased in the same order, while the proportion of AE-COPD and asthma decreased.

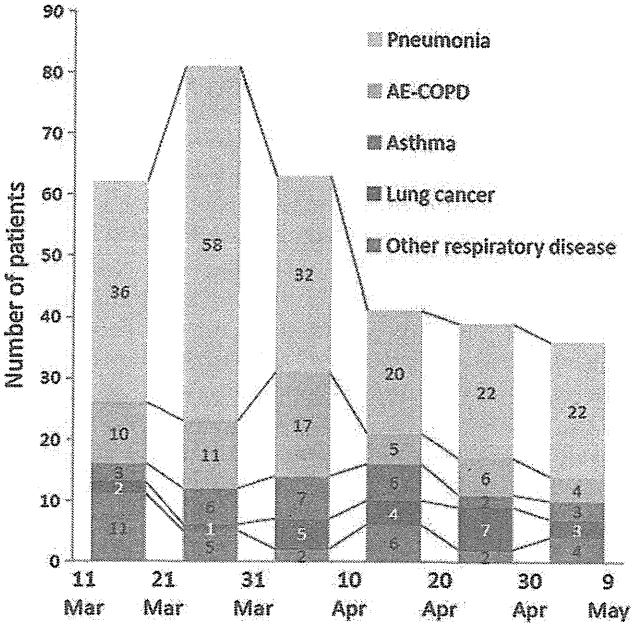

Figure 3 Distribution of patients hospitalised for respiratory disease after the Great East Japan Earthquake from 11 March to 9 May in 2011, presented in 10-day bins. AE-COPD, acute exacerbation of chronic obstructive pulmonary disease.

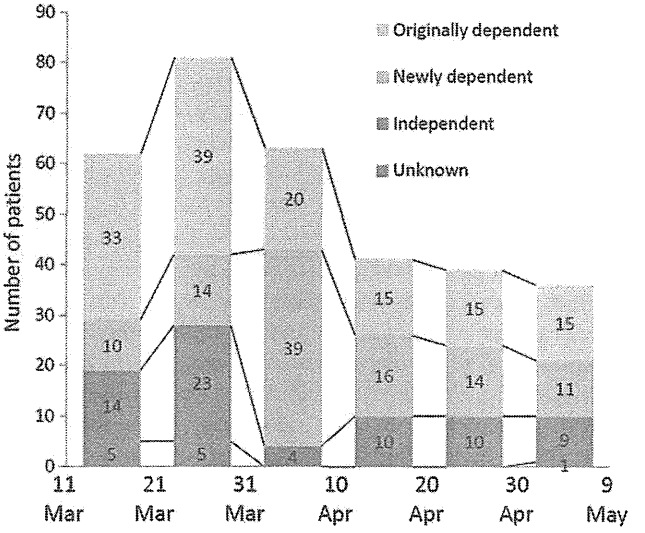

Figure 4 Influence of the disaster on activities of daily living status and its deterioration in patients hospitalised for respiratory disease from 11 March to 9 May in 2011, presented in 10-day bins.

DISCUSSION

Summary

In this retrospective descriptive and cross-sectional study, we found a substantial increase in the proportion of elderly patients hospitalised for respiratory disease after the earthquake and tsunami. Pneumonia, AE-COPD and

Table 1 Relationship between activities of daily living (ADL) and patient characteristics and respiratory disease

	Independent (n=70)	Newly dependent (n=104)	Originally dependent (n=137)
Age (years)	69.9±15.1	73.1±11.2	80.3±10.5
Male	49 (70.0)	63 (60.6)	69 (50.4)
Diagnosis			
Pneumonia	31 (44.3)	59 (56.7)	94 (68.6)
AE-COPD	17 (24.3)	17 (16.4)	15 (11.0)
Asthma	11 (15.7)	11 (10.6)	5 (3.7)
Lung cancer	3 (4.3)	6 (5.8)	12 (8.8)
Others	8 (11.4)	11 (8.0)	11 (8.0)

AE-COPD, acute exacerbation of chronic obstructive pulmonary disease.
Data are mean±SD for numerical variables and number (%) for categorical variables.

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asthma attacks were more common after the disaster. The mean age of patients hospitalised for respiratory disease was significantly higher than that in the corresponding periods in the previous 2 years. The majority of patients had poor ADL status and many experienced deterioration in ADL status after the disaster.

Effect on respiratory disease

Previous reports on the Hanshin-Awaji earthquake showed an initial increase in patients with injury and a subsequent increase in patients with respiratory disease, especially pneumonia.[11–13] Similarly, our observation showed a marked increase in pneumonia patients, although there was no initial increase in patients with serious injury as the majority of victims drowned and heavily injured patients were rarely transferred to hospital.

The epidemiology of respiratory disease varies depending on the situation. For instance, after the 2004 Sumatra-Andaman earthquake and subsequent tsunami, the number of lower respiratory infections in Ache rapidly increased and then sharply declined during the second week.[14] However, after the 1995 Hanshin-Awaji earthquake, the number of patients hospitalised for pneumonia increased gradually and remained high for over 2 months[9 10] as pneumonia developed more slowly. In the Sumatra-Andaman earthquake, many cases of pneumonia resulted from aspiration of tsunami-water in near-drowning events ('tsunami lung').[15 16] On the other hand, in the Hanshin-Awaji earthquake, numerous, mostly elderly patients staying in the unhealthy conditions of shelters developed pneumonia ('shelter pneumonia').[17] In this earthquake and tsunami, we experienced few cases of pneumonia directly caused by aspiration of tsunami-water. A few patients came from the field, but most were from shelters, their own or relative's homes, other hospitals or nursing homes. Their mean age was significantly higher than in 2009 or 2010. Therefore, we regarded and treated most of the pneumonia as 'shelter pneumonia'. We were unable to carry out bacteriological tests for 14 days after the earthquake due to a shortage of water, fuel and manpower. Most pneumonias were considered 'aspiration pneumonia acquired in a nursing home' because of the patients' ADL status.

Cases of AE-COPD were also significantly increased. COPD was one of the most common chronic respiratory diseases, especially in the elderly. It is well known that interruption of treatment for chronic disease frequently exacerbates the patient's condition, as after a natural disaster.[14 18–20] Many patients lost their drugs in the tsunami, and therefore disruption of regular medication may partly account for the increase in AE-COPD admissions. Also, the weather was sunny and windy from the end of March and dust from the tsunami sludge was an important component of particulate air pollution and may have contributed to the significant rise in the number of admissions for AE-COPD.

Although asthma was also a common chronic respiratory disease and had the same precipitating cause as COPD, asthma attacks did not increase as much as AE-COPD, perhaps because of two important differences between the two conditions. First, COPD patients were generally older than those with asthma and so the baseline health status of COPD patients was poorer than that of those with asthma.[21] As a result, COPD patients required more frequent hospitalisation. In our study, the mean age of AE-COPD patients was higher than that of those experiencing asthma attacks. Second, bacterial respiratory infection affects patients with COPD more than those with asthma.[22] In the aftermath of the disaster, poorer hygiene and overcrowding in shelters would have increased the risk of respiratory bacterial infection resulting in AE-COPD.

Hospitalisation for lung cancer related symptoms increased only slightly and actually declined as a proportion of total admissions for respiratory diseases. The mean age of lung cancer patients was similar to that in the previous 2 years. Maeda *et al*[23] also reported that no increase in lung cancer related hospitalisation was observed after the Hanshin-Awaji earthquake. As lung cancer progression may be influenced less by the environment than by growth of the cancer, the disaster would not impact on lung cancer immediately. Although the interruption of chemotherapy and/or radiotherapy would have worsened prognosis, this cannot be confirmed during our study period.

Effect on ADL status

In the acute phase following the disaster, patients with poor ADL status, especially those 'originally dependent', were hospitalised for pulmonary diseases, typically pneumonia, although substantial numbers of patients with good ADL status were also hospitalised. After 3 weeks, there was a sharp increase in 'newly dependent' patients whose ADL status had deteriorated. It was reported that physical disability was an independent risk factor for death in the Hanshin-Awaji earthquake and the 1999 Taiwan earthquake.[9 10] However, those reports investigated mortality in the acute phase, not hospitalisation in the subacute or chronic phases. After the earthquake and tsunami, one in four Ishinomaki residents moved into shelters, many of which were also flooded by the tsunami. They lacked water and food and lived in unheated and overcrowded conditions, with many sleeping on the floor. As a result, the elderly had restricted consumption of food and water, and kept still in a small space, resulting in deterioration in their ADL status. In addition, scarcity of water worsened oral hygiene. Poor functional status and loss of oral hygiene were the major risk factor for pneumonia,[24–27] especially in the elderly, many of whom were subsequently hospitalised for 'shelter pneumonia'. Also, poor oral hygiene induces swallowing dysfunction[28] which could be a risk factor for COPD exacerbation[29] and may explain why AE-COPD increased especially in the elderly.

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Effect on an aging society

According to the report of the Japanese government, in the Great East Japan earthquake 93% of deaths occurred as a result of drowning and over 60% of these victims were over 60 years of age. Many previous studies have noted that the elderly are at greater risk of death after earthquakes; however, the proportion of elderly people killed in this earthquake and tsunami was extremely high compared to other similar disasters.[4–8] Comparable findings were reported only for 1995 Hanshin-Awaji earthquake and the 2004 mid-Niigata earthquake, both in Japan.[12 17] Moreover, 90.8% of patients hospitalised for respiratory disease after the earthquake in our study were over 60 years of age. These results suggest that the elderly are vulnerable immediately and also for a while after earthquakes.

In the 1999 Taiwan earthquake, the 2003 heat waves in the Czech Republic, and the 2004 Sumatra-Andaman earthquake, subsequent decreased mortality in the affected areas was the result of the large number of direct deaths caused by the disasters among vulnerable populations such as the elderly or children,[5 30 31] the so-called 'harvesting effect'. However, our observation suggests that, in an aging society, a disaster not only directly kills the vulnerable but also produces a new vulnerable population. Previous reports demonstrated that a prolonged harmful effect on mental health and slow psychological recovery were seen more frequently in the elderly than in young people.[32–35] Therefore, we should provide long-term care to the elderly after a disaster.

Implications for policy and practice

Our observations suggest two important targets for reducing hospitalisation for respiratory disease after a major disaster in an aging society: interrupted chronic respiratory disease treatment and deterioration in ADL status. Interruption of treatment for chronic respiratory disease could be prevented if a few days' stored drug supply were available. This would necessitate a storage system containing regional prescription data for each drug and personal medication data. Telemedicine systems or web-based patient data storage systems might be useful. Prevention of deterioration in ADL status is also important. Elderly people are potentially vulnerable and their ADL status can easily deteriorate. In our study, living in shelters for more than 3 weeks resulted in deterioration in ADL status and hospitalisation for respiratory diseases. Therefore, we propose that the elderly should be evacuated from disaster areas as quickly as possible.

Strengths and weaknesses of this study

Our study has two important strengths. First, the Great East Japan Earthquake affected one of the most rapidly aging societies in the world.[3] As the proportion of elderly people continues to increase in both developed and developing countries, there is an urgent need for information on and analysis of aging societies. The findings of our study are applicable to natural disasters worldwide. Secondly, we were able to obtain detailed information on patient demographics, diagnosis and ADL status in a catastrophic situation. This was because our hospital continued to function and maintained its electronic medical record systems and laboratory systems, despite a devastating earthquake and tsunami which severely affected most other medical facilities, and because staff in our hospital had received earthquake training and had recorded our experiences as memos or on digital recorders for analysis for disaster medicine.

Our study was conducted in a single centre. This might be a weakness of our study, but our hospital was the only functional hospital after the disaster in the Ishinomaki medical zone which experienced over 30% of the total fatalities in this earthquake. Also, it was the only hospital in the medical zone with a department of respiratory medicine and pulmonary specialists, and previously had accepted most seriously ill patients with pulmonary disease who needed hospitalisation. Therefore, we think our study accurately describes the impact of the earthquake on pulmonary diseases and explains what happened in a hospital directly affected by the earthquake.[2] However, it is also weakness of our study that we only analysed hospitalised patients as there were also numerous outpatients, many of whom died. These events will be analysed in a future report. Another weakness is that a cross-sectional study cannot elucidate a causal relationship. Finally, we did not clearly define conditions for hospitalisation. Because of the destruction of the normal healthcare system and poor hygiene outside the hospital, we admitted some patients who normally would have been treated in an outpatient setting. However, this was a real situation after a devastating disaster.

CONCLUSION

The Great East Japan earthquake and subsequent tsunami affected one of the most rapidly aging societies in the world. After the disaster, pneumonia, COPD exacerbation and asthma attacks associated with low ADL status in the elderly significantly contributed to the increase in hospitalisation for pulmonary diseases. These observations should be used when planning emergency medical management for disasters in a progressive but rapidly aging society.

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Contributors SY was responsible for study design and interpretation of the data, and drafted the manuscript. MH, SK, HS, ST and MY were responsible for the collection and interpretation of the data. KN drafted the statistical analysis section of the manuscript, and provided suggestions on public health and epidemiology. MH, SK and MY were responsible for study design and revised the draft manuscript. SY, MH, SK, HS, ST and MY treated the patients. All authors approved the final version of the manuscript.

Competing interests None.

Ethics approval The ethics review committee of Japanese Red Cross Ishinomaki Hospital approved this study.

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The impact of the 2011 Great East Japan Earthquake on hospitalisation for respiratory disease in a rapidly aging society: a retrospective descriptive and cross-sectional study at the disaster base hospital in Ishinomaki

Shinsuke Yamanda, Masakazu Hanagama, Seiichi Kobayashi, et al.

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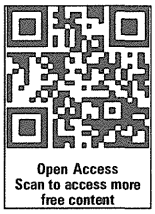

ORIGINAL ARTICLE

Impact of the Tohoku earthquake and tsunami on pneumonia hospitalisations and mortality among adults in northern Miyagi, Japan: a multicentre observational study

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ABSTRACT

Background On 11 March 2011, the Tohoku earthquake and tsunami struck off the coast of northeastern Japan. Within 3 weeks, an increased number of pneumonia admissions and deaths occurred in local hospitals.

Methods A multicentre survey was conducted at three hospitals in Kesennuma City (population 74 000), northern Miyagi Prefecture. All adults aged ≥18 years hospitalised between March 2010 and June 2011 with community-acquired pneumonia were identified using hospital databases and medical records. Segmented regression analyses were used to quantify changes in the incidence of pneumonia.

Results A total of 550 pneumonia hospitalisations were identified, including 325 during the pre-disaster period and 225 cases during the post-disaster period. The majority (90%) of the post-disaster pneumonia patients were aged ≥65 years, and only eight cases (3.6%) were associated with near-drowning in the tsunami waters. The clinical pattern and causative pathogens were almost identical among the pre-disaster and post-disaster pneumonia patients. A marked increase in the incidence of pneumonia was observed during the 3-month period following the disaster; the weekly incidence rates of pneumonia hospitalisations and pneumonia-associated deaths increased by 5.7 times (95% CI 3.9 to 8.4) and 8.9 times (95% CI 4.4 to 17.8), respectively. The increases were largest among residents in nursing homes followed by those in evacuation shelters.

Conclusions A substantial increase in the pneumonia burden was observed among adults after the Tohoku earthquake and tsunami. Although the exact cause remains unresolved, multiple factors including population aging and stressful living conditions likely contributed to this pneumonia outbreak.

Key messages

What is the key question?

- Did the pneumonia incidence increase among the adult population after the Tohoku earthquake/tsunami, what were the characteristics of the disaster-associated pneumonia?

What is the bottom line?

- Our survey in a well defined population of northern Miyagi Prefecture revealed that a marked increase in the incidence of pneumonia hospitalisations and pneumonia-associated deaths was observed during the 3-month period following the disaster, the vast majority of the victims were older people, only 3.6% were associated with near-drowning in the tsunami waters, and the clinical and microbiological characteristics of the post-disaster patients were similar to those of the pre-disaster patients.

Why read on?

- Because this disaster affected a notably aging population with the highest baseline pneumonia incidence rate, the disaster caused a drastic increase in the number of admissions and placed a heavy burden on local hospitals. In addition to using the pneumococcal vaccine for disaster-affected populations, the provision of optimal living conditions, medical check-ups and oral hygiene care must be a priority for older people after natural disasters.

INTRODUCTION

On 11 March 2011, a magnitude 9.0 earthquake struck off the northeastern coast of Japan. Within an hour of the earthquake, devastating tsunamis swept over the east coast of the Tohoku Region, resulting in approximately 20 000 deaths and catastrophic damage to the local infrastructure and environment.[1 2] As a result of the extensive destruction of homes, more than 400 000 displaced people were moved to emergency evacuation shelters that were not supplied with electricity, gas, water or food, despite sub-freezing winter temperatures.[3 4]

Previous studies showed that acute respiratory infections were frequently observed among people displaced by the 2001 earthquake in El Salvador,[5] among those affected by the 2003 Bam earthquake

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in Iran[6] and among people in Aceh Province affected by the 2004 Indian Ocean earthquake and tsunami.[7] Furthermore, severe pneumonia associated with the aspiration of seawater, known as 'tsunami lung', was reported in areas affected by the Indian Ocean tsunami.[8–10] However, these studies were conducted in resource-limited settings without reliable baseline data and lacked a standardised case definition. The impact of natural disasters, including tsunamis, on the risk of pneumonia remains largely unknown.

Within 3 weeks of the earthquake and tsunami on 11 March, a rapid increase in pneumonia hospitalisations and related deaths in northern Miyagi Prefecture was reported by mass media outlets.[11] We undertook an investigation to elucidate the impact of the Tohoku earthquake/tsunami on the incidence of pneumonia-related hospitalisations and mortality among adults aged ≥18 years in Kesennuma. We also sought to describe the clinical characteristics of disaster-related pneumonia and investigate the potential causes of increased rates of pneumonia in the affected population.

METHODS

Setting

Kesennuma is located on the northeastern coast of Miyagi Prefecture (figure 1). The city has a long, saw-toothed coastline with narrow, flat land facing the Pacific Ocean. The total population in February 2011 was 74 257 (source: Department of

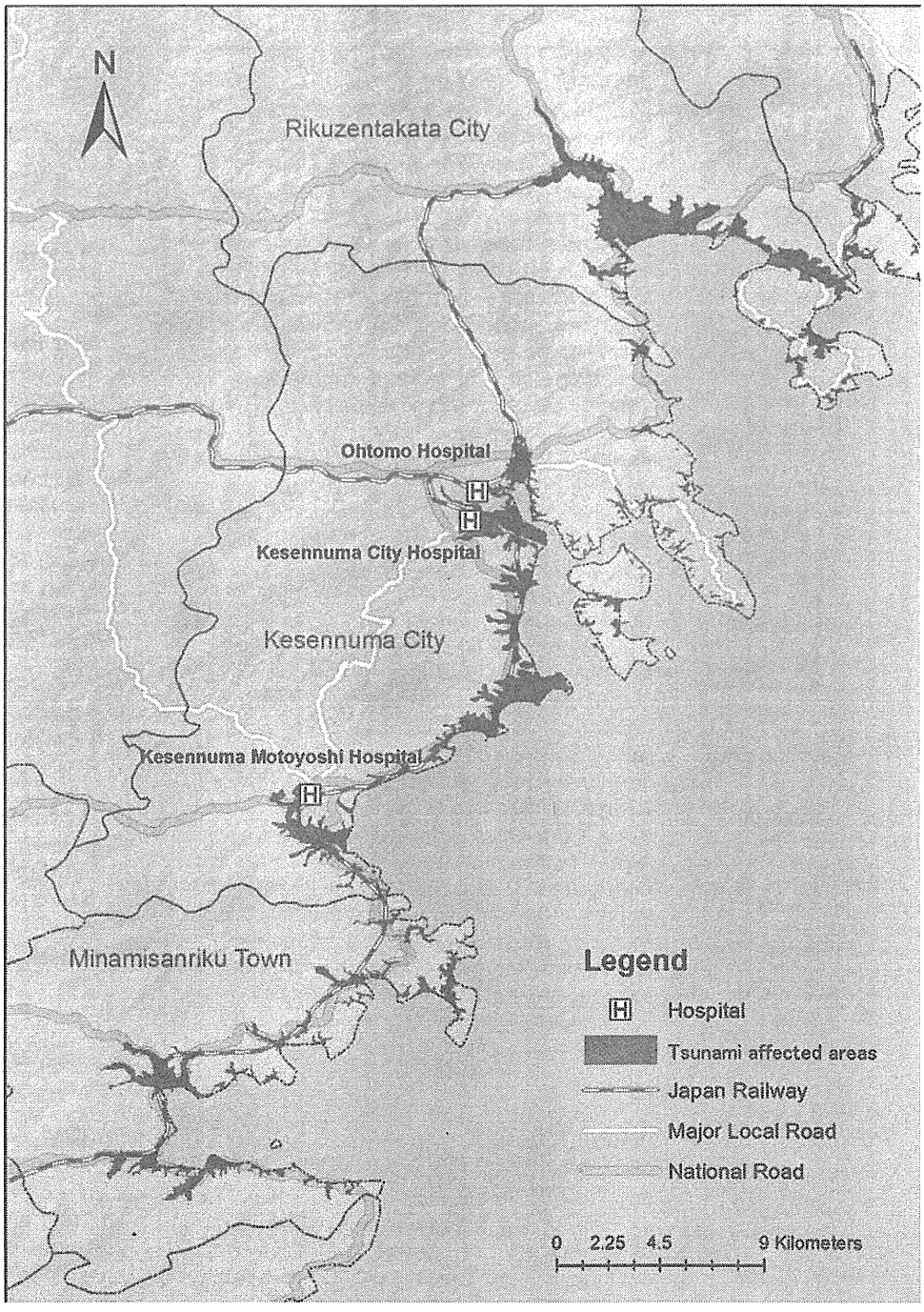

Figure 1 Area affected by the Tohoku earthquake and tsunami, Kesennuma City, Miyagi Prefecture. The disaster area data were obtained from the overview map of tsunami-affected areas released by the Geospatial Information Authority of Japan (http://www.gsi.go.jp/BOUSAI/h23_tohoku.html).