Table 1. Clinical Characteristics and Outcomes of Patients With AMI in 2008–2010 and 2011

	2008–2010 (n=2,995)	2011 (n=942)	P value
Age [median (IQR)], years	71 (60–79)	70 (59–80)	0.69
Female (%)	28.6	25.2	0.04
Hypertension (%)	65.1	70.0	0.06
Diabetes (%)	34.0	36.1	0.24
Dyslipidemia (%)	49.2	39.5	0.42
Smoking (%)	33.4	35.9	0.15
Anterior infarction (%)	46.3	47.1	0.67
Prior infarction (%)	8.8	8.1	0.46
Ambulance use (%), (n)	66.1 (1979)	66.8 (629)	0.69
Time elapsing from onset to admission [median (IQR)], min*	228 (90–647)	150 (72–450)	<0.001
Killip ≥2 on admission (%)	12.7	10.9	0.15
Primary PCI (%)	80.2	84.8	0.001
Peak CPK [median (IQR)], IU/L	1,373 (632–2,713)	1,565 (740–2,963)	0.01
Door-to-balloon time [median (IQR)], min†	75 (46–120)	70 (46–115)	0.21
In-hospital mortality (%), (n)	10.5 (315)	8.3 (78)	<0.05

*Only patients with data available on onset time (n=2,771 in 2008–2010 and n=887 in 2011). †Only patients who underwent primary PCI with data available on door-to-balloon time (n=1,605 in 2008–2010 and n=745 in 2011). CPK, creatinine phosphokinase; PCI, percutaneous coronary intervention.

demonstrated that the Earthquake significantly increased the occurrence of various cardiovascular diseases, including heart failure, ventricular arrhythmias and coronary vasospasm.[11,14–16]

AMI has been a leading cause of morbidity and mortality worldwide, including Japan.[2,17] In order to establish the system of emergency care of AMI in Miyagi prefecture, we have been conducting the Miyagi AMI Registry Study for 34 years since 1979, whereby all AMI patients in Miyagi prefecture are prospectively registered.[2,18–20] The Great East Japan Earthquake has enabled us to examine how the emergency care system for AMI operated during the disaster.

The aim of the present study was to elucidate how the Great East Japan Earthquake affected the emergency care of AMI in Miyagi prefecture using the data from the Miyagi AMI Registry Study.

Methods

This study was approved by the Institutional Review Broad of Tohoku University Graduate School of Medicine under the condition that personal data are protected at all times.

The Miyagi AMI Registry Study and Study Population

The Miyagi AMI Registry Study is a prospective, multicenter and observational study. As previously reported, the registry was established in 1979 and all 44 hospitals with a coronary care unit and/or cardiac catheterization facility in Miyagi prefecture have been participating (**Appendix**).[2,18–20] Miyagi prefecture has a population of approximately 2.35 million people, and almost all AMI patients are transferred to one of the participating hospitals via the emergency medical service. The diagnosis of AMI was based on the WHO-MONICA criteria, including typical severe chest pain accompanied by abnormal ECG changes and increased serum levels of cardiac enzymes.[21] Treatment, including reperfusion therapies, was left to the discretion of the individual cardiologists in charge. In the present study, we analyzed a total of 3,937 AMI patients registered in the Miyagi AMI Registry from 11 January (8 weeks before March 11) to November 15 (40 weeks after 11 March) in 2008–2011.

Statistical Analysis

To examine the effects of the Earthquake on both the clinical characteristics of AMI patients and the emergency care system, we divided the study period of 12 months into six 2-month periods and compared in-hospital mortality between 2011 and 2008–2010 for the following subgroups; age (≥70 and <70 years), sex, elapsing time from onset to admission (≤3 and >3 h) and ambulance use or not. We also compared the clinical characteristics, including elapsing time from onset to admission, door-to-balloon time defined as the time from admission to first balloon dilatation (only in the patients who received primary PCI), treatment delay defined as the time from onset to first balloon dilation (only in the patients who received primary PCI) (**Figure S1**), ambulance use, performance rate of primary PCI, peak creatine phosphokinase (CPK) level, prevalence of symptomatic heart failure with Killip class ≥2 on admission, sex, and age between 2011 and 2008–2010. As a subgroup analysis, we divided the patients into 2 groups according to time from onset to admission as ≤3 h (early admission) and >3 h (late admission), and compared in-hospital mortality and the clinical characteristics of the patients between 2011 and 2008–2010 during the 2 months just before and after the Earthquake.

Furthermore, the tsunami following the Earthquake directly and severely damaged the seacoast area.[9–11] Therefore, to examine the influence of the tsunami on the emergency care of AMI, we divided the patients in 2011 into 2 groups according to transfer hospitals located within 5 km of the sea (seacoast area) or not (inland area) (**Appendix**). We used the Mann-Whitney test for continuous values and chi-square test for categorical variables. Continuous variables are expressed as median and interquartile range (IQR).

In addition, to assess the effect of the Earthquake on in-hospital mortality, we performed multivariate logistic regression analysis by the period before and after the Earthquake and calculated the odds ratios and 95% confidence intervals. The following variables were included in the logistic regression model: age, sex, infarction site, prior MI, transport by ambulance, admission within 3 h of onset, coexisting heart failure with Killip class ≥2 and performance rate of primary

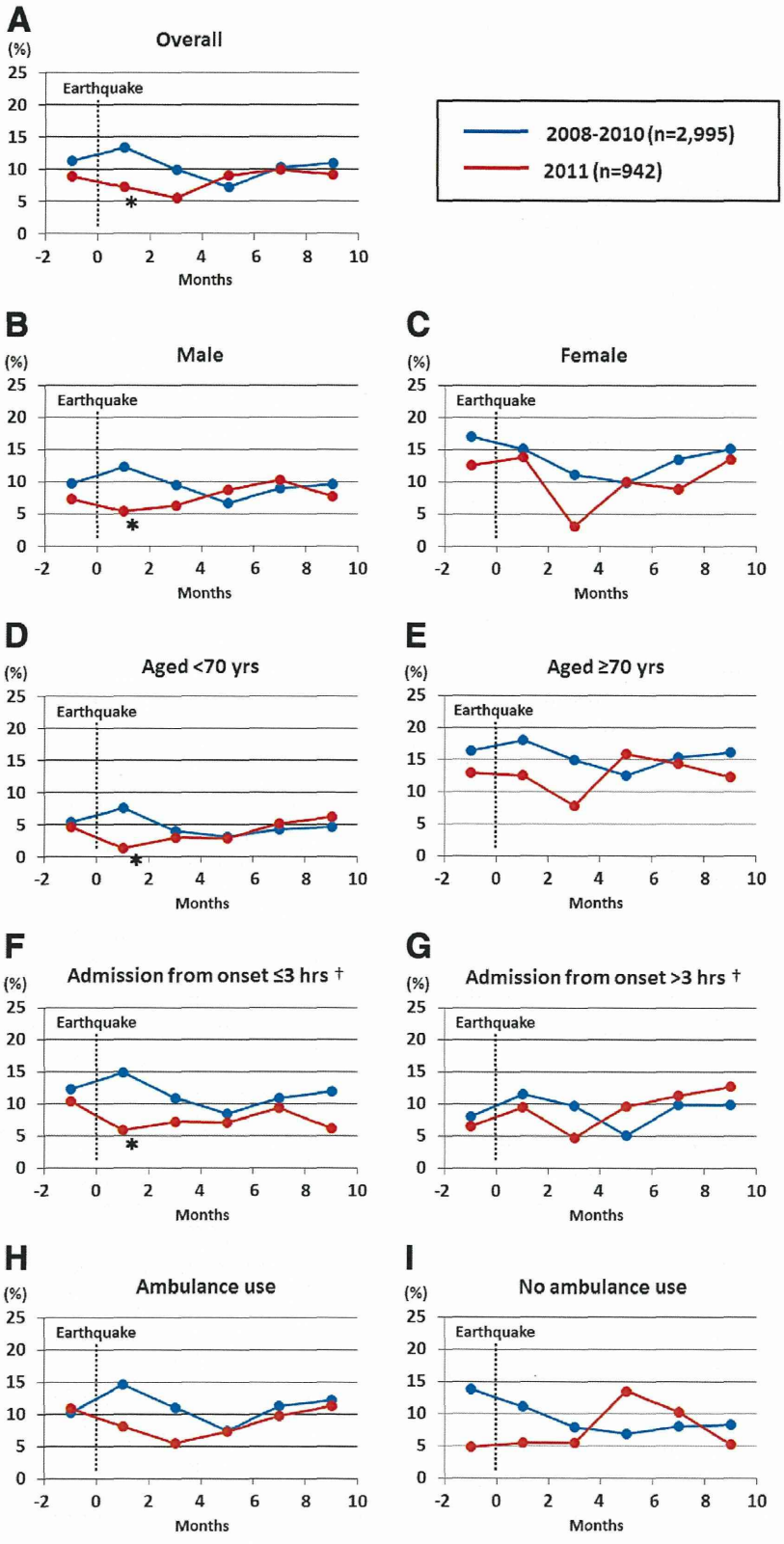

Figure 1. Time course of in-hospital mortality from acute myocardial infarction in 2011 and 2008–2010 in overall population (**A**) and subgroups divided by sex (**B**,**C**), age (**D**,**E**), elapsing time from onset to admission (**F**,**G**) and use of ambulance (**H**,**I**). *P<0.05 vs. 2008–2010. †Only patients with data available on time of onset were enrolled (n=2,944 in 2008–2010 and n=907 in 2011).

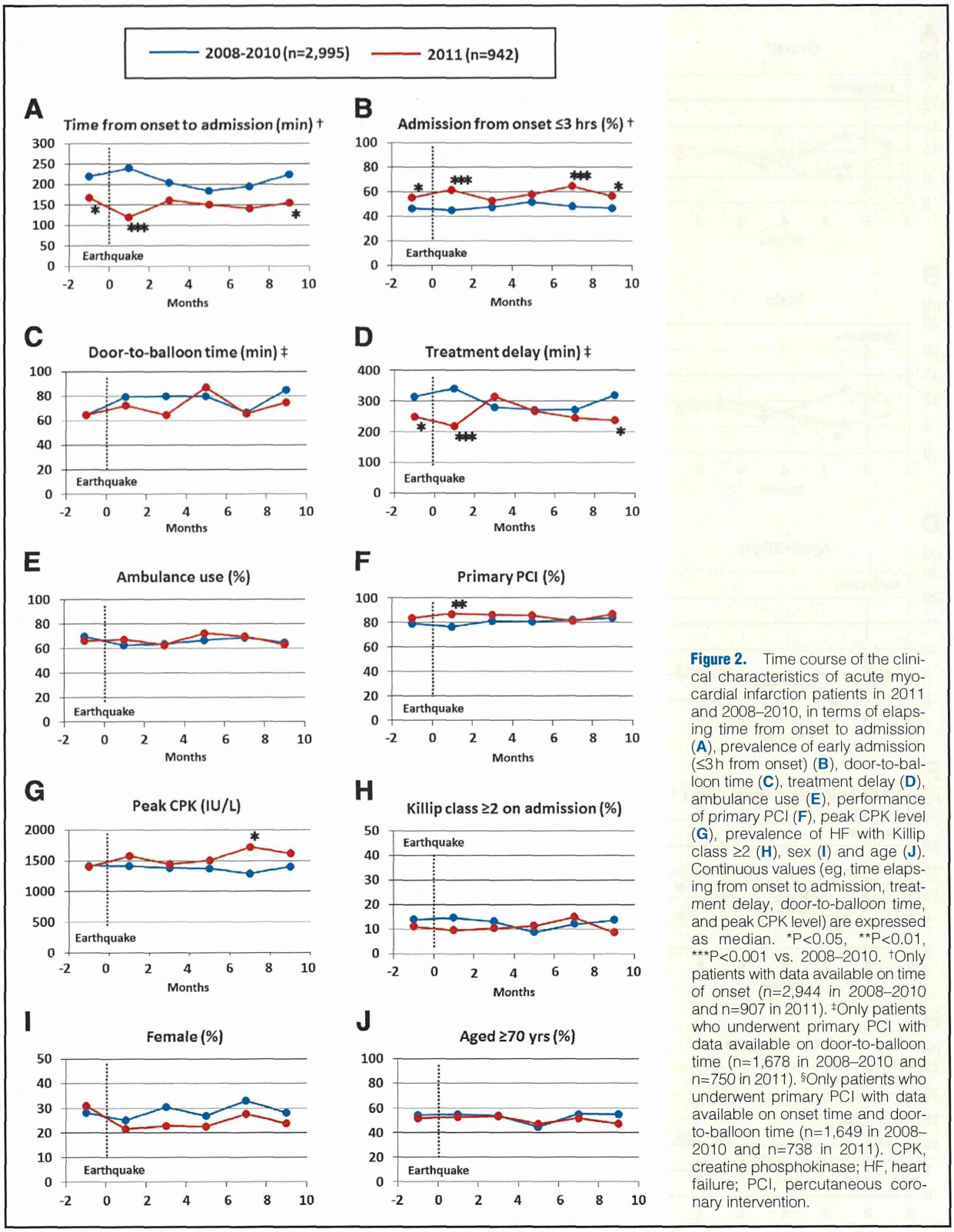

Figure 2. Time course of the clinical characteristics of acute myocardial infarction patients in 2011 and 2008–2010, in terms of elapsing time from onset to admission (**A**), prevalence of early admission (≤3 h from onset) (**B**), door-to-balloon time (**C**), treatment delay (**D**), ambulance use (**E**), performance of primary PCI (**F**), peak CPK level (**G**), prevalence of HF with Killip class ≥2 (**H**), sex (**I**) and age (**J**). Continuous values (eg, time elapsing from onset to admission, treatment delay, door-to-balloon time, and peak CPK level) are expressed as median. *P<0.05, **P<0.01, ***P<0.001 vs. 2008–2010. †Only patients with data available on time of onset (n=2,944 in 2008–2010 and n=907 in 2011). ‡Only patients who underwent primary PCI with data available on door-to-balloon time (n=1,678 in 2008–2010 and n=750 in 2011). §Only patients who underwent primary PCI with data available on onset time and door-to-balloon time (n=1,649 in 2008–2010 and n=738 in 2011). CPK, creatine phosphokinase; HF, heart failure; PCI, percutaneous coronary intervention.

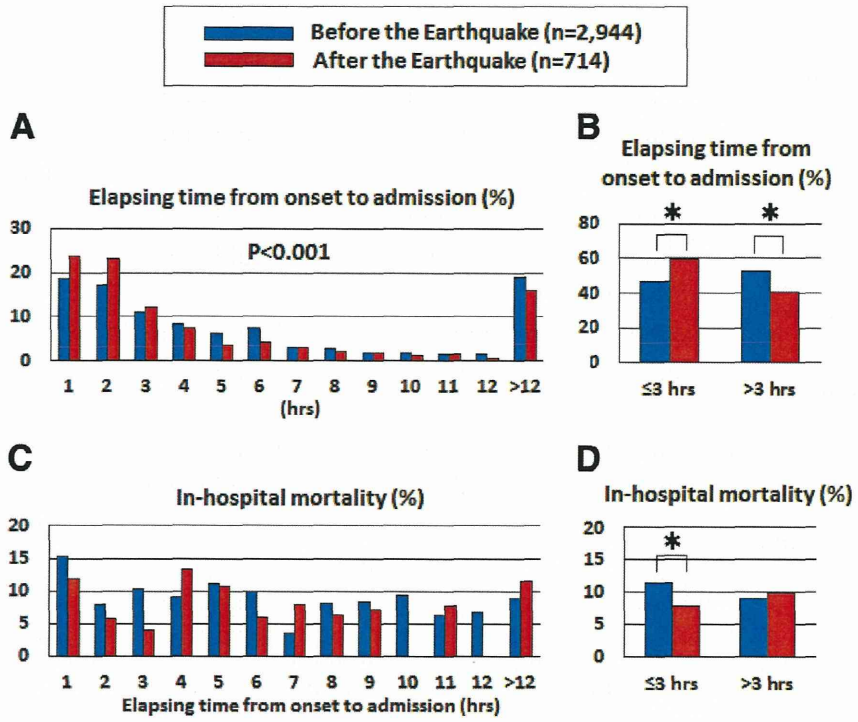

Figure 3. Distribution of the elapsing time from onset to admission before and after the Great East Japan Earthquake (March 11, 2011) (**A**,**B**), and the in-hospital mortality by the elapsing time from onset to admission before and after the Earthquake (**C**,**D**). *P<0.05 between before and after the Earthquake.

PCI. P<0.05 was considered statistically significant. All statistical analyses were performed using the statistical software R. 2.15.2 (http://www.r-project.org/) (See **Supplementary File 1**: **Methods** for details).

Results

The total number of AMI patients in the study period (from January 11 to November 15) in 2008, 2009, 2010 and 2011 was 985, 972, 1038 and 942, respectively. The weekly occurrence of AMI in Miyagi prefecture did not differ significantly after the Great East Japan Earthquake of March 11, 2011 compared with the previous 3 years (**Figure S2**). The clinical characteristics and outcomes of AMI patients in 2008–2010 and 2011 are summarized in **Table 1**. Importantly, the emergency care of AMI was significantly improved in 2011 compared with the previous 3 years, as evidenced by shorter elapsing time from onset to admission, higher performance rate of primary PCI and lower in-hospital mortality despite higher CPK levels. The time-courses of in-hospital mortality according to sex, age, early (≤3 h) and late (>3 h) admission and ambulance use are shown in **Figure 1**. As compared with 2008–2010, significant improvement of in-hospital mortality was noted during the first 2 months after the Earthquake in 2011 (**Figure 1A**), particularly in male patients (**Figures 1B**,**C**), younger patients (<70 years) (**Figures 1D**,**E**) and those with early admission (≤3 h) (**Figures 1F**,**G**), whereas the using an ambulance had no significant effects (**Figures 1H**,**I**).

To explore the factors involved in the improved in-hospital mortality of AMI patients soon after the Earthquake, we performed time-course analyses of the clinical characteristics of AMI patients in 2011 compared with the previous 3 years. In accordance with the imprived in-hospital mortality, the time from onset to admission shortened significantly in 2011 compared with the previous 3 years (**Figures 2A**,**B**), whereas, the door-to-balloon time was comparable (**Figure 2C**). Accordingly, treatment delay, defined as the time from onset to reperfusion, was significantly improved during the first 2 months after the Earthquake (**Figure 2D**) despite no significant change in the ambulance use rate (**Figure 2E**). Performance rate of primary PCI was correspondingly also significantly increased (**Figure 2F**). In contrast, peak CPK levels (**Figure 2G**) and the prevalences of symptomatic heart failure (Killip class ≥2 on admission) (**Figure 2H**), females (**Figure 2I**) and elderly patients (≥70 years) (**Figure 2J**) were almost comparable between 2011 and the previous 3 years.

Furthermore, distribution of the elapsing time from AMI onset to admission showed that the proportion of patients with early admission (≤3 h from onset) was significantly increased after the Earthquake (**Figures 3A**,**B**). We also found a significant reduction in the in-hospital mortality of these patients after the Earthquake (**Figures 3C**,**D**). Multivariate logistic regression analysis demonstrated that before the Earthquake, early admission was significantly associated with a higher incidence of in-hospital mortality but became insignificant after the Earthquake (**Figure 4**). As shown in **Table 2**, the patients with early admission during the first 2 months after the Earthquake were characterized by lower in-hospital mortality as-

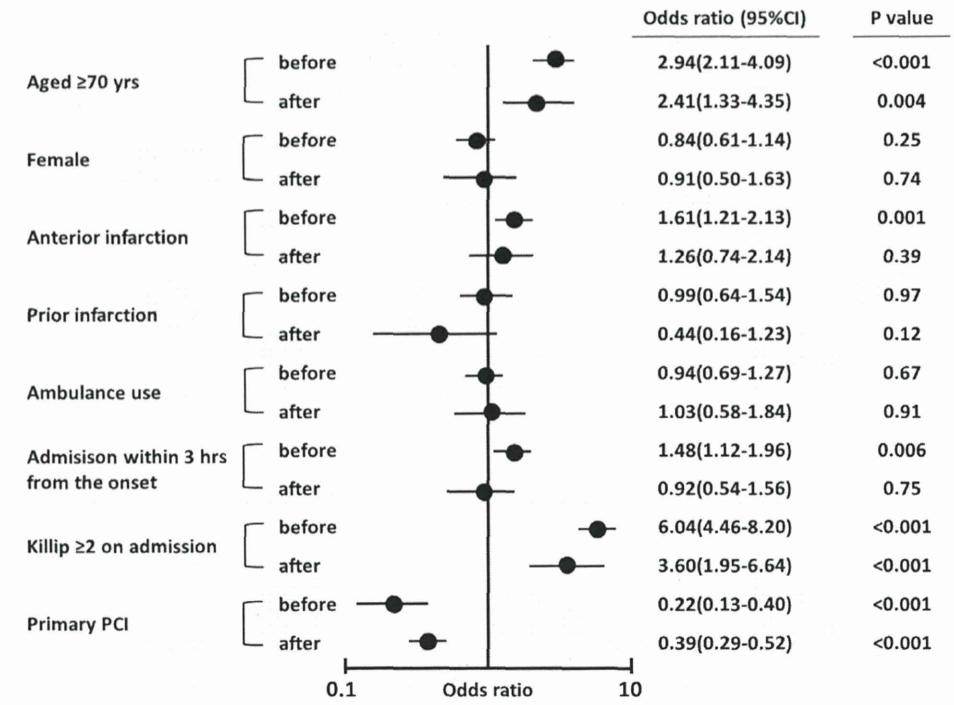

Figure 4. Multivariate adjusted odds ratio and 95% confidence intervals (CI) for in-hospital mortality of patients with acute myocardial infarction patients before and after the Earthquake. PCI, percutaneous coronary intervention.

Table 2. Clinical Characteristics and Outcome of Patients With Early Admission (≤3 h From Onset) in 2008–2010 and 2011*

	2 months before March 11			2 months after March 11		
	2008–2010 (n=243)	2011 (n=96)	P value	2008–2010 (n=216)	2011 (n=101)	P value
Age [median (IQR)], years	68 (57–78)	69 (55–79)	0.62	70 (60–79)	72 (61–82)	0.44
Female (%)	26.1	29.2	0.56	24.0	19.8	0.41
Anterior infarction (%)	50.8	41.7	0.13	42.7	54.5	0.05
Prior infarction (%)	10.7	8.3	0.51	11.6	8.9	0.48
Ambulance use (%), (n)	72.8 (177)	79.2 (76)	0.23	69.9 (151)	66.3 (67)	0.52
Killip ≥2 on admission (%)	13.2	14.6	0.73	16.2	6.9	0.02
Primary PCI (%)	83.1	81.3	0.68	76.4	89.1	0.008
Peak CPK [median (IQR)], IU/L	1,622 (618–3,003)	1,653 (615–2,886)	0.80	1,386 (590–3,058)	1,634 (712–3,389)	0.28
Door-to-balloon time [median (IQR)], min†	62 (45–109)	58 (40–92)	0.61	67 (43–113)	68 (45–110)	0.90
In-hospital mortality (%), (n)	12.3 (30)	10.4 (10)	0.62	14.8 (32)	5.9 (6)	0.02

*Only patients with data available on onset time (n=459 in 2008–2010 and n=197 in 2011). †Only patients who received primary PCI with data available on door-to-balloon time (n=276 in 2008–2010 and n=165 in 2011).
Abbreviations as in Table 1.

sociated with lower prevalence of heart failure with Killip class ≥2 on admission and higher performance rate of primary PCI, compared with those in 2008–2010. In contrast, the clinical characteristics of the patients with late admission (>3 h) did not significantly change after the Earthquake (Table 3).

Although the tsunami directly and severely damaged the seacoast area, there was no regional difference between the seacoast area and inland areas in the factors relevant to the emergency care of AMI (Table 4), suggesting that the emergency medical system of AMI was fairly maintained throughout Miyagi prefecture soon after the Earthquake.

Discussion

The novel findings of the present study are that emergency care of AMI improved soon after the Great East Japan Earthquake as compared with ordinary times, for which a shorter elapsing time from onset to admission and a higher perfor-

Table 3. Clinical Characteristics and Outcome of Patients With Late Admission (>3 Hours From the Onset) in 2008–2010 and 2011*

	2 months before March 11			2 months after March 11		
	2008–2010 (n=296)	2011 (n=77)	P value	2008–2010 (n=261)	2011 (n=63)	P value
Age [median (IQR)], years	73 (63–81)	75 (64–84)	0.02	72 (61–80)	70 (63–78)	0.44
Female (%)	29.4	35.1	0.34	25.0	23.8	0.85
Anterior infarction (%)	45.6	48.1	0.70	48.5	36.5	0.09
Prior infarction (%)	6.1	7.8	0.59	12.3	7.9	0.33
Ambulance use (%), (n)	69.6 (206)	53.2 (41)	0.007	57.9 (151)	68.3 (43)	0.13
Killip ≥2 on admission (%)	12.2	6.5	0.16	14.2	12.7	0.76
Primary PCI (%)	77.7	85.7	0.12	77.4	82.5	0.37
Peak CPK [median (IQR)], IU/L	1,396 (616–2,691)	1,267 (600–2,624)	0.62	1,451 (702–2,812)	1,481 (876–3,228)	0.84
Door-to-balloon time [median (IQR)], min†	65 (45–102)	73 (50–108)	0.91	84 (55–123)	80 (50–120)	0.51
In-hospital mortality (%), (n)	8.1 (24)	6.5 (5)	0.64	11.5 (30)	9.5 (6)	0.66

*Only patients with data available on onset time (n=557 in 2008–2010 and n=140 in 2011). †Only patients who received primary PCI (n=294 in 2008–2010 and n=106 in 2011).
Abbreviations as in Table 1.

Table 4. Differences in the Clinical Characteristics and Outcomes of AMI Patients in the Inland and Seacoast Areas*

	2 months before 11 March			2 months after 11 March		
	Inland (n=146)	Seacoast (n=33)	P value	Inland (n=136)	Seacoast (n=31)	P value
Age [median (IQR)], years	70 (58–81)	70 (61–81)	0.91	69 (60–79)	76 (65–85)	0.009
Female (%)	31.5	27.3	0.63	20.6	25.8	0.52
Anterior infarction (%)	44.5	45.5	0.92	46.3	58.1	0.24
Prior infarction (%)	6.8	12.1	0.31	9.6	3.2	0.25
Ambulance use (%), (n)	67.8 (99)	57.6 (19)	0.26	69.1 (94)	58.1 (18)	0.24
Time elapsing from onset to admission [median (IQR)], min†	156 (60–516)	189 (74–458)	0.68	150 (66–402)	90 (60–312)	0.23
Killip ≥2 on admission (%)	12.3	6.1	0.30	8.8	12.9	0.72
Primary PCI (%)	82.2	87.9	0.43	87.5	83.9	0.59
Peak CPK [median (IQR)], IU/L	1,325 (740–2,470)	1,618 (413–3,336)	0.84	1,597 (755–3,521)	1,316 (670–2,689)	0.60
Door-to-balloon time [median (IQR)], min‡	65 (45–94)	80 (38–128)	0.78	71 (50–120)	78 (45–106)	0.65
In-hospital mortality (%), (n)	9.6 (14)	6.1 (2)	0.64	7.4 (10)	6.5 (2)	0.86

*Patients were divided into 2 groups according to transferred hospital located within 5 km of the sea (seacoast area, n=64) or not (inland area, n=282). †Only patients with data available on onset time (n=278 in the inland area and n=63 in the seacoast area). ‡Only patients who received primary PCI with data available on door-to-balloon time (n=220 in the inland area and n=55 in the seacoast area).
Abbreviations as in Table 1.

mance rate of primary PCI may be involved. To the best of our knowledge, this is the first report demonstrating that the emergency care of AMI can be improved through improved chain of survival, especially earlier admission from onset, following a natural disaster in a large community.

Occurrence of AMI After the Great East Japan Earthquake

The present study demonstrated that the occurrence of AMI per se did not significantly increase after the Earthquake, a finding consistent with our recent report.[14] In contrast, it has been reported that the occurrence of AMI increased after previous earthquakes that occurred in the early morning, such as the Northridge earthquake in 1994 (Los Angeles, CA, USA), and the Hanshin-Awaji earthquake in 1995 (Kobe, Japan).[22,23] This discrepancy might be attributable, at least in part, to the type of earthquake (ocean-trench earthquake in the present study vs. inland ones in the previous studies) and when the earthquake occurred (afternoon in the present study vs. early morning in the previous studies). AMI would be more likely to occur if an extreme emotional stress following abrupt awakening by an earthquake is superimposed, as in the previous studies, whereas it was reported that the incidence of AMI did not significantly increase after earthquakes in the afternoon such as the Loma Prieta earthquake in 1989 (San Francisco, CA, USA) and the Niigata-Chuetsu earthquake in 2004 (Niigata, Japan).[24,25] In addition, the discrepancy could also be explained by differences in subject numbers and study period, as the present study had a large study population and a longer study period compared with previous studies.[22,23] We also had the advantage of being able to compare the data after the Earthquake with historical data from the previous 3 years.

Increased Rate of Performing Primary PCI After the Great East Japan Earthquake

During the first 2 months after the Earthquake, in-hospital mortality of AMI patients was significantly improved in Miyagi prefecture, associated with a shorter elapsing time from onset to admission and higher performance rate of primary PCI, as compared with the previous 3 years. Previous clinical studies have demonstrated that coronary reperfusion therapies, includ-

ing primary PCI, effectively reduce infarct size and improve the clinical outcomes of AMI patients.[1,3] In the Miyagi AMI Registry Study, the use of primary PCI has dramatically increased since the 1990s and more than 80% of AMI patients underwent the therapy in recent years.[2] In the present study, the performance rate of primary PCI was approximately 85% in 2011 and during the first 2 months after the Earthquake, it was significantly higher compared with the previous 3 years.

Such a higher performance rate of primary PCI may have substantially contributed to the better prognosis of AMI patients in 2011.

Improved Chain of Survival of AMI After the Great East Japan Earthquake

In addition to the increased performance rate of primary PCI, the elapsing time from symptom onset of AMI to reperfusion therapy (ie, the chain of survival) is another important factor in the clinical outcome of AMI patients.[4–6] This treatment delay is divided into 2 major components: (1) the time from onset to the first contact by a patient with emergency care (patient delay) and (2) from the first contact with emergency care to first balloon dilatation (system delay)[4] (**Figure S2A**). Although previous trials have succeeded in improving the system delay,[26,27] no attempt has been made regarding the patient delay.[7,8] In the present study, we found that the time from onset to admission was significantly shortened after the Earthquake and that the trend continued throughout the year of 2011. Before the Earthquake, patients with early admission had a significantly higher mortality despite their younger age compared with those with late admission (**Table S1**). These paradoxical findings were consistent with a recent report from Japan[28] that indicated patients with signs of left ventricular failure have a significantly shorter patient delay.[29] Indeed, a multivariate analysis also showed that early admission correlated with worse in-hospital mortality before the Earthquake, suggesting that the severity of AMI in those patients were high (eg, complicated with cardiac arrest or cardiogenic shock). In contrast, after the Earthquake, the patients with early admission had a better in-hospital outcome, associated with a lower prevalence of symptomatic heart failure, despite peak CPK levels comparable to those before the Earthquake. These findings indicate that after the Earthquake, AMI patients were transferred to hospitals earlier regardless of the severity of the disorder. As demonstrated in previous studies,[1,30] it is probably the earlier admission and less severe condition on admission that were associated with the higher performance rate of primary PCI after the Earthquake than in ordinary times (**Figure S2B**). In contrast, the ambulance use rate was unchanged before and after the Earthquake. Thus, it is highly possible that the patient delay was reduced with a resultant favorable prognosis soon after the Earthquake. Indeed, a recent study also emphasized that efforts to minimize patient delay are recommended to improve clinical outcomes in AMI patients because the benefit of a short door-to-balloon time was limited only to patients with early admission.[31] The present study also demonstrates that in-hospital mortality in the acute phase of AMI was improved after the Earthquake, together with the increased rate of early admission and unchanged door-to-balloon time as compared with ordinary times (**Figure S2B**). Additionally, based on the fact that the Niigata-Chuetsu earthquake significantly increased long-term mortality from AMI,[32] we have to recognize the need for long-term prevention of AMI in the future.

It remains to be elucidated why patients with AMI presented earlier after the Earthquake. Disaster-related mental and physical stresses are known to activate the sympathetic nervous system and enhance the activity of key molecules associated with coronary artery vasomotion such as Rho/Rho-kinase.[13,16] It is possible that those activated pathways reduce the threshold level of ischemia-related symptoms. Furthermore, disasters can cause various manifestations of psychological distress in survivors, including feelings of tension and anxiety, concentration difficulty, hostility and rage, sleep problems and intrusion/avoidance of disaster-related memories.[33,34] It has been reported that exposure to extreme stressors may enhance an individual's reactivity to subsequent stressors. That process is termed "stress sensitization", in which an organism responds more strongly to a variety of stimuli after exposure to a potentially threatening or noxious stimulus.[35–37] In the present critical situation caused by the Earthquake, tsunami and subsequent aftershocks, many residents in Miyagi prefecture would have experienced stress sensitization. Generally, the human instinct to survive is the most powerful drive and the fight-or-flight reaction, which is the best-known expression of our survival instinct, is triggered when we perceive a situation as a threat to our existence.[38–40] Thus, it is highly possible that in the present disaster, stress sensitization and enhanced survival instincts made the AMI patients more sensitive to their health or physical disorder with resultant earlier admission than in ordinary times.

However, it is important to note that a previous study of a community intervention targeting mass media and patient education failed to improve appropriate action for AMI symptoms.[7] In the present study, we also found no difference in door-to-balloon time that would reflect the system delay before and after the Earthquake, suggesting that the medical system itself functioned as well as in ordinary times, despite the fact that the Earthquake damaged infrastructure and caused shortages of medicines. We also found no difference in the ambulance use rate, elapsing time from onset to admission, performance rate of primary PCI or in-hospital mortality between the inland and seacoast areas, which suggests that the emergency medical system was well maintained throughout the prefecture during the disaster period.

Study Limitations

First, although almost all AMI patients were transferred to participating hospitals in Miyagi prefecture, not all patients may have been registered in the registry, especially during the disaster period. Second, as shown by several previous studies, including our own recent reports, the occurrence of cardiopulmonary arrest significantly increases after large earthquakes.[11,41] Thus, it is conceivable that patients who died from AMI-related cardiopulmonary arrest were not included in the present study and the incidence of AMI after the Earthquake could be underestimated. However, we found that the emergency care of AMI worked better soon after the Great East Japan Earthquake than in ordinary times. Third, there was no detailed angiographic data in our database. Thus, we were unable to determine the subtypes of MI based on the universal definition[42] or the incidence of takotsubo cardiomyopathy misdiagnosed as AMI. In addition, because we have no data available on the prevalence of pre-infarction angina and glucose levels on admission, both of which have been shown to be associated with the prognosis of AMI patients,[43,44] we were unable to examine how those prognostic factors had been affected by the Earthquake. Fourth, since the present study was observational in nature, the precise mechanisms of the improvement in the emergency care of AMI, especially that of the improved time from onset to admission, remain to be fully elucidated.

Conclusions

Emergency care of AMI patients worked better soon after the Great East Japan Earthquake than in ordinary times, for which several factors, including shorter elapsing time from onset to admission and higher performance rate of PCI, may be involved.

Acknowledgments

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Disclosures

Conflict of interest: None declared.

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Appendix

Participating Hospitals and Investigators of the Miyagi AMI Registry Study

Hospitals in the Seacoast Area

Ishinomaki Medical Association; Ishinomaki Municipal Hospital, Akai K, MD; Ishinomaki Red-cross Hospital, Sukegawa H, MD; Kesen-numa Hospital, Ogata K, MD; Miyagi Eastern Cardiovascular Institute, Kikuchi Y, MD; Miyagi Social Insurance Hospital, Hanadate Y, MD; Saito Hospital, Otsuka K, MD; Saka General Hospital, Watanabe K, MD; Sen-en General Hospital, Hashiguchi R, MD; Shiogama City Hospital, Goto J, MD; Tohoku Pharmaceutical University Hospital, Katahira Y, MD.

Hospitals in the Inland Area

Fukaya Hospital, Akiho H, MD; Hikarigaoka Spellman Hospital, Shimura S, MD; JR Sendai Hospital, Honda H, MD; Katta General Hospital, Kanno H, MD; Kurihara Central Hospital, Akai K, MD; Labour Welfare Corporation Tohoku Rosai Hospital, Kato H, MD; Marumori National Health Insurance Hospital, Otomo M, MD; Miyagi Cancer Center, Owada N, MD; Miyagi Cardiovascular and Respiratory Center, Komaru T, MD; Mori Hospital, Mori A, MD; Nagamachi Hospital, Mitobe H, MD; Nishitaga National Hospital, Kitaoka S, MD; NTT EAST Tohoku Hospital, Yamada A, MD; Oizumi Memorial Hospital, Koiwa Y, MD; Osaki Citizen Hospital, Hiramoto T, MD; Sendai Cardiovascular Center, Fujii S, MD; Sendai City Hospital, Yagi T, MD; Sendai Kosei Hospital, Meguro T, MD; Sendai Medical Center, Shinozaki T, MD; Sendai Open Hospital Sendai City Medical Center, Kato A, MD; Sendai Public Health Insurance Hospital, Oikawa Y, MD; Sendai Red-cross Hospital, Sugimura A, MD; Sendai Tokushukai Hospital, Fukuchi M, MD; Shichigashuku National Health Insurance Clinic, Nagashima T, MD; South Miyagi Medical Center, Inoue K, MD; Tohoku Kosai Hospital, Suzuki S, MD; Tohoku University Hospital, Department of Cardiovascular Medicine, Shimokawa H, MD; Department of Cardiovascular Surgery, Saiki Y, MD; Department of Medical Engineering and Cardiology, Institute of Development, Aging and Cancer, Yanbe T, MD; Tome Citizen Hospital, Izuma M, MD; Toyama Clinic on Tome City, Ishii M, MD.

Supplementary Files

Supplementary File 1.

Methods.

Figure S1. Emergency care of acute myocardial infarction and the involvement of the 3 delays in treatment response.

Figure S2. Weekly occurrence of acute myocardial infarction in 2011 and 2008–2010.

Figure S3. (**A**) Shortened delay from onset to admission and unchanged door-to-balloon time in the present study. (**B**) Factors involved in the improved outcome of patients with acute myocardial infarction patients after the Great East Japan Earthquake.

Table S1. Differences between patients with early (≤3 h) and late admission (>3 h) after onset of acute myocardial infarction

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Letter to the Editor

Factors influencing the occurrence of cardiopulmonary arrest in the Great East Japan Earthquake disaster

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On March 11, 2011, the Great East Japan Earthquake hit the northeast region of Japan with a magnitude of 9.0 on the Richter scale, which was one of the largest ocean-trench earthquakes recorded in Japan [1]. The epicenter of the Earthquake was located at 38° latitude, 06.2′ North, 142° longitude, 51.6′ East, where it was closest to our Miyagi Prefecture (Fig. 1A). In the Miyagi prefecture, there was the largest amount of damage and victims including 9538 dead, 1269 missing persons, and 238,114 destroyed houses as of August 8, 2014, especially in the seacoast areas by the tsunami [2].

It had been previously reported that cardiopulmonary arrest (CPA) could be triggered by earthquake disaster [3–5]. Recently, we also reported that the CPA was significantly increased after the Great East Japan Earthquake [6], however, the details remain to be elucidated. In this study, we examined the factors influencing the occurrence of CPA after the Earthquake.

In the present study, we extracted 5857 patients with CPA from all ambulance transport records in the Miyagi Prefecture from February 11 to June 30 (4 weeks before to 16 weeks after March 11) in each year of 2008–11 (n = 124,152). Among those CPA patients, as we excluded 3323 patients caused by trauma or diseases with non-cardiac origin, 2534 patients with CPA of presumed cardiac origin were finally subjected to analysis. The Ethics Committees of Tohoku University Hospital approved this study protocol.

To assess the differences in the occurrences of CPA between 2011 and the previous 3 years, we used the Poisson regression model, as previously reported [6]. Sub-group analyses were performed for age (<75 or ≥75 years), sex, and residence (seacoast or inland area). We defined the municipalities facing the Pacific Ocean as the seacoast area where the Tsunami directly attacked and the remaining inner area as the inland area (Fig. 1A). Furthermore, to compare the effects of the 3 factors used for dividing sub-groups on the change in the incidence of CPA after the Earthquake, we performed multivariate logistic regression analysis and calculated odds ratios (ORs) of CPA patients in 2011 to those of previous 3 years during the following 3 periods; March 11–24 (0–2 weeks after the Earthquake), March 25–April 7 (2–4 weeks after the Earthquake), and April 8–23 (0–2 weeks after the largest aftershocks). All statistical analyses were performed using R 2.15.0 (www.r-project.org/). $P < 0.05$ was considered to be statistically significant.

In the whole patients, the weekly occurrence of CPA was significantly increased with the bimodal peaks noted in the first 2 weeks after the Earthquake (March 11, 2011) and after the largest aftershock (April 7, 2011) compared with the previous 3 years (Fig. 1B). Sub-group analyses showed that the occurrence of CPA was significantly increased soon after the Earthquake in all groups, whereas the second peak after the aftershock was noted only in female, elderly and inland patients (Fig. 2A). In addition, elderly and seacoast patients had a sustained increase in the occurrence of CPA over the period of 4 weeks after the Earthquake. Multivariate analysis demonstrated that significant influence of age ≥75 years was noted on the increase in CPA [1.82 (1.04–3.20), P = 0.04] in 0–2 weeks after the aftershock and that female gender [OR (95% CI); 1.57 (0.97–2.54), P = 0.07] and seacoast residence [1.54 (0.91–2.59), P = 0.11] tended to correlate with the increase in CPA during 0–2 weeks and 2–4 weeks after the Earthquake, respectively (Fig. 2B).

It has been previously reported that CPA could be triggered by abrupt stress such as earthquake disaster [4,6,7] and there were individual differences in the response to stress [4], while the details remain to be elucidated. The present study showed that the occurrence of CPA was increased with the bimodal peaks after the Earthquake and the largest aftershock. On the other hand, the recent report which aimed at Iwate, Miyagi, and Fukushima Prefectures did not demonstrate the second peak after the aftershock [7]. As a report which investigated population-based incidence of CPA in part of Iwate Prefecture after the Earthquake indicated that the occurrence rates of CPA were significantly correlated with seismic activity [8], the largest seismic intensity of the aftershock in Miyagi Prefecture could create the second peak of the

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