Influence of the Great East Japan Earthquake and Tsunami 2011 on Occurrence of Cerebrovascular Diseases in Iwate, Japan

Shinichi Omama, MD; Yuki Yoshida, MD; Kuniaki Ogasawara, MD; Akira Ogawa, MD; Yasuhiro Ishibashi, MD; Motoyuki Nakamura, MD; Kozo Tanno, MD; Masaki Ohsawa, MD; Toshiyuki Onoda, MD; Kazuyoshi Itai, MD; Kiyomi Sakata, MD

Background and Purpose—Little information is available regarding the occurrence of cerebrovascular diseases after tsunamis. This study was performed to determine the influence of the tsunami damage caused by the Great East Japan earthquake on occurrence of cerebrovascular diseases.

Methods—Subjects from the coastline and inland areas of Iwate Prefecture who developed cerebrovascular diseases before and after the disaster were included in the analysis. Standardized incidence ratios of 2011 against the previous 3 years were calculated in two 4-week periods before and four 4-week periods after the disaster, according to stroke subtype, sex, age group, and flood damage.

Results—The standard incidence ratio for cerebrovascular diseases was 1.20 (1.00–1.40) in the first 4-week period after the disaster and was not significant in other periods. The standard incidence ratios in the first 4-week period for cerebral infarction, intracerebral hemorrhage, and subarachnoid hemorrhage were 1.22 (0.98–1.46), 1.15 (0.76–1.55), and 1.20 (0.52–1.88), respectively. These values were 1.51 (1.19–1.88) for men, 1.35 (1.06–1.64) for subjects aged ≥75 years, and 1.35 (1.06–1.64) for the high flooding areas. The standard incidence ratio of cerebral infarction in the first 4-week period for men aged ≥75 years in the high flooding areas was 2.34 (1.34–3.34).

Conclusions—In the areas highly flooded by the tsunami caused by the Great East Japan earthquake, the occurrence of cerebral infarction among elderly men more than doubled in the first 4 weeks after the disaster. (Stroke. 2013;44:1518-1524.)

Key Words: cerebrovascular disease ■ earthquake ■ epidemiology ■ stress ■ tsunami

On March 11, 2011, a massive earthquake with a magnitude 9.0 on the Richter scale hit the northeast of Japan, and a following huge tsunami caused huge damage along the northeast coast of Japan, leaving 15,872 dead, 2777 missing, and 129,577 houses destroyed.1 In Iwate Prefecture, which is >100 km apart from the epicenter of the earthquake and >200 km from the disabled Fukushima Daiichi atomic power plant, the Great East Japan earthquake and tsunami caused huge damage leaving 4671 dead, 1203 missing, and 19,199 houses destroyed mainly by the tsunami,2 but with some small damage attributable to the earthquake and the atomic power plant accident. Many people in the areas flooded by the tsunami had to live in shelters for several months, and some people had to move to inland areas. In coastal areas, lifeline damage to electric power, water supply, city gas, as well as communications, failure of phone lines, mobile phones, and Internet connections, and failure of the supply of food, fuel, and essentials for life continued for several months. Even in inland areas, these damages continued for several days or weeks. Increases in acute coronary syndrome, takotsubo cardiomyopathy, pulmonary embolism, pneumonia,3–6 and cerebrovascular diseases3 after past huge earthquakes were reported previously in Japan. Increases in the incidences of cerebrovascular diseases and pneumonia7 and acute heart failure8 were reported after the Great East Japan earthquake. However, the reason for the increase in cerebrovascular diseases after this disaster (ie, whether stress attributable to the quake or stress attributable to tsunami damage, or insufficiency of medical care service increased cerebrovascular attacks) was unclear. The present study was performed to determine the influence of the tsunami caused by the Great East Japan earthquake on the occurrence of cerebrovascular diseases in

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From the Department of Critical Care Medicine (S.O., Y.Y.), Department of Neurosurgery (K.O., A.O.), Department of Internal Medicine, Division of Neurology and Gerontology (Y.I.), Department of Internal Medicine, Division of Cardiology (M.N.), and Department of Hygiene and Preventive Medicine (K.T., M.O., T.O., K.I., K.S.), Iwate Medical University, School of Medicine, Morioka, Japan.

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Correspondence to Shinichi Omama, MD, Department of Critical Care Medicine, Iwate Medical University, 19-1 Uchimaru, Morioka, Iwate 020-8505, Japan. E-mail somama@iwate-med.ac.jp

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1518
the surrounding areas. This is the first report of the influence of the tsunami on cerebrovascular diseases.

Methods

Study Area
The 17 municipalities in the whole area along the shore and northern inland areas of Iwate Prefecture were divided into areas showing high flooding or no/low flooding after the tsunami. The high flooding areas included municipalities with percentage of the population living in the flooded areas (%PFA $\geq 20^{\circ}$) (Rikuzentakata, Ofunato, Kamaishi, Otsuchi, Yamada, Miyako, Hanawa, and Noda: a total population of 208,063 on October 1, 2010, before the disaster), and the no/low flooding areas included municipalities with %PFA $< 20^{\circ}$ (Sumita, Iwaihumi, Kuji, Hirono, Kunohe, Karumai, Ichinohe, and Ninohe: a total population of 131,717 on October 1, 2010, before the disaster). Location, %PFA, and seismic intensity of the main shock of the earthquake in each municipality are shown in Figure 1. Seismic intensity in each municipality was determined, according to officially published data from the Japan Meteorologic Agency. For municipalities where this information was unavailable, data from the nearest town were used instead.

Subjects
Subjects living in 17 municipality in the whole area along the shore and northern inland areas of Iwate Prefecture who developed cerebral infarction (CIF), intracerebral hemorrhage, or subarachnoid hemorrhage between January 15, 2011 (8 weeks before the disaster), and July 1, 2011 (16 weeks after the disaster), and cases of these cerebrovascular diseases in the same region around the same period in 2008, 2009, and 2010 were used as references. Information regarding the occurrence of cerebrovascular diseases, including age at onset, sex, date of onset, subtype of stroke, and municipality of residence, were obtained from the Iwate Stroke Registry. Details of the Iwate Stroke Registry are available in the online-only Data Supplement.

Places of residence of patients with stroke were registered in the stroke registry based on the addresses on medical records. It was difficult to determine the precise places of residence of refugees who lost their homes after the disaster until moving to temporary housing or other accommodation. In most municipalities in Iwate’s coastal area, which were surrounded by coastline and mountains and far from the inland area, it was difficult to move to other municipalities for several weeks because of damage to roads and the transportation system by the tsunami and lack of fuel for vehicles. Many refugees were thought to have lived within the same municipality as before the disaster until moving to temporary housing or other accommodation. Patients with stroke who were residents outside the study area were excluded from this study.

Survey System of the Stroke Registry
After the disaster, hospitals and medical facilities in the coastal area had limited resources and there was loss of function due to damage caused by the shock of the earthquake or flood damage by the tsunami. The voluntary task for the stroke registry was difficult for physicians in the devastated area, and the number of registry cases was reduced around the time of the disaster. From September 13, 2011, 6 months after the disaster, a nonvoluntary survey system of the stroke registry was implemented in the study area. For the inventory survey, trained research nurses were assigned to the hospitals with neurologists or neurosurgeons, and doctors and trained research nurses were dispatched to the medical facilities without neurologists or neurosurgeons. All the medical records of inpatients and deceased outpatients who developed cerebrovascular diseases from January 1, 2008, were checked retrospectively and registered with the stroke registry. There are 17 hospitals in the study area, not including psychiatric hospitals. Three hospitals lost medical function and all medical records because of tsunami; 4 hospitals did not treat cerebrovascular diseases in the acute stage. The inventory survey was done in the remaining 10 hospitals, which treated acute cerebrovascular diseases. The survey system of the stroke registry did not refer to death certification.

Analysis
In this study, March 11 and 12, 2011, were defined as the predisaster day and postdisaster day, respectively. This definition was made because huge tsunami waves struck the coastline several times until midnight after the main shock of the earthquake on March 11, 2011, and few cases of cerebrovascular disease after the main shock of the earthquake were transferred to medical facilities on the day of the disaster, and their onset times were often not recorded in the medical records.

The 24-week period from $\approx 2$ months before to $\approx 4$ months after the disaster was divided into the following 4-week periods: before the disaster period 2 (BD2), January 15, 2011, to February 11, 2011; before the disaster period 1 (BD1), February 12, 2011, to March 11, 2011; after the disaster period 1 (AD1), March 12, 2011, to April 8, 2011; after the disaster period 2 (AD2), April 9, 2011, to May 6, 2011; after the disaster period 3 (AD3), May 7, 2011, to June 3, 2011, and after the disaster period 4 (AD4), June 4, 2011, to July 1, 2011.

The standard incidence ratios (SIR) of cerebrovascular diseases (ie, the ratios of actual incidence number relative to the expected incidence number) in all 4-week periods were calculated. The

Figure 1. Map of study area depicting the high flooding areas (gray) and no/low flooding areas (empty). Municipalities (number) and the epicenter of the earthquake (bull’s eye) are shown. %PFA indicates percentage of the population living in flooded areas; and SIR, seismic intensity.
expected incidence number was the sum of the numbers of multiplying mean age–specific incidence rate between 2008 and 2010 by age-specific population number in 2010 instead of that of in 2011. The population on October 1, 2011, reflected not only those who were dead or missing because of the earthquake and tsunami disaster, but also those who had moved to other municipalities or who died because of illness or trauma unrelated to the disaster. The population numbers referred to the population statistics in October 1 in each year10 and the incidence numbers were analyzed from the data of the Iwate Stroke Registry. The 95% confidence intervals (CIs) and probability values of SIR were calculated. SIRs were calculated by stroke subtype, sex, age group (<75 years at onset and ≥75 years), and 2 areas of no/low flooding areas (%PFA <20) and high flooding areas (%PFA ≥20). SIRs for 4 groups (2 sexes by 2 age groups: men ≥75 years, men <75 years, women ≥75 years, and women <75 years), according to no/low flooding areas and high flooding areas, were calculated.

This study was approved by the committees of the Iwate Stroke Registry and the ethics committees of Iwate Medical University.

Results

The characteristics of the registered cases were shown in the Table. There were no significant differences by year in the crude incidence rate, mean age at onset, ratio of men, ratio of each stroke subtype, ratio of cases in high flooding areas, and ratio of diagnostic imaging with computed tomography or MRI. The mean seismic intensity and SD in the high flooding areas was 5.0 (0.5) and that in the no/low flooding areas was 4.5 (0.3). There was no difference between seismic intensities in high and no/low flooding areas (P=0.061).

SIRs in each 4-week period are shown in Figure 2. The SIR of all cases for AD1 was 1.20 (95% CI, 1.00–1.40; P=0.028), which was significantly higher than the mean incidence rate around the same period from 2008 to 2010, but the values for BD2, BD1, AD2, AD3, and AD4 were not significantly different.

SIRs in each 4-week period by 3 stroke subtypes, by sex, by 2 age groups, and by 2 areas (no/low or high flooding areas) were calculated. In AD1, the SIRs for men, ≥75 years, and high flooding areas were significantly higher, but there were no significant differences in other periods. SIRs by subtypes and subgroups in AD1 are shown in Figure 3.

In the high flooding areas, SIR of all cases for men ≥75 years was 2.41 (95% CI, 1.49–3.34; P=0.001), which was significantly high, whereas those for other groups were not significant in AD1. In the no/low flooding areas, SIR of CIF was not significant for all subgroups in AD1 (Figure 5).

Discussion

Previous reports regarding the relationship between disasters and the occurrence of cerebrovascular diseases showed an increase in incidence of intracerebral hemorrhage during a 5-week period after the severe earthquake at Noto peninsula in Japan5 and an increase in number of transferred patients who developed CIF by emergency medical services for 3 weeks after the Great East Japan earthquake.7 The present study indicated that the incidence rate of CIF among elderly men in high flooding areas doubled during the first 4 weeks after the earthquake and tsunami. Some previous studies indicated increased rates of cerebrovascular death and cardiovascular disease in elderly people after disasters,12–14 but there have been no reports discussing sex differences in cardio- and cerebrovascular diseases after disasters. The declared vital statistics indicated annual standard mortality ratios in this study area referring to the mortality rate of the whole of Iwate Prefecture increased from 0.99 (95% CI, 0.91–1.08) in the previous 3 years to 1.25 (95% CI, 1.08–1.41) in 2011 for men and did not change significantly from 1.02 (95% CI, 0.94–1.10) to 1.06 (95% CI, 0.93–1.13) for women in the high flooding area. In the no/low flooding area, these showed no changes from 1.11 (95% CI, 1.00–1.22) to 1.05 (95% CI, 0.87–1.23) for men and from 0.99 (95% CI, 0.88–1.08) to 1.18 (95% CI, 0.86–1.18) for women. These data corroborate the results of this study.

There have been several reports of elevation of blood pressure after huge earthquakes,15,16 hurricane,17 and nuclear power plant accident18 and elevation of serum cholesterol, triglycerides,19 hematocrit, fibrinogen, and blood viscosity20 were reported after previous disasters. Increases in blood pressure and aggravation of diabetes mellitus were reported after the Great East Japan earthquake and tsunami.21,22 This disaster placed many people in northeastern Japan under a great deal of stress because of loss of their families, loss of their homes, life in shelter, lifeline damage, lack of daily necessities, and insufficiency of medical service. Mental stress and environmental changes after disasters caused increased sympathetic nervous activity, elevation of blood pressure, elevation of blood viscosity, increased coagulation function, and platelet activation, and these factors can trigger

Table. Characteristics of Cases of Cerebrovascular Diseases Between January 15 and July 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Population Number</th>
<th>Onset Number</th>
<th>Crude Incidence Rate Per 100000</th>
<th>Mean Age (SD)</th>
<th>Men</th>
<th>Cerebral Infarction</th>
<th>Intracerebral Hemorrhage</th>
<th>Subarachnoid Hemorrhage</th>
<th>High Flooding*</th>
<th>By Imaging†</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>349246</td>
<td>707 (100%)</td>
<td>202.4</td>
<td>74.5 (11.4)</td>
<td>353 (49.9%)</td>
<td>480 (67.9%)</td>
<td>172 (25.2%)</td>
<td>49 (6.9%)</td>
<td>385 (54.5%)</td>
<td>696 (88.4%)</td>
</tr>
<tr>
<td>2009</td>
<td>344238</td>
<td>702 (100%)</td>
<td>203.9</td>
<td>74.7 (11.3)</td>
<td>360 (51.3%)</td>
<td>461 (65.7%)</td>
<td>176 (25.1%)</td>
<td>65 (9.3%)</td>
<td>364 (51.9%)</td>
<td>691 (98.4%)</td>
</tr>
<tr>
<td>2010</td>
<td>339780</td>
<td>701 (100%)</td>
<td>206.6</td>
<td>74.7 (12.0)</td>
<td>367 (52.4%)</td>
<td>494 (70.5%)</td>
<td>154 (22.0%)</td>
<td>53 (7.6%)</td>
<td>406 (57.9%)</td>
<td>695 (99.1%)</td>
</tr>
<tr>
<td>2011</td>
<td>339780‡</td>
<td>668 (100%)</td>
<td>196.6</td>
<td>74.5 (12.0)</td>
<td>365 (54.6%)</td>
<td>459 (68.7%)</td>
<td>153 (22.9%)</td>
<td>56 (8.4%)</td>
<td>378 (56.6%)</td>
<td>663 (99.3%)</td>
</tr>
</tbody>
</table>

*Subjects who lived in the area that was highly flooded by the Tsunami in 2011.
†Cases diagnosed by CT or MRI.
‡The population number in 2010 was used instead of the inaccurate population number from 2011.
cardio- and cerebrovascular diseases.\textsuperscript{23} More damage from the disaster may cause more mental stress after the disaster, and risk factors (such as hypertension, diabetes mellitus, and past history of cardio- and cerebrovascular disease) may increase the rates of cardio- and cerebrovascular diseases. In a large cardiovascular cohort study in Iwate Prefecture, the registrants from the general population showed higher values of blood pressure and HbA1c, higher incidences of hypertension and diabetes mellitus in the elderly, higher incidences of hypertension and diabetes mellitus, and higher incidences of past history of cardio- and cerebrovascular diseases in men.\textsuperscript{24} These background characteristics of the general population in Iwate may explain the higher incidence of cerebrovascular disease in elderly men in the high flooding area in Iwate Prefecture.

This study and the report by Aoki et al.,\textsuperscript{7} which involved analysis of the number of cases of cerebrovascular disease transferred by ambulance around the Great East Japan earthquake and tsunami in Miyagi Prefecture, showed similar results of increase stroke cases during the 3 or 4 weeks after the disaster and a tendency toward higher incidence rates in the elderly and in men after the disaster, but opposite results of more transport stroke cases in inland areas than in the coastal area. Difficulty in calling an ambulance in the coastal area with the huge damage to communication lines and ease of moving to inland areas with many flat roads in a short distance from the coastal area in Miyagi may have been responsible for the differences between the 2 studies.

Separating the influence of the shock attributable to the earthquake and damage by the tsunami was very difficult.
in the Great East Japan earthquake and tsunami. In the Great Hanshin-Awaji earthquake without tsunami damage, it was reported that the incidence rates of cerebrovascular diseases increased in the area with modified Mercalli intensity >9.5, which is equivalent to the seismic intensity of Japan Meteorologic Agency >5.5.\textsuperscript{25} In this study area, few houses were destroyed due to the earthquake shock because seismic intensities of Japan Meteorologic Agency of the high flooding area were mostly under 5.5, but many houses were destroyed due to the tsunami disaster.\textsuperscript{9} Nevertheless, the frequency of acute decompensated heart failure increased in the high flooding area.\textsuperscript{9} Therefore, the influence of the disaster on cardio- and cerebrovascular diseases was thought to be mainly due to the degree of destructive damage to the living environment.

This study had some other limitations. Patients with stroke who were not admitted to medical facilities or who were transferred and admitted to medical facilities outside the survey system of the Iwate Stroke Registry were missed partly. There may have been some patients with stroke who were treated as outpatients or who were admitted to hospitals outside the survey system of the Iwate Stroke Registry because of chaos and crowding in medical facilities after the disaster. These lost stroke cases would have reduced the incidence rate after the disaster but would not affect the conclusions of this study. It was impossible to check the medical records before the disaster in 3 hospitals that were lost due to the tsunami. These were small- or medium-scale hospitals with 70 to 135 beds and mainly handled the patients in the chronic stages of illness and few patients with cerebrovascular disease in the acute stage. Therefore, their influence on the incidence rate before the disaster would have been small. The population in the study area has been declining by \textasciitilde 5000 people (1.5% of the population) annually. After the disaster, 5874 people (1.7% of the population in 2010) were dead or missing over a short time. The expected incidence number in 2011, which was calculated from the 2010 population data, was overestimated and the SIR was underestimated by >3%. Even taking these limitations into consideration, there was no change in the conclusion that the incidence of cerebrovascular diseases, especially CIF in elderly men in high flooding areas, increased during the first 4 weeks after the disaster.

The incidence rate for cerebrovascular diseases after the first 4 weeks declined to the same level as around the same period before the disaster. This may have been because of recovery of lifelines, supply of necessities, and medical service. This study indicated that immediate recovery of medical care, medical support, and supply of drugs, and adequate control of blood pressure, water intake, and nutrition for disaster victims are required to prevent and reduce the incidence of cerebrovascular diseases, especially among elderly men.
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Disclosures
None.

References


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Supplemental Methods

About the Iwate Stroke Registry

The Iwate Stroke Registry program was initiated on January 1, 1991, and continues to the present. The registry was coordinated by the government of Iwate Prefecture and the Iwate Medical Association with all medical facilities (hospitals, medical offices, and nursing homes) in Iwate Prefecture. Stroke diagnostic criteria of cerebral infarction, intracerebral hemorrhage, and subarachnoid hemorrhage in this registry are based principally on the criteria established for the Monitoring System for Cardiovascular Disease commissioned by the Ministry of Health and Welfare. These criteria correspond to ICD-9 code, which published by the World Health Organization and define stroke as sudden onset of neurological symptoms. Registration has been performed prospectively by submitting registry sheets to the registry office by mail at discharge of stroke cases from hospital or completion of treatment. All data in the stroke registry were checked by well-trained staff for defects. The registry did not refer to death certification.

A total of 33 facilities participated among all 77 hospitals, not including psychiatric hospitals, 14 clinics, and one nursing home in the whole of Iwate Prefecture. Most of the hospitals that treat cerebrovascular disease in the acute stages participated in the registry. In the Iwate Stroke Registry, annual age-adjusted incidence rates of first-ever cerebrovascular diseases per 100000 people in the whole of Iwate Prefecture from 2004 to 2008 were 114.5 for men and 67.1 for women according to the Japan standard population in the 1985 census, and 167.2 for men and 83.9 for women by the world standard population (35 – 64 years old).

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