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>> OnlineFirst Version of Record - Jun 11, 2014

What is This?

Original scientific paper

Impact of the Japan earthquake disaster with massive Tsunami on emergency coronary intervention and in-hospital mortality in patients with acute ST-elevation myocardial infarction

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Abstract

Aims: The aims of this study were to evaluate reperfusion rate, therapeutic time course and in-hospital mortality pre- and post-Japan earthquake disaster, comparing patients with ST-elevation myocardial infarction (STEMI) treated in the inland area or the Tsunami-stricken area of Iwate prefecture.

Method and results: Subjects were 386 consecutive STEMI patients admitted to the four percutaneous coronary intervention (PCI) centers in Iwate prefecture in 2010 and 2011. Patients were divided into two groups: those treated in the inland or Tsunami-stricken area. We compared clinical characteristics, time course and in-hospital mortality in both years in the two groups. PCI was performed in 310 patients (80.3%). Door-to-balloon (D2B) time in the Tsunami-stricken area in 2011 was significantly shorter than in 2010 in patients treated with PCI. However, the rate of PCI performed in the Tsunami-stricken area in March–April 2011 was significantly lower than that in March–April 2010 (41.2% vs 85.7%; $p=0.03$). In-hospital mortality increased three-fold from 7.1% in March–April 2010 to 23.5% in March–April 2011 in the Tsunami-stricken area. Standardized mortality ratio (SMR) in March–April 2011 in the Tsunami-stricken area was significantly higher than the control SMR (SMR 4.72: 95% confidence interval (CI): 1.77–12.6: $p=0.007$).

Conclusions: The rate of PCI decreased and in-hospital mortality increased immediately after the Japan earthquake disaster in the Tsunami-stricken area. Disorder in hospitals and in the distribution systems after the disaster impacted the clinical care and outcome of STEMI patients.

Introduction

Reperfusion of infarct-related artery in patients with ST-elevation myocardial infarction (STEMI) is an important therapy for improving in-hospital outcome.[1–7] Percutaneous coronary intervention (PCI) using not only bare-metal intra-coronary stents, but also drug-eluting stents is an important standard therapy in patients with STEMI.[8,9] Recently, the need to shorten onset time to PCI, in addition to reperfusion of infarct-related artery, has become more important in

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Table 1. Summary data on the Japan Earthquake Disaster: record-breaking Tsunami (Japan Meteorological Agency and Nuclear Regulation Authority).

- Main shock occurred at 14:46 on Friday, March 11, 2011
- Magnitude of the earthquake: 9.0 - the most powerful earthquake ever measured in Japan.
- Estimated height of Tsunami: It is reported that the 13-m (43-ft)-high Tsunami destroyed the Fukushima Daiichi nuclear power plant.
- Run-up height of Tsunami: Tsunami ran up to a maximum height of 39.7m (130 ft).
- Inundated area: approximately 561 square kilometers (138,600 acre) - A total of six prefectures on the Pacific coast of eastern Japan: Aomori, Iwate, Miyagi, Fukushima, Ibaraki and Chiba
- Three prefectures in the Tohoku (North-eastern) region of Japan, Miyagi, Iwate, and Fukushima, had been most seriously devastated.
  As a result of the quake, the tsunami and aftershocks, 16,278 people died, 2,994 remain unaccounted for and 6,179 were injured, 129,198 houses were destroyed, 254,238 were severely damaged, 715,192 were partially damaged, 20,427 were flooded above floor level and 15,502 were flooded below floor level (statistics as of March 11, 2012, from the Fire and Disaster Management Agency of the Ministry of Internal Affairs and Communications).

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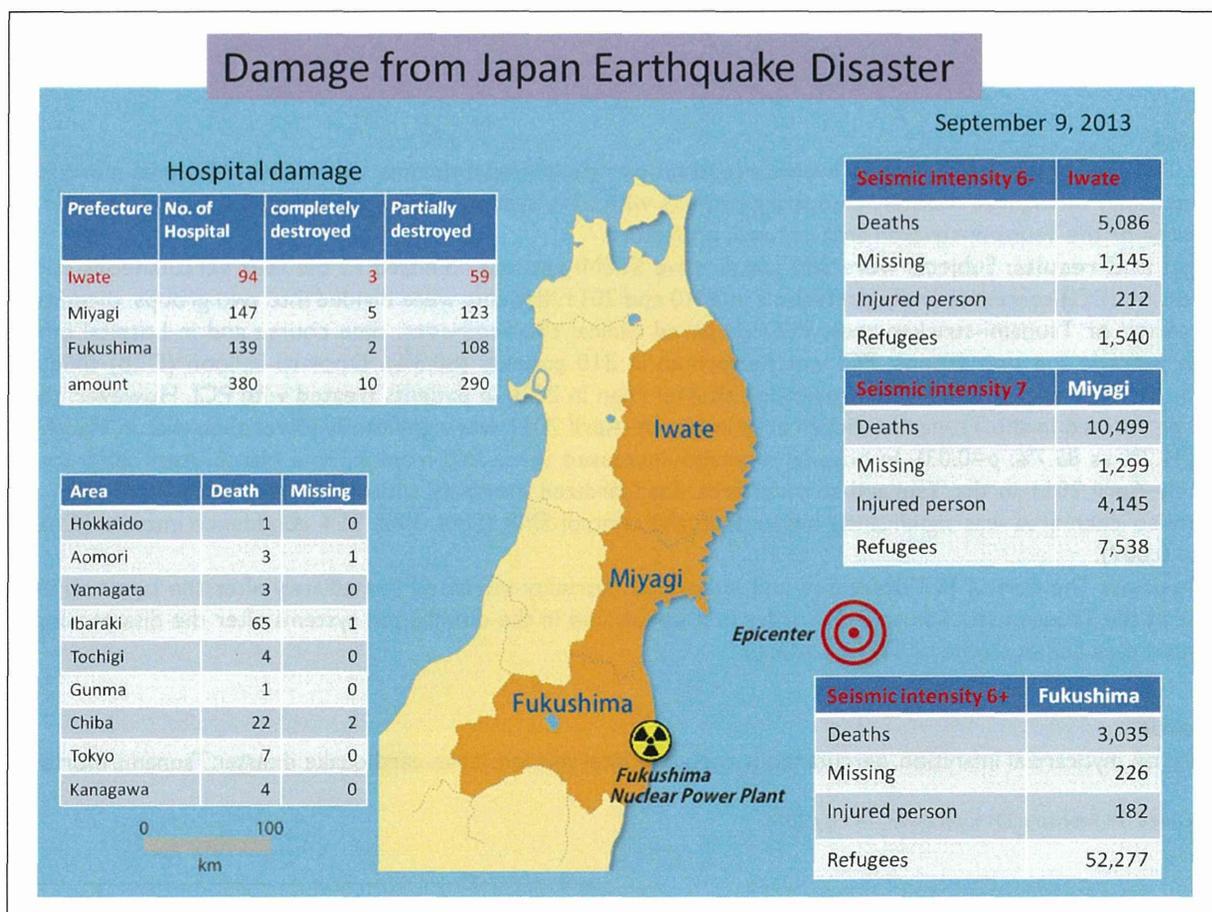
Figure 1. Damage from the Japan earthquake disaster.

patients with STEMI. Shortened door-to-balloon (D2B) time with PCI is a very important factor that affects in-hospital mortality in patients with STEMI. Recommended D2B time and total ischemic time are 90 and 120 min respectively according to 2004 STEMI clinical guidelines.[4–7,10–16]

Disorder in hospitals after the Japan earthquake disaster with massive Tsunami (Table 1, Figure 1) and electrical
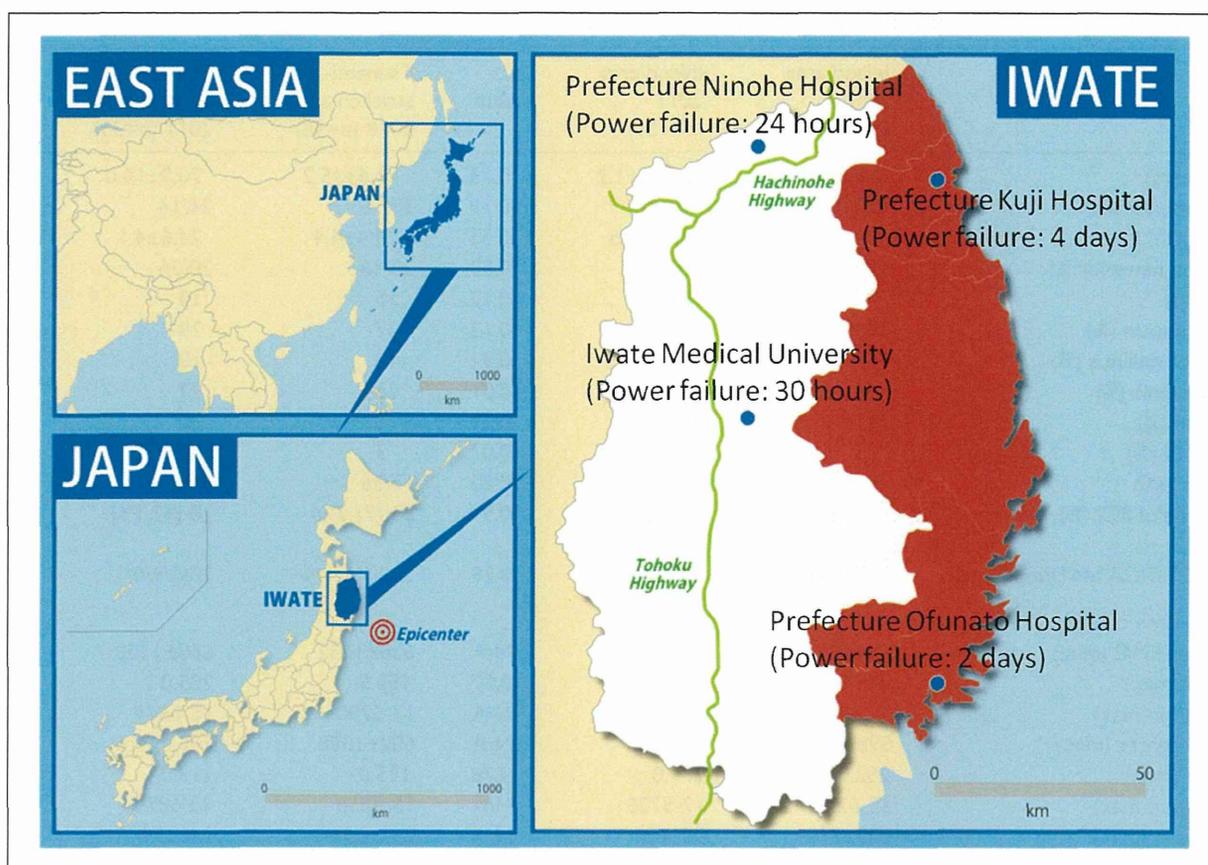
Figure 2. Four objective percutaneous coronary intervention (PCI) centers in Iwate prefecture: no building damage, but power was lost in all hospitals, area covered: Tsunami-stricken area.

power failure on 11 March 2011 may have impacted the clinical care of STEMI patients. The magnitude of the earthquake was 9.0 on the Richter scale–the most powerful earthquake ever measured in Japan. Three prefectures in the Tohoku (North-eastern) region of Japan, Miyagi, Iwate, and Fukushima, have been most seriously devastated. In Iwate prefecture, total area, population and population density are 15,278.40 km², 1,330,530 persons and 90 person/km² respectively. The total number of hospitals is 94, including those where PCI is/is not possible. Three of these hospitals were completely destroyed and 59 were partially destroyed immediately after the disaster. Fortunately, hospitals with PCI centers were not destroyed by the earthquake and Tsunami.

We estimated the effects on clinical care for STEMI after the earthquake to be as follows: longer onset to first medical contact, longer D2B, lower incidence of PCI and increased mortality. However, no report is available associating clinical care for STEMI and the Japan earthquake disaster in the Tsunami-stricken area.

The aims of this study was to evaluate reperfusion rate, therapeutic time course and in-hospital mortality pre- and post-Japan earthquake disaster, and compare patients treated in the inland area with those in the Tsunami-stricken area of Iwate prefecture.

Method

Patients

Subjects were 386 consecutive STEMI patients admitted to the four PCI centers (Figure 2) in Iwate prefecture in 2010 and 2011. Patient criteria included having an acute STEMI onset within 28 days, with ST elevation in contiguous two-lead in 12-lead electrocardiogram (ECG) and elevation of cardiac enzymes (i.e. World Health Organization (WHO)-MONItoring of Trends and Determinants in CArdiovascular Disease criteria). We collected these consecutive STEMI patients using the Iwate Heart Disease Registry Consortium system. We retrospectively evaluated the rate of emergency PCI, time course and in-hospital mortality in STEMI patients in the years 2010 and 2011. Moreover, patients were divided into two groups, i.e. patients treated in the inland or Tsunami-stricken area. We compared clinical characteristics, time course and in-hospital mortality in both years in the two groups

Table 2. Baseline clinical characteristics comparing inland and Tsunami-stricken area.

	Inland area 2010 (n=154)	Inland area 2011 (n=151)	p value	Tsunami-stricken area 2010 (n=46)	Tsunami-stricken area 2011 (n=35)	p value
Age (years)	68.3±11.8	68.8±11.2	0.73	71.6±15.2	70.9±16.0	0.88
Sex (male/female)	122/32	110/41	0.19	30/16	21/14	0.63
BMI (kg/m2)	24.2±3.7	23.9±3.5	0.33	24.4±4.4	24.6±4.1	0.92
Location (anterior %)	80	70	0.33	20/46	20/36	0.39
Killip (>1)	41	53	0.12	15	10	0.59
Hypertension (%)	104	113	0.12	37	29	0.44
Diabetes mellitus (%)	54	50	0.92	14	18	0.16
Dyslipidemia (%)	58	84	<0.01	25	23	0.49
Prior MI (%)	11	16	0.27	2	0	0.45
Prior PCI (%)	5	12	0.07	3	0	0.30
Smokers (%)	64	55	0.82	17/36	8/25	0.62
Incidence of PCI (%)	130 (84.4%)	127 (84.1%)	0.94	33 (71.7%)	20 (57.1%)	0.26
IRA (LAD/CX/RCA/LMT/undefined)	74/52/16/5/7	67/57/22/1/4	0.29	20/5/16/1/4	20/5/9/0/1	0.55
Clinical time course						
Onset to FMC (min.)	584±913	493±713	N/A	638±1232	660±1300	N/A
Median (min.)	245.5	262.0	0.57	182.5	205.0	0.75
Range (min-max)	31-6245	17-5736	N/A	13-5790	18-6874	N/A
To PCI center (min.)	598±917	507±709	N/A	607±1088	706±1316	N/A
Median (min.)	252.0	271.0	0.78	185.0	213.0	0.75
Range (min-max)	35-6245	17-5736	N/A	13-4550	40-6874	N/A
D2B mean (min.)	100±73	90±62	N/A	247±236	140±79	N/A
Median (min.)	75.5	66.5	0.64	160.5	122.0	0.045
Total IT (min.)	564±671	549±667	0.93	617±599	499±503	0.78
Peak CK (IU/L)	3784±9680	3120±3060	0.80	2521.4±2465.1	2520±2590	0.98
In-hospital death (%)	10 (6.5%)	10 (6.6%)	0.96	4 (8.7%)	5 (14.3%)	0.66
Cardiac death	8	6		3	5	
Non-cardiac death	2	4		1	0	

BMI: body mass index; CK: creatine kinase; CX: circumflex artery; D2B: door-to-balloon; FMC: first medical contact; IRA: infarction related artery; IT: ischemic time; LAD: left descending artery; LMT: left main trunk; MI: myocardial infarction; N/A: not available; PCI: percutaneous coronary intervention; RCA: right coronary artery.

and in the acute (March–April) and chronic (excluding March–April) phases. D2B time was defined as first wire pass time to the culprit lesion because thrombus aspiration before balloon dilatation had been performed beforehand. This protocol was approved by the ethical committee in Iwate Medical University.

Statistical analysis

Data are presented as mean±standard deviation (SD) or median value. Comparison of means between the two groups was performed with the unpaired t-test and Mann-Whitney U-test. Statistical comparison of the differences in categorical data between the two groups was performed using the chi-square test. Differences were considered significant at $p<0.05$. All statistical analysis was performed using SPSS 17.0 for Windows. Standardized mortality ratio (SMR) was calculated to compare in-hospital mortality in

the year of 2010 in Iwate prefecture and each area. Control SMR value (1.0) was derived from the whole patient cohort in the year 2010 in Iwate prefecture.

Results

Baseline clinical characteristics of patients are demonstrated in Table 2. Emergency PCI was performed in 310 patients (80.3%). As D2B time became prolonged, in-hospital mortality increased (within 90 min.: 2.4%, 91–180 min: 4.5%, over 180 min: 9.1%, PCI not performed: 23.7%; $p<0.001$). D2B time in the Tsunami-stricken area in 2011 was significantly shorter rather than longer than in 2010 ($p=0.045$), whereas there was no change between 2010 and 2011 in the inland area. In addition, D2B time in 2011 was shorter rather than longer than in 2010 in the two groups in patients treated with PCI; however, there were no significant differences between the two groups in the acute and chronic phases (Table 3 and

Table 3. Comparison of clinical time course in patients treated with emergency PCI in both years in the two groups.

	Inland area 2010 (n=130)	Inland area 2011 (n=127)	p value	Tsunami-stricken area 2010 (n=33)	Tsunami-stricken area 2011 (n=20)	p value
Clinical time course						
Onset to FMC (min)	497±831	444±674	N/A	483±895	324±517	N/A
Median	230	240	0.53	187	150	0.50
To PCI center (min)	509±832	507±709	N/A	506±925	357±521	N/A
Median (min)	238	243	0.70	187	160	0.84
D2B mean (min)	100±73	90±62	N/A	247±236	140±79	N/A
Median (min)	74.5	66.5	0.64	160.5	122.0	0.045
Total IT (min)	564±672	549±667	N/A	617±599	499±503	N/A
Median (min)	335	336	0.93	350	336	0.78
Peak CK (IU/l)	4068±10215	3563±3136	0.43	3072±2666	2928±2418	0.96
In-hospital death (%)	5 (3.8%)	4 (3.1%)	0.97	2 (6.1%)	1 (5.0%)	0.65
Cardiac death	3	3		2	1	
Non-cardiac death	2	1		0	0	

CK: creatine kinase; D2B: door-to-balloon; FMC: first medical contact; IT: ischemic time; PCI: percutaneous coronary intervention

Table 4. Comparison of door to balloon time in patients treated with emergency PCI between the both years in the two groups at each phase.

	Acute phase March–April				Chronic phase Excluding March–April			
	Inland area		Tsunami-stricken area		Inland area		Tsunami-stricken area	
	2010 (n=19)	2011 (n=36)	2010 (n=12)	2011 (n=7)	2010 (n=111)	2011 (n=91)	2010 (n=21)	2011 (n=13)
D2B time								
Mean (min.)	133.6±97.2	93.3±64.3	304.9±136.3	136.3 ±72.4	94.4±66.9	89.3±61.3	217.4±188.7	141.3±85.4
median (min.)	86.0	66.5	159.5	118.5	72.0	66.5	161.5	121.5
p value	0.13		0.26		0.87		0.09	

PCI: percutaneous coronary intervention; D2B: door-to-balloon; p value: 2010 vs. 2011

4). Although the incidence of PCI performed in 2011 and 2010 in the inland area was similar (84.1% vs 84.4%), the incidence was lower in 2011 than in 2010 in the Tsunami-stricken area (57.1% vs 71.7%; p=0.26). In particular, the rate of PCI performed in the Tsunami-stricken area in March–April 2011 was significantly lower than that in March-April 2010 (41.2% vs 85.7%; p=0.03: Figure 3).

Although in-hospital mortality in 2011 was similar to that in 2010 in the inland area (6.5% vs 6.6%; p=0.96), this increased from 8.7% in 2010 to 14.3% in 2011 in the Tsunami-stricken area (p=0.66: Table 2). Moreover, in-hospital mortality increased three-fold from 7.1% (one death out of 14 patients) in March–April 2010 to 23.5% (four deaths out of 17 patients) in March–April 2011 in the Tsunami-stricken area (Figure 4). Moreover, the SMR in March–April 2011 in the Tsunami-stricken area was significantly higher than in the entire patient cohort (SMR=4.72: 95% confidence interval (CI): 1.77–12.6; p=0.007), although the SMR in March-April 2011 in the inland area was even (Figure 5).

Discussion

In the present study, D2B time and the rate of PCI were equal in the inland area pre- and post-disaster. D2B time in 2011 was significantly shorter than in 2010 in the Tsunami-stricken area. Nonetheless, the rate of PCI decreased and in-hospital mortality increased shortly after the Japan earthquake disaster. This is the first report of disorder in hospitals and in the distribution system after the Japan earthquake disaster impacted the clinical care and outcome of STEMI patients.

Earthquake disaster and cardiovascular disease

Several clinical studies of relationships between natural disasters and increased cardiovascular events have been reported. The Hanshin-Awaji and Niigata-Chuetsu earthquakes are representative cases.[17–20] Moreover, stress immediately after missile attacks in war and watching
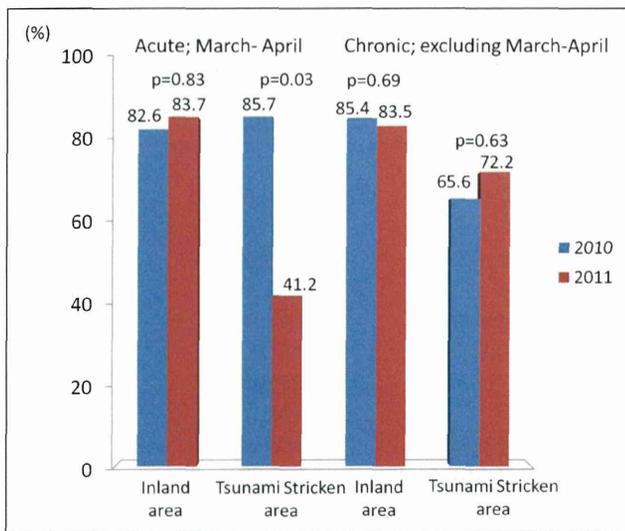
Figure 3. Incidence of percutaneous coronary intervention (PCI) in both years in the two groups in the acute (March–April) (left bars) and chronic phases (excluding March–April) (right bars). The incidence of PCI in the Tsunami-stricken area in March–April 2011 was significantly lower than that in March–April 2010 (41.2% vs 85.7%; p=0.03). However, the incidence of PCI was even in both years in the two groups excluding March–April.
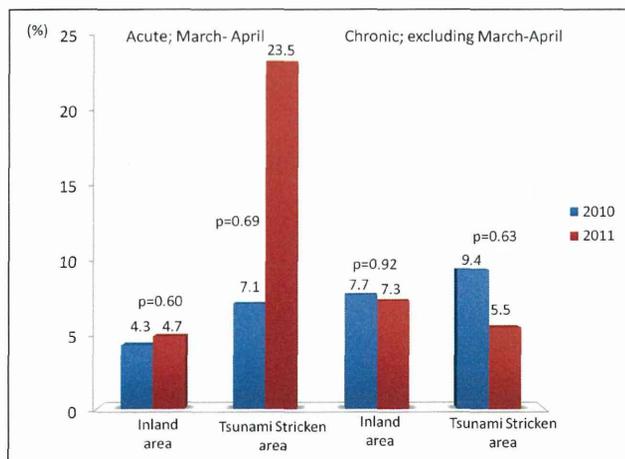

Figure 4. In-hospital mortality in both years in the two groups in acute (March–April) (left bars) and chronic phases (excluding March–April) (right bars). In-hospital mortality increased three-fold from 7.1% (one death out of 14 patients) in March–April 2010 to 23.5% (four deaths out of 17 patients) in March––April 2011 in the Tsunami-stricken area. However, in-hospital mortality in the chronic phase in the Tsunami-stricken area was even over the two years. On the contrary, there were no significant differences, not only in the chronic phase, but also in the acute phase, between 2010 (one death out of 23 patients) and 2011 (two deaths out of 43 patients) in the inland area regarding in-hospital mortality.

World Cup soccer games has been associated with increasing levels of acute cardiovascular events in previous
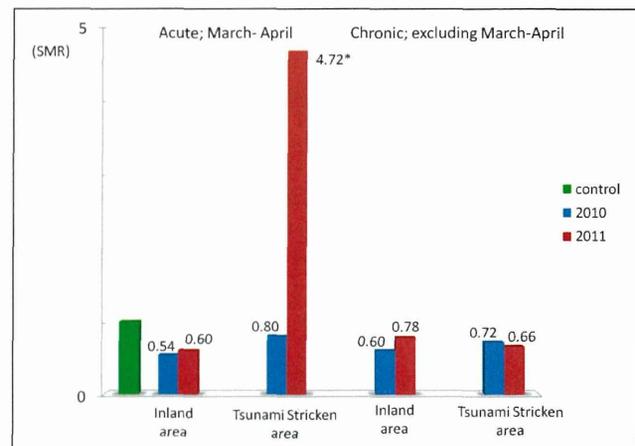

Figure 5. Standardized mortality ratio (SMR) in both years in the two groups in each phase. SMR in March–April 2011 in the Tsunami-stricken area was significantly higher than the control SMR (SMR 4.72: 95% CI: 1.77–12.6: *p=0.007). There were no significant changes among the other SMRs: March–April 2010 in the Inland area: 0.54 (95% CI: 0.08–3.85; p=0.91), March–April 2011 in the Inland area: 0.60 (95% CI: 0.15–2.38; p=0.61), March–April 2010 in the Tsunami stricken area: 0.80 (95% CI: 0.11–5.66; p=0.94), excluding March–April 2010 in the Inland area: 0.60 (95% CI: 0.25–1.43; p=0.13), excluding March–April 2011 in the Inland area: 0.78 (95% CI: 0.37–1.63; p=0.21), excluding March–April 2010 in the Tsunami stricken area: 0.72 (95% CI: 0.10–5.12; p=0.86), excluding March–April 2011 in the Tsunami stricken area: 0.66 (95% CI: 0.49–24.8; p=0.39).

studies. The reason for this phenomenon is thought to be activation of the sympathetic nervous system. In the Hanshin-Awaji earthquake, a positive relationship was identified between the collapsed area and number of cardiovascular deaths. Nakagawa et al. and Ogawa et al. reported that both the Niigata-Chuetsu and Hanshin-Awaji earthquakes significantly increased long-term mortality from acute myocardial infarction.[21,22] Moreover, prognosis in patients implanted with an implantable cardio-defibrillator (ICD) after the 911 World Trade Center attack in the United States deteriorated after the event.[23] However, there has been no report to date of an association between clinical time course of STEMI and the earthquake disaster.

Incidence of PCI performed

The incidence of PCI performed was high in both groups before the earthquake, although the present study was performed in a large rural area. In previous studies undertaken outside Japan, the incidence of emergent PCI was 40% in Global Registry of Acute Coronary Events (GRACE) and approximately 20% of patients in the Canadian registry underwent in-hospital revascularization.[24,25] Even in a previous Japanese AMI registry, although patients were enrolled between 1999 and 2001, PCI was performed in 58% of patients.[26] The incidence of PCI was very high in the Prevention of AtherothrombotiC Incidents Following

Ischemic Coronary attack (PACIFIC) Registry study, which was recently performed in Japan.[27] The cause of this result (higher incidence of PCI) was that PCI centers were prepared in each medical care area, not only in the Iwate prefecture, but also widely distributed in Japan, in the last 10 years. Kristensen et al. report a major increase, from 2007 to 2010–2011, in the overall numbers of primary PCIs performed in 13 countries.[28] Further, McLenachan et al. report a significant increase in the number of patients treated by primary PCI in England and Wales, from <40% of the STEMI population in 2006 to >90% in 2011.[29] Thus the prevalence of primary PCI in patients with STEMI increased, not only in Japan, but all over the world. However, although in-hospital mortality decreased with increasing prevalence of primary PCI, we should remember the importance of thrombolytic agents, not only now, but also in the future and especially after disasters.

D2B time and clinical care for STEMI

D2B time is an important factor for prognosis in patients with STEMI. We speculated that D2B time was prolonged and its outcome may have deteriorated immediately after the earthquake. Although D2B time was not prolonged in patients treated by PCI, in-hospital outcome deteriorated because incidence of PCI was less than before the earthquake in the Tsunami-stricken area. To be specific, the factors responsible were lack of PCI devices because the distribution system experienced significant interruption and catheter rooms were non-functional due to power failure. As a result, in-hospital mortality increased three-fold from 7.1% in March–April 2010 to 23.5% in March–April 2011 in the Tsunami-stricken area due to disorder in the hospital environment.

In a previous study of clinical care in patients with acute coronary syndrome after the Japanese earthquake disaster, case transfer number increased from the Tsunami-stricken area to the inland area; as a result, the incidence of PCI increased, but mortality also increased.[30] However, there are several limitations to this study: (a) it was a retrospective single center study; (b) the number of patients was very small; (c) not only STEMI but also non-STEMI were included; (d) there was a selection bias for transfer between hospitals; (e) Moreover, the severity of cases was greater because patients with cardiogenic shock in the Tsunami-stricken area after the disaster were included. However, there was a lack of time course assessment such as D2B and time of onset to arrival at PCI center.

The role of thrombolysis

Coronary thrombolysis is currently ranked as an adjunct therapy in patients with super-acute phase STEMI (onset within 2–3 h).[29,31] Regular facilitated PCI is not well recommended in such studies because side effects are more prominent than overall benefit.[32] However, pre-intervention thrombolysis should be performed in cases of early phase STEMI (within 2–3 h) and when primary PCI on site is impossible[33] according to clinical care guidelines for STEMI patients. Moreover, recent studies have assessed not only pre-intervention thrombolysis, but also pre-hospital thrombolysis in patients with STEMI.[34] We should consider on-site pre-intervention thrombolysis and patient transfer to an alternative inland hospital with a functioning catheter laboratory, when hospital functions including operation of the catheter laboratory have ceased due to the earthquake disaster. The Iwate Myocardial infarction Prospective Observation by Randomized Trial for Analysis of usefulness of intravenous t-PA (IMPORTANT) study,[35] which was performed to assess pre-intervention thrombolysis compared to previous primary PCI at Iwate prefecture, showed that long-term prognosis of indirect transfer with pre-intervention thrombolysis was equivalent to direct transfer with primary PCI.

Current recommendations state that to avoid bleeding complications PCI should be performed immediately after at least 3 h of successful thrombolysis. However, coronary angiography should be performed immediately if thrombolysis is unsuccessful (rescue PCI).[36] Therefore the assessment of reperfusion success or failure after thrombolysis is vital after a disaster, and the emergency room cardiologist should prioritize cases requiring rescue PCI after on site triage.

Immediately after the Japan earthquake disaster, aggressive transportation by helicopter was important because transportation by mobile ambulance was no longer possible.[37] The medical helicopter in Iwate prefecture was not available shortly after the earthquake and patient transfer was not functioning. Immediately after such a large-scale disaster, it was important to supply thrombolytic agent to the Tsunami-stricken area and transfer STEMI patients from the area. Another appropriate procedure involved dispatch of a mobile catheter room to the Tsunami-stricken area.

Study limitations

There were several limitations to this study. Firstly, this was a retrospective observational study undertaken immediately after the Japan earthquake. However, confidence in D2B time data is high because we recorded D2B times in consecutive STEMI patients using the Iwate Heart Disease Registry Consortium system. Secondly, D2B time was significantly longer in the Tsunami-stricken area than in the inland area in both years (2010: 160.5 min (median) vs 74.5 min, 2011: 122.0 min vs 66.5 min; $p<0.01$). The cause of increased mortality in the Tsunami-stricken area may have been the longer D2B time, in addition to the reduced prevalence of PCI. Thirdly, a universal definition of acute myocardial infarction has recently been

published.[38] The inclusion criteria used in this study depend on the WHO-MONICA definition, not the new universal definition where cardiac troponin levels are evaluated. However, apart from this, our definition is identical to that cited in the new universal definition of type 1 myocardial infarction. In the future, the universal definition of myocardial infarction should be used in studies such as ours. Finally, patient numbers receiving thrombolysis were small. We speculated that it was difficult to obtain thrombolytic agents because the distribution system was not functioning. Immediately after an earthquake disaster, we should support the supply of thrombolytic agents, which play an important role in reperfusion therapy for patients with STEMI. We should consider the role of thrombolysis in cases where PCI may be impossible after disasters in the future.

Conclusions

The rate of PCI decreased and in-hospital mortality increased immediately after the Japan earthquake disaster in the Tsunami-stricken area. Disorder in hospitals and in the distribution system after the Japan earthquake disaster impacted the clinical care and outcome of STEMI patients.

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Impact of the Great East Japan Earthquake on Acute Myocardial Infarction in Fukushima Prefecture

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ABSTRACT

Objective: The incidence of cardiovascular disease (CVD) reportedly increases following a huge disaster. On March 11, 2011, the Great East Japan Earthquake hit a large area of eastern Japan. In Fukushima prefecture, many people suffered from the consequences of the earthquake, the subsequent tsunami, and especially the Fukushima Daiichi Nuclear Power Plant accident. We assessed whether the incidence of acute myocardial infarction (AMI) increased after the earthquake.

Methods: We enrolled AMI patients admitted to 36 hospitals in Fukushima prefecture between March 11, 2009, and March 10, 2013 (n = 3068). We compared the incidence of AMI after the earthquake for more than 3 months and 1 year with that in the control years.

Results: The incidence of Fukushima's annual AMI patients (per 100 000 persons) in 2011 was similar to that of previous years (n = 38.9 [2011] vs 37.2 [2009] and 38.5 [2010], P = .581). However, a significantly higher incidence of AMI was found in the Iwaki district after the disaster that corresponded to the 1-year period of observation (n = 38.7 [2011] vs 27.3 [2009] and 32.8 [2010], P = .045).

Conclusion: The Great East Japan Earthquake affected the incidence of AMI only in limited areas of Fukushima prefecture. (*Disaster Med Public Health Preparedness*. 2014;8:212-219)

Key Words: acute myocardial infarction, the Great East Japan Earthquake, Fukushima prefecture

On March 11, 2011, at 2:46 PM, the Great East Japan Earthquake hit a large area of eastern Japan, causing enormous damage. The catastrophic earthquake and its accompanying tsunami devastated the Pacific coast of northeastern Japan. The magnitude of this earthquake was 9.0. The number of dead and missing was reported to be 21 176, and the number of injured was 6217. The economic impact of this earthquake was estimated at 16.9 trillion Japanese yen. In Fukushima prefecture, many people suffered from the consequences of the earthquake, the subsequent tsunami, and especially the Fukushima Daiichi Nuclear Power Plant accident.

Fukushima prefecture is divided into 6 districts, and the Fukushima Daiichi Nuclear Power Plant is in the Soso district (Figure 1). The extent of damage differed from region to region. Table 1 shows the maximum seismic intensity by the Japanese Meteorological Agency seismic intensity scale (which differs from the modified Mercalli intensity scale); the number of dead, missing, and injured people; the number of completely destroyed houses; and the tsunami-devastated areas resulting from the earthquake in each of the 6 districts. The Soso and Iwaki districts are located along the Pacific coast (Figure 1), and most of the deaths and destroyed houses were due to the subsequent tsunami rather than the earthquake itself.

In the wake of a huge disaster such as an earthquake, the incidence of cardiovascular disease (CVD) has been reported to increase.[1-5] We therefore sought to determine whether the incidence of acute myocardial infarction (AMI) increased after this earthquake, using the registry study of AMI in Fukushima prefecture that we have conducted since 2009.

METHODS

The study area comprised all 6 districts of Fukushima prefecture (Figure 1). Table 2 shows the residents' population, gender, and average age in 2011, and the population change from 2011 to 2012 in the 6 districts of Fukushima prefecture, as reported by the Fukushima prefecture municipality. Because the Soso and Iwaki districts border on the Pacific coast, they have a temperate climate year round and received light snowfall. In contrast, the Aizu district has heavy snowfall and cold winters. The Kenpoku, Kenchu, and Kennan districts have an intermediate climate.

FIGURE 1

Map of the Study Area in Fukushima Prefecture.
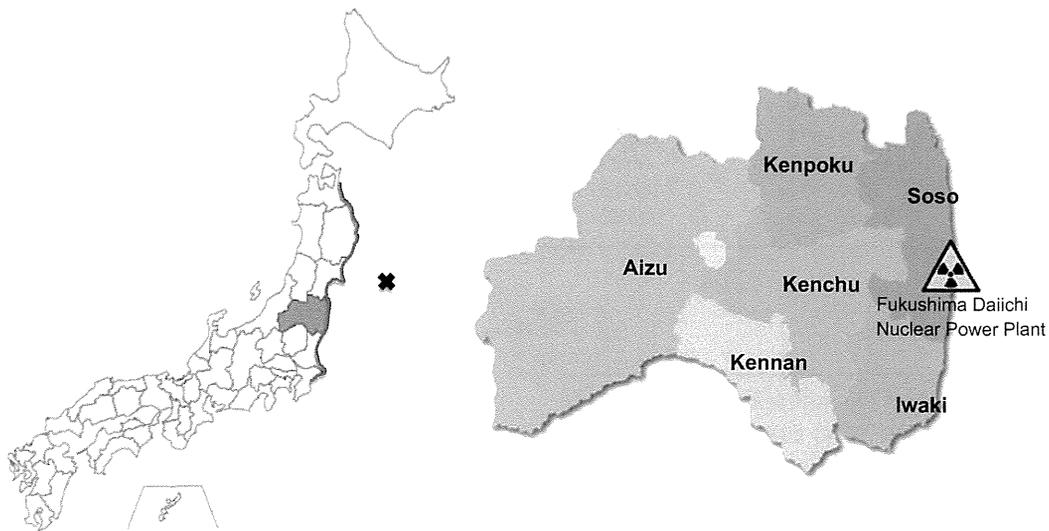
The map on the left shows an outline of Japan. The blue area is Fukushima prefecture, the red line indicates the penetration of the tsunami, and the X marks the epicenter of the earthquake. The map on the right shows the 6 districts of Fukushima prefecture.

TABLE 1

Seismic Intensity and Damage Caused by the Great East Japan Earthquake in Fukushima Prefecture

Fukushima Districts	Maximum Seismic Intensity[a]	No. of Dead	No. of Missing	No. of Injured	No. of Completely Destroyed Houses	Tsunami-Devastated Area, km²
Kenpoku	6.3	7	0	46	772	0
Kenchu	6.0	14	1	21	4002	0
Kennan	6.2	15	0	19	916	0
Aizu	5.5	1	0	10	22	0
Soso	6.3	1456	4	81	8068	97
Iwaki	5.7	330	0	4	7917	15
All of Fukushima	6.3	1823	5	181	21697	112

[a] Maximum seismic intensity measured by the Japanese Meteorological Agency seismic intensity scale.

Most deaths from this earthquake resulted from the tsunami in the coastal area of Fukushima prefecture (Table 1).

Figure 2 shows the number of aftershocks with magnitudes higher than 5.0 occurring every 4 weeks after the Great East Japan Earthquake. Aftershocks occurred predominantly in the first 4 weeks, and decreased after 12 weeks. In our preliminary data, the number of AMI patients for 4 weeks and 8 weeks in 2011 did not increase compared with that of the previous 2 years. Based on this finding, we analyzed the incidence of AMI for 1 year and 3 months before and after the earthquake from the Fukushima prefecture AMI registration survey. We defined a year as the anniversary of the earthquake to understand its impact. Therefore, 2011 corresponds to March 11, 2011, to March 10, 2012.

The Fukushima Prefecture AMI Registration Survey

The registry study was established to elucidate the status of AMI and to improve treatment outcomes in Fukushima prefecture in 2009. A total of 36 hospitals that accepted AMI patients participated.[6] All AMI patients of Fukushima prefecture were taken or transferred to the 36 participating hospitals and registered in this study. Patients were georeferenced based on the place of their hospitalization.
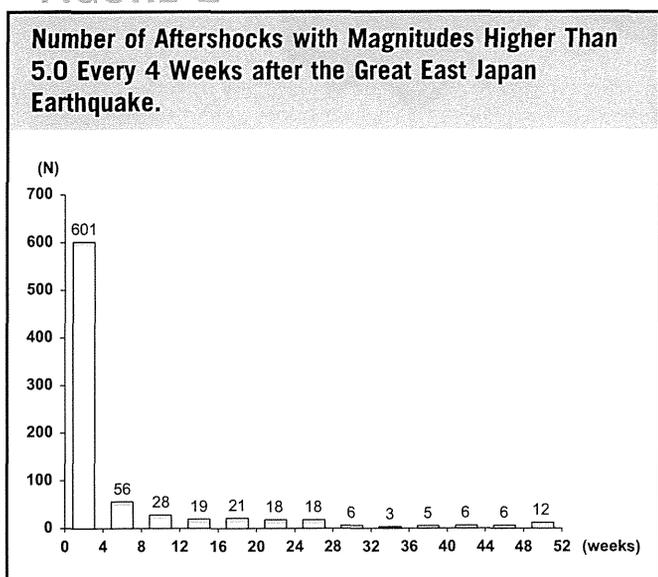
Diagnosis of AMI was based on the World Health Organization (WHO) multinational monitoring of trends and determinants of cardiovascular disease (MONICA) criteria. Patients needed to be registered within 72 hours after the onset of symptoms if their level of creatinine phosphokinase (CK) or its MB isoform (CK-MB) increased to more than twice the normal range.

TABLE 2

Gender, Average Age, and Change of Resident Populations					
Fukushima Districts	Population in 2011	No. of Men (%)	No. of Women (%)	Age, y	Change in Population[a]
Kenpoku	496 586	239 589 (48.2)	256 997 (51.8)	45.7	-9348
Kenchu	551 672	270 339 (49.0)	281 333 (51.0)	44.0	-10 697
Kennan	149 885	73 997 (49.4)	75 888 (50.6)	45.0	-1 732
Aizu	291 374	138 731 (47.6)	152 643 (52.4)	48.4	-2 875
Soso	195 717	95 982 (49.0)	99 735 (51.0)	46.3	-10 927
Iwaki	341 904	165 189 (48.3)	1 76 715 (51.7)	45.6	-8 568
All of Fukushima	2 027 138	983 827 (48.5)	1 043 311 (51.5)	45.6	-44 147

[a] From 2011 to 2012.

FIGURE 2

Number of Aftershocks with Magnitudes Higher Than 5.0 Every 4 Weeks after the Great East Japan Earthquake.

This study was conducted in a prospective manner. Each physician filled in the survey form in detail and sent it to the registry office. The survey included coronary risk factors; symptoms; change in electrocardiogram (ECG); CK and CK-MB values; infarction site; reperfusion therapies; duration of hospitalization; and outcomes 30 days after hospitalization. These data were entered into the database and analyzed at the headquarters of the registry study (Fukushima Medical University). This study was continued in spite of the enormity of the disaster. The study protocol was approved by the ethics committee of Fukushima Medical University.

Statistical Analysis

Data are expressed as the number of patients, and the incidence of AMI is shown as the number of patients per 100 000 persons per year. We assessed the differences between the incidence of AMI after the earthquake and during the corresponding period of the previous 2 years in the same area. The incidence of AMI after the earthquake was compared to average incidences of AMI in the previous 2 years, and confirmed using the χ^2 test and Fisher exact test.[7]

These analyses were carried out with SAS software version 9.1 (SAS Institute, Inc). A P value less than .05 was considered statistically significant.

RESULTS

In the present study, we registered a total of 3068 AMI patients who were taken to 36 hospitals between March 11, 2009, and March 10, 2013. The number of AMI patients throughout Fukushima prefecture was 772 in 2011. The number was almost identical to that in 2009, 2010, and 2012 (n = 759, n = 780, and n = 757, respectively; Figure 3A). The average age of the patients in 2011 was identical to those in 2009, 2010, and 2012 (68.4 vs 69.6 [2009], 69.2 [2010], and 68.4 [2012]). The gender of AMI patients in 2011 did not change compared with that of the control years (72% [2011] vs 70% [2009], 73% [2010], and 73% [2012]). Figure 3B shows the incidence of AMI corrected per 100 000 persons. No significant difference was found between 2011 and the previous 2 years, as compared to the incidence of AMI after the earthquake in Fukushima prefecture (n = 38.9 vs 37.9; χ^2 = 0.30; P = .58).

Next, those numbers were counted on a regional basis, because Fukushima is the prefecture with the third largest landmass in Japan, and the extent of the disaster damage differed from region to region (Figure 1 and Table 1). In the Iwaki district, the incidence of AMI patients in 2011 increased remarkably compared with those of the previous 2 years (n = 38.7 vs 30.1; χ^2 = 4.01; P = .045), as shown in Figure 3B. On the other hand, the incidence of AMI was not increased in the Soso district, although it was most affected by the tsunami and nuclear power plant disaster. No significant changes were observed in the other districts.

To focus on the effect of this disaster on AMI patients, we analyzed data from 3 months before to 3 months after the earthquake (Figure 4). The incidence of AMI patients from March 11 to June 2, 2011, did not increase, as compared with the previous year in the entire prefecture (n = 9.4 vs 10.1; χ^2 = 0.54; P = .462). No significant difference was noted in the incidence of AMI from March 11 to June 2, 2011, as

FIGURE 3

Trend of Acute Myocardial Infarction (AMI) in Fukushima Prefecture From 2009 to 2012.

(A)
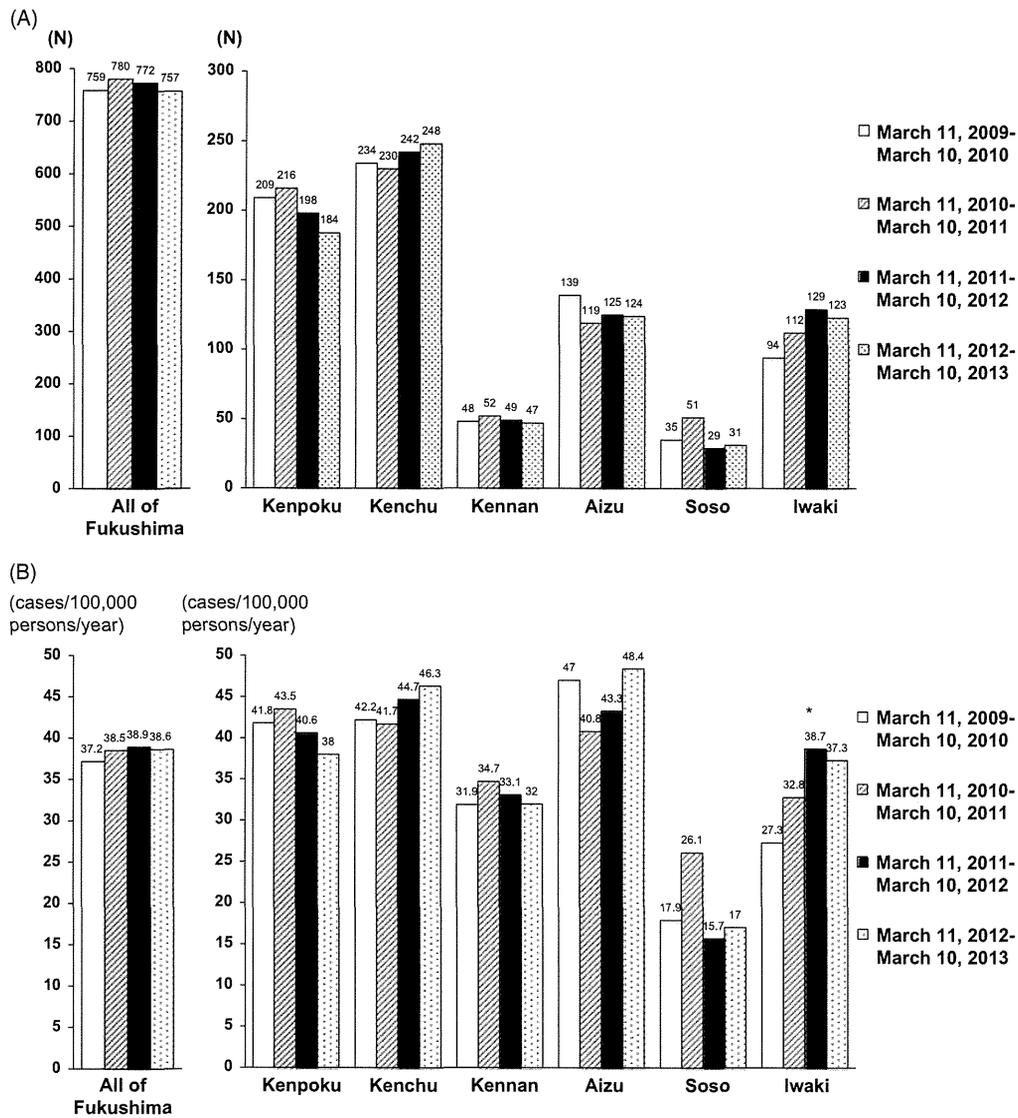
A, The graph on the left shows the number of AMIs in the entire prefecture. The graph on the right shows the number of AMIs in each district of Fukushima prefecture. B, The trend in the annual incidence of AMI (per 100 000 persons). *P < .05 compared to the previous 2 years.

compared with the previous year (n = 11.0 vs 12.9; $\chi^2 = 0.03$; $P = .8634$) in the Iwaki district. There was also no significant difference in any other district. Considering the incidence of AMI during 1 year and 3 months after the earthquake in the Iwaki district, the incidence increased from 4 to 12 months after the disaster.

DISCUSSION

The major findings of the present study were that the incidence of AMI did not increase during the first 3 months

after the earthquake in Fukushima prefecture compared with the control years, but it did increase in the Iwaki district from 4 to 12 months after the earthquake.

The incidence of intrinsic CVD, which includes acute coronary syndrome (ACS), increases after major disasters.[2,8,9,10] The mechanisms of inducing ACS entails increased vasomotor reflex response, sympathetic nerve stimulation, worsening of living conditions, and a thrombotic tendency. The physical and psychological stress due to the disaster was assumed to cause AMI. Casualties of the Great East Japan Earthquake

were mainly from tsunami damage, which may have affected the incidence of AMI less than an epicentral earthquake.[2,3]

One study reported no significant increase in the incidence of AMI with an earthquake at less vulnerable circadian periods.[11] That report compared the incidence of AMI in the 1989 Loma Prieta earthquake at 5:04 PM with that of the 1994 Northridge earthquake at 4:31 AM. Both were similarly intense earthquakes, but the incidence of AMI increased only in the Northridge earthquake. We thought that the Great East Japan Earthquake, which occurred at 2:46 PM, might not have posed as great a risk of AMI as the Northridge earthquake.

Although infection due to worsening environmental conditions might have affected the incidence of AMI, there were no outbreaks of cold or flu in Fukushima prefecture (including Iwaki district) after the earthquake. Also no cold temperature spells were reported after the earthquake in Fukushima prefecture.

A significant increase in the incidence of AMI was observed in the Iwaki district after the earthquake, as compared to the previous 2 years. However, the precise reason for this increase remains unclear. Because victims were severely stressed mentally as well as physically, we speculated that their sympathetic nervous activation and high blood pressure combined with the unavailability of medications, poor nutrition, and lack of hygiene might have triggered major coronary plaque rupture.[12] Additional studies would be necessary to elucidate the detailed mechanisms of AMI to prevent it in this district in the future.

Limitations

This study has several limitations. First, the tally of the number of AMI patients in Fukushima prefecture may not have been precise, because the study was based on hospital registers. It was not a population-based cohort study, such as the Framingham Heart Study in the United States.
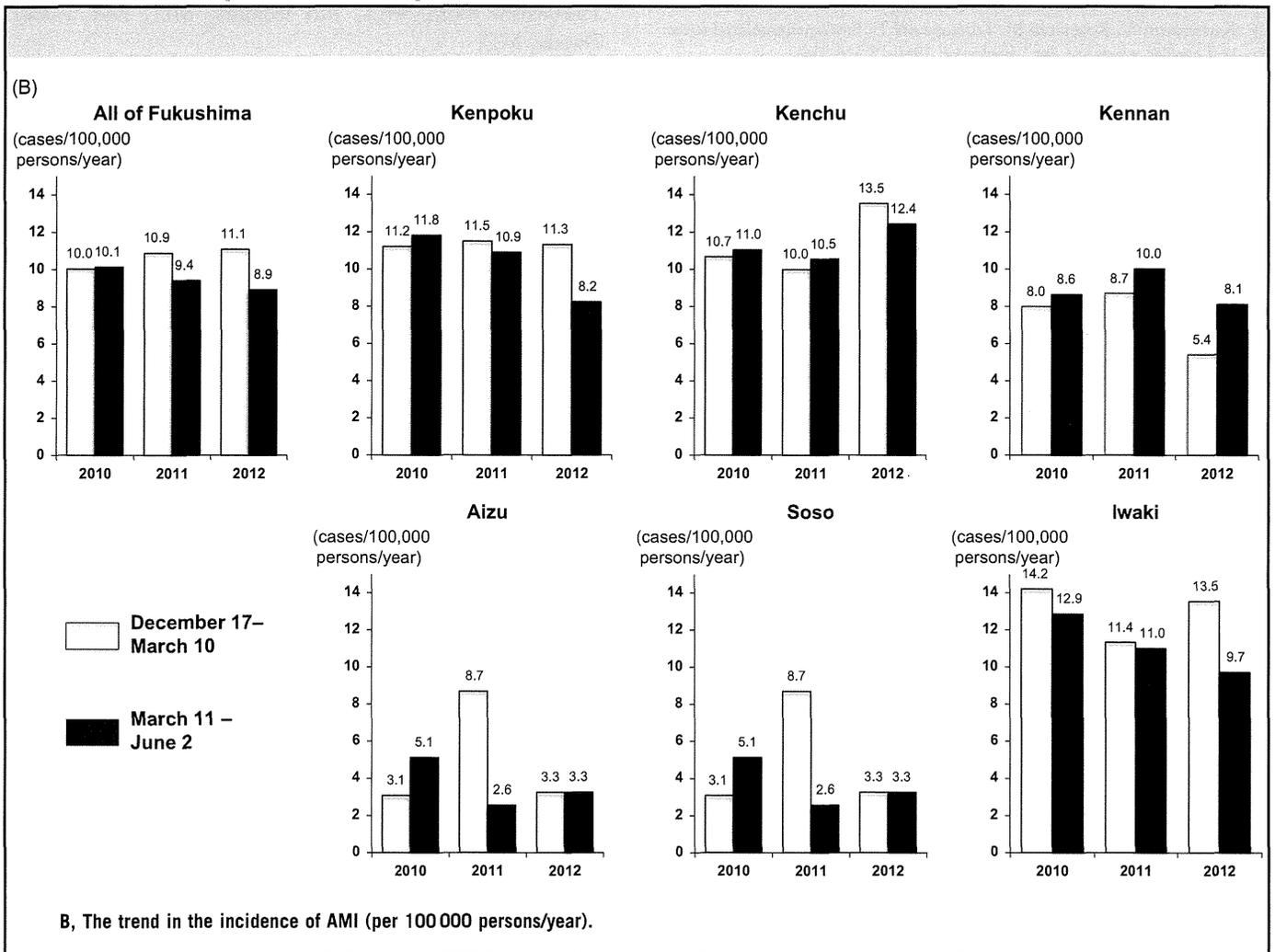
FIGURE 4

Acute Myocardial Infarction (AMI) Cases From 3 Months Before to 3 Months After the Great East Japan Earthquake in 2011 and Control Years in Fukushima Prefecture.
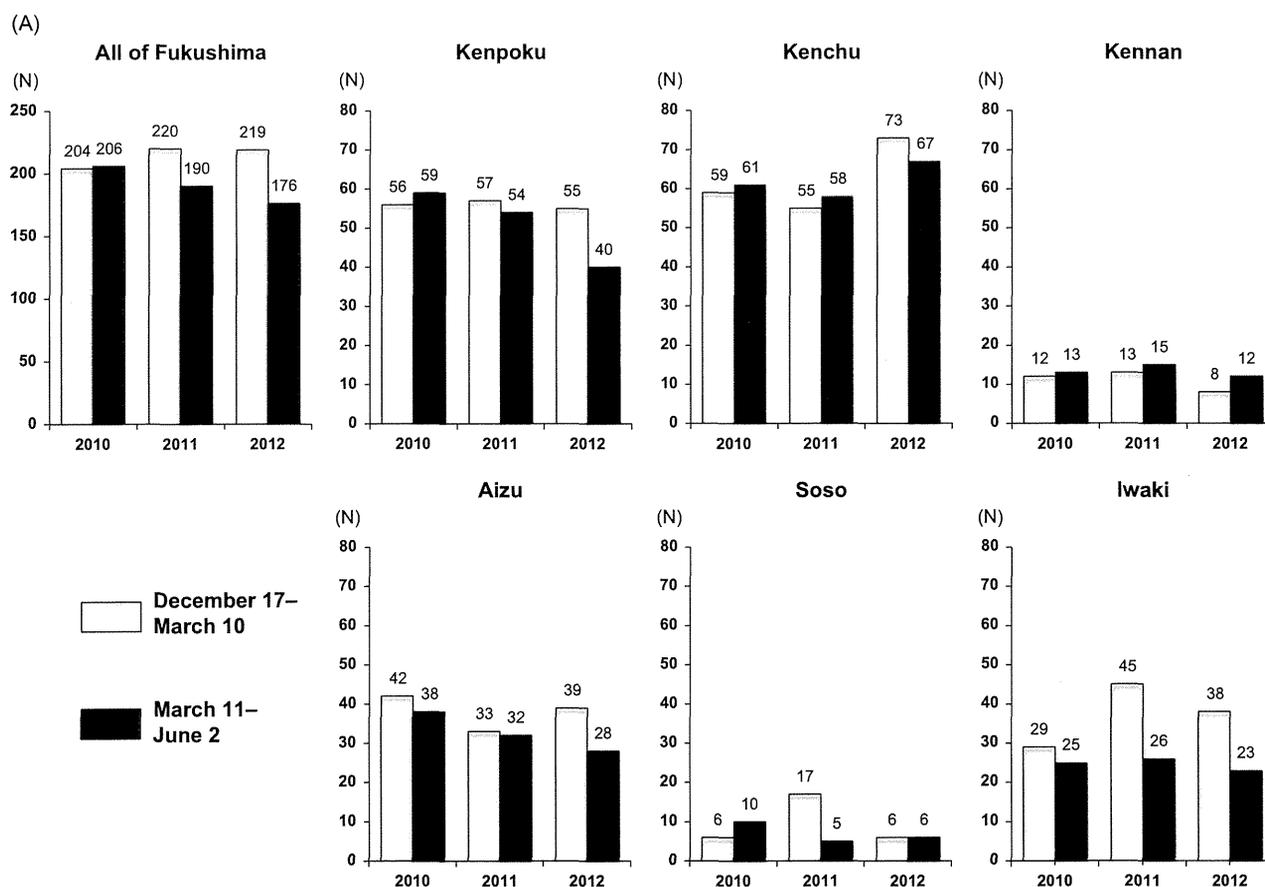
A, Number of AMI patients in Fukushima prefecture.

FIGURE 4 (Continued)

(B)

B, The trend in the incidence of AMI (per 100 000 persons/year).

Second, we used the place of hospitalization rather than the place of residence to georeference the AMI patients. In future studies, we should use the place of residence. Third, it has been reported that the number of patients with out-of-hospital cardiac arrest increases under stressful situations.[13] Because this study comprised hospitalized patients, a certain number of AMI cases may have been missed before their admission to the hospital. Fourth, stress cardiomyopathy may have been involved in AMI. However, because a high rate (more than 90%) of the coronary angiograms was performed in the acute stage in our study, most cases of stress cardiomyopathy were distinguished from AMI. Fifth, no changes were found in the average age and gender of the AMI patients in the study period, but the age of the patients was not referenced according to gender. Some studies have reported that younger women may have increased susceptibility to earthquake-induced stress. Further studies would be necessary to clarify this issue. Last, because we analyzed the data for 12 weeks and 1 year in this study, the choice of time-windows may have affected our findings.

CONCLUSIONS

The findings of our study demonstrated that the incidence of AMI increased only in limited areas of Fukushima prefecture after the Great East Japan Earthquake.

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福島県急性心筋梗塞発症登録調査
2012年集計

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福島県急性心筋梗塞発症登録調査
2012年集計

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　　　　　阿部　　亘[19]、吉田　　浩[20]、福本　優作[20]、袖長　安積[21]
　　　　　本田　恒雄[22]、大口　真寿[22]、松井遵一郎[23]、阿部　諭史[24]
　　　　　小林　利男[25]、安藤　正樹[25]、比佐　新一[26]、齋藤　行世[27]
　　　　　高平　　浩[28]、佐藤　敏光[28]、標葉隆三郎[29]、鈴木　史雄[30]
　　　　　坪井　正夫[31]、大原　直人[32]、油井　徳雄[33]、佐川　恵一[34]
　　　　　前山　忠美[35]、高谷　雄三[36]、前原　和平[37]、丸山　幸夫[3]
　　　　　竹石　恭知[1]

はじめに

　2009年1月より福島県における急性心筋梗塞患者の実態の把握、治療成績の向上を目的として、福島県保健福祉部、福島県医師会、福島県病院協会の御賛同と御協力をいただき、福島県立医科大学医学部循環器・血液内科学講座（旧内科学第一講座）を事務局として、福島県内全域の施設において急性心筋梗塞の発症登録調査を行うこととなり、関係各施設の御協力のもとに毎年調査を継続し実施している。

　今回、2012年の集計結果が得られたため、過去の結果と比較して報告する。

1）調査方法および登録概要

　2009年1月1日より福島県内の医療機関の中から急性心筋梗塞患者を受け入れる可能性があり、かつ登録調査への参加に同意の得ら

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