Sustained Increase in the Incidence of Acute Decompensated Heart Failure After the 2011 Japan Earthquake and Tsunami

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This study investigated the long-term impact of the 2011 Japan earthquake and tsunami on the incidence of acute decompensated heart failure (HF) in the disaster area. This was a population-based study using comprehensive registration for all hospitals within the study area. The standardized incidence ratio (SIR) and 95% confidence interval (CI) for new onset of HF during the disaster year (2011) and postdisaster years (2012 to 2014) were determined. When SIR were compared between the low- and high-impact areas, as defined by the extent of tsunami inundation in residential areas, SIR showed a significant increase in high-impact areas in 2011 (1.67, 95% CI 1.45 to 1.88) and tended to return to baseline in 2012, the first postdisaster year (1.25, 95% CI 1.06 to 1.43). The rate again increased in 2013 (1.38, 95% CI 1.18 to 1.57) and 2014 (1.55, 95% CI 1.35 to 1.75). In low-impact areas, no such increase was apparent during either the disaster year or the post-disaster years. Mean postdisaster period SIR for municipalities significantly correlated with the percentage of tsunami flooding in residential areas ($r = 0.52$, $p < 0.05$) and with the percentage of refugees within the population ($r = 0.74$, $p < 0.01$). There was no significant relation between maximum seismic intensity and mean SIR in these municipalities. In conclusion, these results suggest that the catastrophic tsunami but not the earthquake per se resulted in a prolonged increase in the incidence of HF among the general population living in tsunami-stricken areas. **(Am J Cardiol 2016;118:1374–1379)**

Previous studies have reported a short-term increase in the incidence of acute cardiovascular events such as acute myocardial infarction and sudden cardiac death after major earthquakes[1–6] and devastating storms.[7–10] In terms of acute decompensated heart failure (HF), we have previously reported that the number of HF admissions in the tsunami-stricken area in our prefecture doubled and reached a peak several weeks after the 2011 northeast Japan earthquake and tsunami (which occurred on March 11, 2011), with admission levels returning to baseline within 2 months.[11] In the same disaster, the number of ambulance transfers for possible patients with HF in the adjoining prefecture doubled immediately after the disaster and remained high for several weeks.[12] Few studies have examined the long-term effect on the incidence of HF after combined disasters such as an earthquake and subsequent tsunami. This study, which used comprehensive registration across the entire study area, examined the impact of the devastating 2011 earthquake and tsunami on the incidence of cardiovascular events, specifically HF.

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See page 1378 for disclosure information.

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Methods

The study area included the coastal and inland areas of Iwate prefecture in northeast Japan (Figure 1, *left*). According to national census data, the population of the study area was 334,500 in 2010 before the disaster. The area comprises 16 municipalities, and the percentage of elderly (age ≥65 years) in the area was 32% before the disaster.

As in our previous report,[11] to elucidate the effects of the tsunami on HF events, each municipality was categorized as either a low- or high-impact area according to the degree of tsunami inundation (Figure 1, *right*). This definition was based on the percentage of tsunami flood area per built up area (TFA) in each municipality.[13] This ratio

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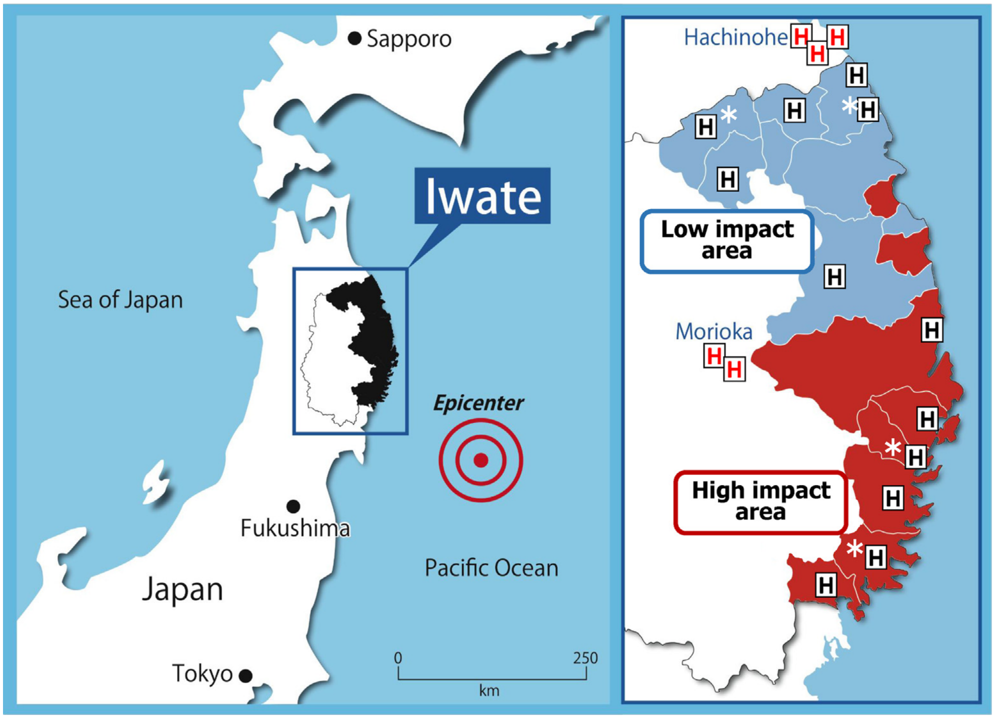

Figure 1. Map of the study area. The *black zone* in Iwate shows the study area. The epicenter is marked by the *bull's eye*. The study area was divided by the percentage of tsunami flooding per built up area <10% or inland (low-impact area; *blue*) or >10% (high-impact area; *red*). The *black "H"* indicates locations of all hospitals within the study area (n = 12), and the *red "H"* indicates nearby teaching hospitals outside the study area (n = 5). *Hospitals with a cardiology department.

represented the degree and extent of damage caused by the tsunami in residential areas of each town. The low-impact area was defined as TFA <10% or a remote area without a coastline, and the high-impact area was defined as TFA ≥10%. The low-impact area comprised 8 municipalities with a population of 129,800 in the predisaster years (2009 to 2010), with a gradual decrease to 121,600 in 2014. The high-impact area comprised 8 municipalities with a population of 206,300 in predisaster years, with a rapid decrease after the disaster to 184,700. In both areas, there were 6 general hospitals, with 2 of those having a cardiology department. Patients with decompensated acute HF were mostly admitted to the hospitals which had a cardiology department. General practitioners in the study area did not provide any care for patients with serious acute cardiac events.

In terms of maximum seismic intensity in these municipalities,[14] there was no significant difference in scale between the low- and high-impact areas (4.6 ± 0.4, n = 8 vs 5.0 ± 0.6, n = 8; p = 0.11). The number of deaths on the day of the disaster was 12 in the low-impact area and 5,898 in the high-impact area. The number of evacuees in community centers or school gymnasiums at 1 month after the disaster (April 10, 2011) was 386 in the low-impact area and 42,880 in the high-impact area.[15]

As completeness of case ascertainment is an important prerequisite for reliable analysis and estimation of trends for the incidence of cases in a particular area, the registry system in the present study was planned so as to capture all cases of decompensated acute HF in the study area by covering all hospitals in the study area. To ensure that as many as possible appropriate cases were identified, we visited all operating hospitals within the study area (n = 12) and 5 high-level hospitals outside the study area (Morioka and Hachinohe; Figure 1, *right*) and retrospectively reviewed medical charts and/or discharge summaries for patients in cardiology and internal medicine wards and emergency rooms.

The study team included cardiologists and trained research nurses who checked medical charts and registered all hospitalized cases with HF that met Framingham diagnostic criteria.[16] Approval was obtained from the ethics review board of each participating hospital and Iwate Medical University before commencement of the study.

The present study examined the incidence (new onset) of decompensated acute HF in the study area from the date of the disaster (March 11, 2011) until the end of the postdisaster period (December 31, 2014). In addition, cases of HF for the corresponding periods in 2009 and 2010 were also surveyed to act as a time control. Patients who had been transferred to another hospital were counted on the admission index only. The standardized incidence ratio (SIR) and 95% confidence interval (CI) for HF during the disaster year (2011) and the following postdisaster years were determined respectively from the number of observed cases relative to the number of expected cases calculated by age adjusted by incidence for 2 predisaster years (2009 and 2010). Postdisaster SIR were compared between the low- and high-impact areas. Continuous variables are expressed as mean ± SD. Trend analysis among

Table 1
Temporal trend of number of HF case and clinical characteristics of patients with HF in the study areas

Variables	Pre-disaster 2009-2010*	Disaster 2011	Post-disaster 2012	Post-disaster 2013	Post-disaster 2014	*p* for trend
Overall area						
number of case	280	384	318	371	380	
age ≥ 75yrs	73%	77%	76%	70%	77%	0.93
men	48%	46%	48%	45%	48%	0.96
atrial fibrillation	56%	58%	52%	43%	51%	<0.01
left ventricular EF ≥ 50%	49%	47%	45%	48%	50%	0.61
in hospital mortality	13%	10%	12%	12%	9%	0.33
Low-impact area						
number of case	137	156	145	176	156	
age ≥ 75yrs	76%	77%	79%	72%	83%	0.45
men	45%	46%	44%	44%	46%	0.95
atrial fibrillation	55%	54%	54%	44%	57%	0.63
left ventricular EF ≥ 50%	50%	49%	45%	44%	46%	0.30
in hospital mortality	10%	10%	12%	13%	11%	0.60
High-impact area						
number of case	143	228	173	195	224	
age ≥ 75yrs	70%	76%	75%	69%	72%	0.62
men	51%	46%	51%	46%	50%	0.99
atrial fibrillation	56%	60%	51%	43%	46%	<0.001
left ventricular EF ≥ 50%	48%	46%	45%	52%	52%	0.21
in hospital mortality	16%	9%	12%	11%	8%	0.09

* Mean values of 2009 and 2010.

before- and after-disaster groups are based on the Cochran−Armitage test for trend. Pearson correlation coefficients were used to examine relation between mean SIR for the postdisaster period (2011 to 2014) and the percentage of TFA or the percentage of evacuees within each municipality population. A p value <0.05 was considered statistically significant.

Results

In the high-impact area, approximately 6,000 people (3% of the population) drowned or were missing on the day of the tsunami. This sudden population decrease was followed by a progressive decrease and reached approximately −10% of the initial population level in 2014, which was used for comparison with the predisaster level. In the low-impact area, the population gradually decreased to approximately −6% of the predisaster population level in 2014.

For clinical characteristics of HF, the percentage of elderly people (aged >75 years) and the percentage of men did not change during the study period in both low- and high-impact areas (Table 1). In the low-impact area, the percentage of atrial fibrillation among HF cases was stable. In the high-impact area, the percentage gradually but significantly decreased during the study period (p for trend <0.001). In cases evaluated using 2-dimensional transthoracic echocardiography (83%), secular trend for the percentage of preserved left ventricular ejection fraction of ≥50% did not change in both study areas. For in-hospital mortality, there were no significant differences during the study period in either area.

Temporal changes in SIR (95% CI) in the overall area were 1.40 (1.26 to 1.54) in 2011, 1.14 (1.01 to 1.26) in 2012, 1.30 (1.17 to 1.44) in 2013, and 1.31 (1.18 to 1.44) in 2014. When the SIR was separately analyzed according to the degree of TFA (≥10% vs <10%), in the high-impact area, SIR significantly increased in the disaster year (1.67 [1.45 to 1.88] Figure 2, *left*). In the first postdisaster year (2012), SIR showed a trend to return to baseline (1.25 [1.06 to 1.43]); however, the ratio again increased in 2013 (1.38 [1.18 to 1.57]) and further increased in 2014 (1.55 [1.35 to 1.75]). In contrast, in the low-impact area, SIR was stable and did not show a significant elevation throughout the study period except for 2013 (1.21 [1.03 to 1.39]; Figure 2, *right*). Mean SIRs for the postdisaster period (2011 to 2014) were calculated for each municipality and compared with the percentage of TFA or the percentage of refugees evacuated to community centers or school gymnasiums at 1 month after the disaster in each municipality population. SIR for HF events significantly correlated with several parameters related to tsunami damage (%TFA: $r = 0.52$, p <0.05; %evacuees: $r = 0.74$, p <0.01; Figure 3). There was no significant relation between maximum seismic intensity and mean SIR (2011 to 2014) in these municipalities ($r = 0.27$, p = 0.32).

Discussion

The results of this study show that, in the tsunami-stricken area, the incidence of decompensated acute HF increased significantly during 2011, the disaster year, and tended to decrease in the first postdisaster year (2012). The rate did, however, gradually increase in 2013 and 2014. The degree of increase in incidence significantly correlated with the severity of tsunami damage, as represented by the tsunami inundation index or the number of evacuees in each municipality.

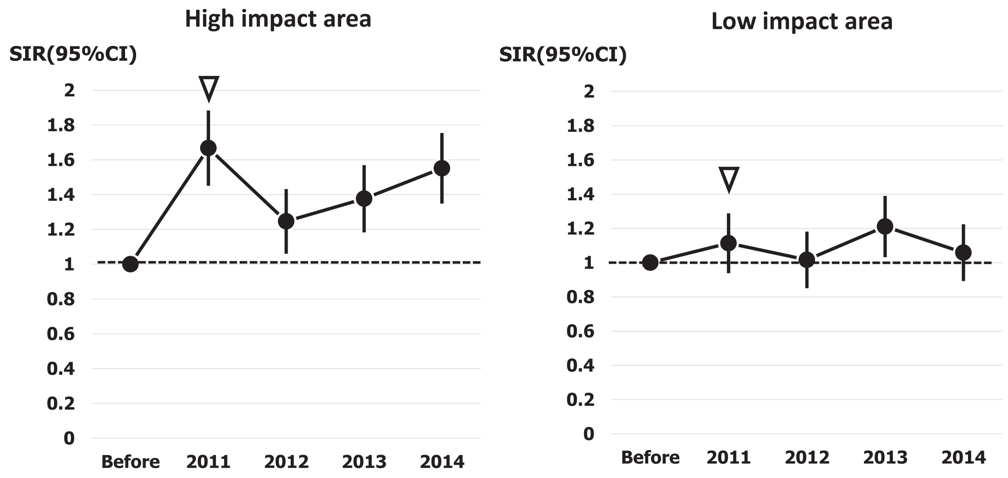

Figure 2. Comparison of temporal trends in mean standardized incidence and its 95% CI for the 4 years after disaster (2011 to 2014) in the high-impact area *(left)* and the low-impact area *(right)*. The *triangle* indicates the disaster year (2011).

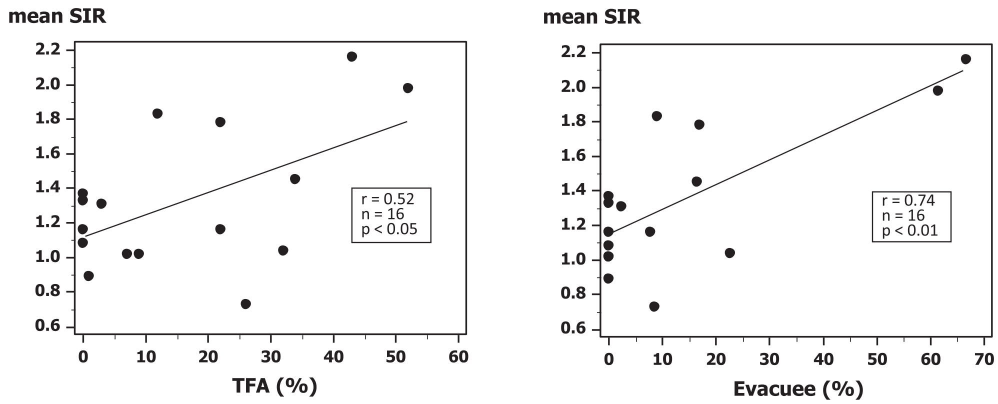

Figure 3. Relation between mean standardized incidence for the 4 years after disaster (2011 to 2014) versus percentage of tsunami flooded area *(left)* and percentage of evacuees *(right)* of the 16 municipalities in the study area.

Brown[17] used regional hospital discharge data and found that the number of admissions for HF did not increase immediately after the 2 major earthquakes that occurred in the United States in Loma Prieta in 1989 and in Northridge in 1994. In the 2011 Japanese earthquake and tsunami, however, agreeing with our previous report,[11] several single-center studies have reported that the number of admissions for HF during the first 3 weeks after the disaster was twice that of the time control period of the previous year.[18,19] The admission level returned to baseline in the next 3 weeks and remained at baseline for at least 10 months.[19] Yamauchi et al.[20] reported that the number of patients admitted for treatment for HF at a university hospital during the 6 months after the disaster was 1.5 times that of the control period before the disaster. These reports have suggested a short-term increase in the incidence of HF for the 2011 earthquake and tsunami. However, to the best of our knowledge, no reports have investigated the long-term effects, specifically for more than 1 year after the 2011 earthquake and tsunami, for the incidence of HF.

For acute myocardial infarction, a single-center study from New Orleans has reported that the number of patients with a coronary event divided by the total number of hospital admissions showed a 3-fold increase during first 3 years after Hurricane Katrina.[8] This increase rose to a 4-fold increase during the 3 to 6 years after the disaster.[10] This increasing trend in myocardial infarction events for the several years after the hurricane is comparable with the current HF trend. One of important factors for the prolonged increase in incidence is suggested to be because of sudden changes in the day-to-day lives of survivors and disaster-related psychological and socioeconomic problems.[8,10] These factors have also been reported as common risk factors for HF.[21–24] Even now, several years after the 2011 earthquake and tsunami, disaster damage in coastal areas of our prefecture is yet to be repaired, and many residents in the tsunami-stricken area are still living in narrow temporary housing (~30,000), without employment (~30,000), and with missing family (~6,000). It is therefore likely that social networks, economic problems, and mental health in these areas have not restored to predisaster levels. One study has reported that the prevalence of posttraumatic stress disorder was significantly high in patients with HF admitted during the first 6 months after the 2011 disaster and also suggested that the tsunami experience was an important risk factor associated with this mental disorder in patients with

HF.[25] As mental illnesses of this type are usually sustained over a long period after a catastrophic natural disaster,[26] we hypothesize that disaster-related stress might be an important factor for the sustained increase in the incidence of HF in tsunami survivors.

Another factor for the increased incidence of HF might be because of changes in population characteristics within the tsunami area. The prevalence of elderly people with a functional disability in the tsunami area is reported to show a steep increase from 9% at 1 year after to 15% at 3 years after the event.[27] This relative increase in fragile or more vulnerable people within the coastal population may have some bearing on the increased incidence of HF in that area.

For clinical characteristics of HF, there was a significant decreasing trend in prevalence of atrial fibrillation, from 56% during the predisaster period to 46% in 2014 in the tsunami area. Reasons for the decreased co-morbidity of atrial fibrillation in the HF cohort are not known in the present study. However, Thomas et al.[28] recently reported that complications of depression and diabetes mellitus in patients with HF were negatively associated with the incidence of atrial fibrillation in a large registry data set. The incidence of mental illness and glucose intolerance has been reported to increase over the long term after major natural disasters including earthquakes and tsunamis.[29,30] It is possible that increased incidences of these disorders after the disaster may have contributed to the observed relative decrease in the frequency of atrial fibrillation among tsunami survivors.

Although this population-based study may be the largest and most systematic registration survey examining the long-term effects of a devastating earthquake and tsunami on the incidence of acute HF events, it does have some limitations. Medical charts were lost in 3 branch hospitals located within the tsunami area, which may result in bias. However, these small hospitals without full-time cardiologists did not provide any care for patients with decompensated acute HF on a regular basis; therefore, few patients were admitted to these medical facilities before the disaster. As this epidemiologic study aimed to investigate the long-term effects of the 2011 disaster on the incidence of HF in our prefecture, detailed cardiac examinations and psychological and socioeconomic surveys were not mandatory inclusion criteria for the study, so we could not, therefore, determine the cause of HF and the psychosocial status of the patients.

Disclosures

The authors have no conflicts of interest to disclose.

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