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ORIGINAL ARTICLE
Ischemic Heart Disease

Number of Board-Certified Cardiologists and Acute Myocardial Infarction-Related Mortality in Japan

— JROAD and JROAD-DPC Registry Analysis —

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Background: The appropriate number of board-certified cardiologists (BCC) for the treatment of acute myocardial infarction (AMI) has not been thoroughly examined in Japan. This study investigated whether the number of BCC/50 cardiovascular beds affects acute outcome in AMI treatment.

Methods and Results: Data on 751 board-certified teaching hospitals and 63,603 patients with AMI were obtained from the Japanese Registry Of All cardiac and vascular Diseases (JROAD) and JROAD Diagnosis Procedure Combination (JROAD-DPC) databases between 1 April 2012 and 31 March 2014. The hospitals were categorized into 3 groups based on the median number of BCC/50 cardiovascular beds: first tertile, 5.0 (IQR, 4.0–5.7); second, 8.3 (IQR, 7.4–9.8); third, 15.3 (IQR, 12.5–22.7), and the patients with AMI admitted to the categorized hospitals were compared (first tertile, 12,002 patients; second, 23,930; third, 27,671). On hierarchical logistic modeling, the adjusted OR for 30-day mortality were 0.86 (95% CI: 0.74–1.00) for the second tertile and 0.75 (95% CI: 0.65–0.88) for the third tertile.

Conclusions: Patients with AMI admitted to hospitals with a large number of BCC/50 cardiovascular beds had a lower 30-day mortality rate. This tendency was independent of patient and hospital characteristics. This is the first study to provide new information on the association between the number of BCC and in-hospital AMI-related mortality in Japan.

Key Words: Acute myocardial infarction; Cardiologist; Diagnosis Procedure Combination (DPC); Japanese Registry Of All cardiac and vascular Diseases (JROAD); Mortality

Reduction of mortality in acute myocardial infarction (AMI) has been an important issue for cardiologists. The age-standardized mortality rate of AMI has been gradually decreasing over the past 3 decades in several countries,[1,2] which is probably due to the development of emergency medical network systems, and the carrying out of reperfusion therapy and optimal medical therapy.[3,4] AMI, however, remains one of the most common causes of death.[1,5]

In 2016, 68,907 patients in Japan were hospitalized because of AMI, and the in-hospital mortality rate was 8.2%, which has not improved in recent years despite the advancements in medical technology.[6,7] Thus, to further improve the acute outcome of AMI treatment, structural and clinical properties of the hospital, including the quality and quantity of medical staff, require more attention.

The aim of this study was to determine whether or not the number of cardiovascular specialists affects the acute mortality of AMI. The Japanese Circulation Society (JCS) launched the board of cardiovascular specialist system in 1989.[8] There were 6,568 JCS board-certified cardiologists (BCC) working full time in 1,612 hospitals in 2012, which included almost all cardiovascular beds in Japan. All hospitals with cardiovascular beds were divided into different classes: class A hospitals have >2 BCC and >30 cardiovascular beds; class B hospitals have >1 BCC and >15 cardiovascular beds, and class C hospitals do not have BCC or they have <15 cardiovascular beds. The number of BCC per hospital in classes A and B widely varied from 1 to 87, and whether this current status is appropriate or

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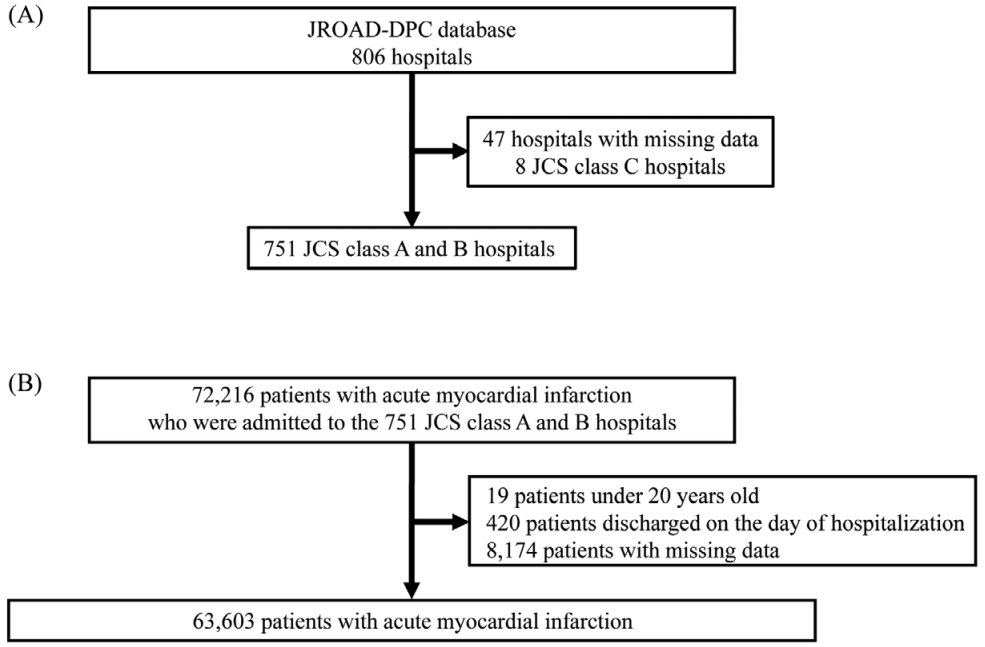

Figure 1. Study flow chart. (**A**) Flow chart for hospital selection, (**B**) flow chart for patient selection class A hospitals need more than 2 BCC and 30 cardiovascular beds, class B hospitals need more than 1 BCC and 15 cardiovascular beds. DPC, Diagnosis Procedure Combination; JCS, Japanese Circulation Society; JROAD, Japanese Registry Of All cardiac and vascular Diseases.

not for the treatment of AMI remains unknown, especially given that available related studies in Japan are limited.

The aim of this study was therefore to clarify the associations between the number of BCC/50 cardiovascular beds and 30-day AMI mortality.

Methods

Patients

This was a cross-sectional study, and we used the Japanese Registry Of All cardiac and vascular Diseases (JROAD) database and Diagnosis Procedure Combination (DPC) discharge database from 2012 to 2014. JROAD is conducted by JCS, and the data were collected from almost all teaching hospitals with cardiovascular beds, except for stroke.[9,10] Of 1,613 hospitals included in the JROAD, 806 provided DPC data to JCS.

We obtained the following data on JCS-certified class A and B teaching hospitals: number of hospital beds and cardiologists; presence or absence of cardiac surgery division and coronary care unit; hospital teaching status (teaching hospitals are defined as JCS-certified cardiovascular specialist training facilities with >2 BCC and >30 cardiovascular beds); and annual number of percutaneous coronary interventions (PCI) and coronary artery bypass grafts (CABG). Consequently, 751 hospitals were enrolled in this study (**Figure 1A**).

Subsequently, we collected data for 72,216 patients from the 751 hospitals based on the following inclusion criteria: (1) hospitalized because of AMI between 1 April 2012 and 31 March 2014; and (2) diagnosis of AMI based on the International Classification of Diseases (ICD-10) codes for AMI (I21.0, I21.1, I21.2, I21.3, I21.4, and I21.9). We excluded 19 patients <20 years old, 420 patients discharged on the day of hospitalization, and 8,174 patients with insufficient data. Consequently, we analyzed 63,603 patients in 751 hospitals (**Figure 1B**).

We categorized the 751 hospitals into 3 groups according to the number of BCC/50 cardiovascular beds and compared the groups of patients admitted to the categorized hospitals. In the subanalysis, we divided the 63,603 patients with AMI into 2 groups according to Killip classification on admission: not severe (Killip I and II) or severe (Killip III and IV).

Ethics

The ethics committees at both JCS and Nara Medical University, which waived the requirement for individual informed consent because no information specifying individuals was included, approved the study protocol. The original DPC data were anonymized using the code change equations, and were then sent to the Ministry of Health, Labor, and Welfare.

Statistical Analysis

Data are presented as mean±SD for normally distributed data, and as median (IQR) for asymmetrically distributed data, or absolute number (proportion) for categorical data. The differences between tertiles were compared using analysis of variance for continuous variables and the chi-squared test with Bonferroni correction for non-continuous and categorical variables. The main outcome measure was in-hospital or 30-day mortality. The tendency for tertile 30-day mortality was analyzed using the Cochran-Armitage trend test. The association between the number of BCC/50 cardiovascular beds and 30-day mortality was

Table 1. Hospital Characteristics vs. No. JCS Board-Certified Cardiologists

	Total	First tertile	Second tertile	Third tertile	P-value
JCS BCC/50 CV beds (range)	0.63–75.58	0.63–6.58	6.63–10.98	11.05–75.58	
No. hospitals§	751	238	282	231	
Hospital beds	444 (300–558)	317 (230–400)	406 (307–500)	621 (441–735)	<0.001†
CV beds	38 (30–46)	39 (30–48)	37 (30–42)	39 (28–46)	0.005†
JCS BCC/50 CV beds	8.3 (6.3–13.2)	5.0 (4.0–5.7)	8.3 (7.4–9.8)	15.3 (12.5–22.7)	<0.001†
JCS BCC/hospital	5.4 (3–6)	2.8 (2–3)	4.2 (3–5)	9.4 (5–12)	<0.001†
JCS BCC and non-JCS BCC/hospital	8.3 (4–9)	3.7 (3–5)	6.2 (4–7)	15.8 (8–19)	<0.001†
Cardiac intensive care units	85	71	87	96	<0.001‡
Coronary angiography/year	444 (182–595)	247 (107–326)	434 (193–547)	636 (383–807)	<0.001†
Emergency PCI for AMI/year	49 (20–69)	29 (10–40)	49 (23–64)	68 (38–94)	<0.001†
Cardiac surgery	61	42	57	87	<0.001‡
No. CABG/year	31 (13–40)	16 (2–23)	27 (8–38)	41 (19–54)	<0.001†
Hospital teaching status	94	82	95	99	<0.001‡

Data given as median (IQR), n§ or %. †Kruskal-Wallis test; ‡X^2 test with Bonferroni correction. AMI, acute myocardial infarction; BCC, board-certified cardiologists; CABG, coronary artery bypass graft; CV, cardiovascular; JCS, Japanese Circulation Society; PCI, percutaneous coronary intervention.

analyzed using multilevel mixed-effect logistics regression, with hospital characteristics at the first level and patient characteristics at the second. The number of BCC/50 cardiovascular beds was analyzed as a continuous variable and as a categorical variable (first, second, and third tertile). The models were adjusted for the following covariates based on previous reports: age; gender; Charlson comorbidity index; comorbidity (hypertension, dyslipidemia, diabetes mellitus, chronic kidney disease, and atrial fibrillation); presence of cardiac surgery division and coronary care unit; hospital teaching status; use of ambulance; and Killip classification. Stepwise analysis was performed to determine whether any combination of clinical findings was associated with 30-day mortality. In addition, propensity score analysis was conducted to evaluate the robustness of the results. We performed one-to-one propensity score matching between the 2 groups by the number of cardiologists. The cut-off for the number of cardiologists was 10.0, which was determined on receiver operating characteristic analysis. Propensity scores were estimated using a logistic regression model with independent variables selected on stepwise analysis. A caliper of 0.001-fold the SD was used.

In the sub-analysis, we performed stratified analysis according to AMI severity to ascertain whether the effect of the number of BCC/50 cardiovascular beds on 30-day mortality is dependent on AMI severity. Biological interaction between the number of BCC/50 cardiovascular beds and AMI severity was evaluated by calculating the relative excess risk.[11–13] STATA (version 14, Stata Corp., College Station, TX, USA) was used for the analysis.

Results

Hospital Characteristics

The median number of BCC/50 cardiovascular beds was 5.0 (IQR, 4.0–5.7) in the first tertile hospitals, 8.3 (IQR, 7.4–9.8) in the second, and 15.3 (IQR, 12.5–22.7) in the third. As the number of BCC/50 cardiovascular beds increased, the following variables also increased: number of hospital beds and cardiologists; presence of cardiac surgery division and coronary care unit; hospital teaching status; and annual number of PCI and CABG (**Table 1**).

Patient Characteristics

Approximately 82% of the patients were admitted to the second or third tertile hospitals. Sex, age, Charlson comorbidity index, Killip classification, comorbidity, ambulance use, and medication were similar between the 3 groups, whereas the use of circulation devices, such as intra-aortic balloon pump (IABP) and percutaneous cardiopulmonary support system (PCPS), increased and the length of hospital stay decreased as the number of BCC/50 cardiovascular beds increased (**Table 2**).

Crude in-hospital mortality was 11.5% for the first tertile, 10.0% for the second, and 8.3% for the third, which all decreased as the number of BCC/50 cardiovascular beds increased.

No. BCC/50 Cardiovascular Beds and 30-Day Mortality

On multilevel mixed-effect logistics regression analysis of the number of BCC/50 cardiovascular beds as a continuous variable, the OR for 30-day mortality was 0.987 (95% CI: 0.982–0.994, P<0.01), and the adjusted OR (AOR) for 30-day mortality was 0.988 (95% CI: 0.982–0.995, P<0.01).

On tertile analysis of the number of BCC/50 cardiovascular beds, unadjusted OR for 30-day mortality was significantly lower in the second tertile (OR, 0.81; 95% CI: 0.71–0.92, P<0.001) and third tertile (OR, 0.66; 95% CI: 0.58–0.76, P<0.001) than in the first tertile. Moreover, inverse trends in 30-day mortality were observed between the tertiles (trend test P<0.01). The AOR for 30-day mortality was 0.88 (95% CI: 0.75–1.03, P=0.10) for the second tertile and 0.77 (95% CI: 0.65–0.92, P<0.001) for the third tertile. The number of BCC remained an independent risk factor after stepwise analysis. On stepwise analysis, the AOR for 30-day mortality was 0.86 (95% CI: 0.74–1.00, P=0.05) in the second tertile and 0.75 (95% CI: 0.65–0.88, P<0.01) in the third tertile (**Table 3**). The OR for the large BCC group vs. the small BCC group was 0.87 (95% CI: 0.78–0.98, P=0.019) after propensity score matching (**Table S1**).

Table 2. Patient Characteristics vs. No. JCS Board-Certified Cardiologists

	Total	First tertile	Second tertile	Third tertile	P-value
JCS BCC/50 CV beds (range)	0.63–75.58	0.63–6.58	6.63–10.98	11.05–75.58	
Patients	63,603 (100)	12,002 (19)	23,930 (38)	27,671 (44)	
Age (years)	69±13	70±13	69±13	69±13	<0.001*
Male	73	71	73	74	<0.001‡
Charlson comorbidity index	2 (1–3)	2 (1–3)	2 (1–3)	2 (1–3)	<0.001†
Killip classification					
I	30,336 (48)	5,028 (42)	11,658 (49)	13,650 (49)	<0.001‡
II	18,521 (29)	3,910 (33)	6,514 (27)	8,097 (29)	
III	5,561 (9)	1,197 (10)	2,098 (9)	2,266 (8)	
IV	9,185 (14)	1,867 (16)	3,660 (15)	3,658 (13)	
Comorbidities					
Hypertension	62	61	61	63	<0.001‡
Diabetes mellitus	29	29	28	29	<0.001‡
Dyslipidemia	56	55	55	58	<0.001‡
CKD	4.2	3.7	4	4.5	<0.001‡
Atrial fibrillation	5.0	5.6	5.2	4.7	<0.001‡
Ambulance use	69	59	64	66	<0.001‡
Medication					
ACEI or ARB	88	86	87	89	<0.001‡
β-blockers	58	61	60	56	<0.001‡
Antiplatelets	98	98	98	99	<0.001‡
CCB	63	66	64	60	<0.001‡
Statins	91	89	90	92	<0.001‡
Oral anti-diabetic drugs	64	67	66	62	<0.001‡
Device					
IABP	15	12	15	17	<0.001‡
PCPS	2.3	1.5	2	2.8	<0.001‡
LVAD	0.01	0.00	0.02	0.01	0.36‡
CRRT	1.1	0.9	0.9	1.3	<0.001‡
Respirator	18	17	17	18	<0.001‡
LOHS (days)	17 (9–20)	18 (10–22)	17 (10–20)	16 (9–19)	<0.001†
30-day mortality	9.6	11.5	10.0	8.3	<0.001*

Data given as mean±SD, median (IQR), n (%) or %. *ANOVA; †Kruskal-Wallis rank sum test; ‡X^2 test with Bonferroni correction. ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; CCB, calcium channel blockers; CKD, chronic kidney disease; CRRT, continuous renal replacement therapy; IABP, intra-aortic balloon pumping; LOHS, length of hospital stay; LVAD, left ventricular assist device; PCPS, percutaneous cardiopulmonary support. Other abbreviations as in Table 1.

Table 3. No. JCS BCC/50 CV Beds and 30-Day Mortality

	No. JCS BCC/50 CV beds (range)	n	Unadjusted analysis			Multivariate analysis			Stepwise analysis		
			OR	95% CI	P-value	AOR	95% CI	P-value	AOR	95% CI	P-value
First tertile	0.63–6.58	12,002	Ref.			Ref.			Ref.		
Second tertile	6.63–10.98	23,930	0.81	0.71–0.92	<0.001	0.88	0.75–1.03	0.10	0.86	0.74–1.00	0.05
Third tertile	11.05–75.58	27,671	0.66	0.58–0.76	<0.001	0.77	0.65–0.92	<0.001	0.75	0.65–0.88	<0.001

The model includes age (per 10 years), gender, Charlson comorbidity index, Killip classification, hypertension, hyperlipidemia, diabetes, CKD, atrial fibrillation, cardiac surgery, ambulance use, coronary care unit, hospital teaching status, and JCS BCC/50 CV beds. Stepwise analysis includes age (per 10 years), gender, Charlson comorbidity index, Killip classification, hypertension, hyperlipidemia, diabetes, CKD, atrial fibrillation, and ambulance use. AOR, adjusted OR. Other abbreviations as in Tables 1,2.

Patient Characteristics and AMI Severity

To investigate whether AMI severity affects the association between the number of BCC/50 cardiovascular beds and 30-day mortality, we performed a stratified analysis according to AMI severity. Similar tendencies were observed in both the not-severe and severe groups. The number of patients and the use of circulation devices increased as the number of BCC/50 cardiovascular beds increased, whereas patient characteristics and medication remained almost unchanged. The length of hospital stay and the crude 30-day mortality decreased as the number of BCC/50 cardiovascular beds increased (**Table 4**).

Table 4. Patient Characteristics vs. AMI Severity and Cardiologist Tertile

	Not-severe					Severe				
	Total	First tertile	Second tertile	Third tertile	P-value	Total	First tertile	Second tertile	Third tertile	P-value
JCS BCC/50 CV beds (range)	0.63–75.58	0.63–6.58	6.63–10.98	11.05–75.58		0.63–75.58	0.63–6.58	6.63–10.98	11.05–75.58	
Patients	48,857 (100)	8,938 (18)	18,172 (37)	21,747 (45)		14,746 (100)	3,064 (21)	5,758 (39)	5,924 (40)	
Age (years)	68±13	69±13	68±13	67±13	<0.001*	72±13	74±13	73±13	72±13	<0.001*
Male	75	73	74	75	<0.001‡	68	66	68	70	<0.001‡
Charlson comorbidity index	2 (1–3)	2 (1–3)	2 (1–2)	2 (1–3)	<0.001†	2 (1–3)	2 (1–3)	2 (1–3)	2 (1–3)	<0.001†
Comorbidities										
Hypertension	68	67	67	69	<0.001‡	43	42	43	45	<0.001‡
Diabetes mellitus	29	30	29	30	<0.001‡	26	28	25	27	<0.001‡
Dyslipidemia	63	62	61	68	<0.001‡	34	33	34	35	0.077‡
CKD	3.5	2.9	3.4	3.7	<0.001‡	6.5	5.7	6	7.4	<0.001‡
Atrial fibrillation	4.8	5.5	5	4.5	<0.001‡	5.7	5.9	5.8	5.4	<0.001‡
Ambulance use	61	56	61	62	<0.001‡	75	70	74	78	<0.001‡
Medication										
ACEI or ARB	87	86	87	88	<0.001‡	88	87	88	89	0.04‡
β-blockers	56	58	57	54	<0.001‡	68	68	69	66	<0.001‡
Antiplatelets	99	99	99	99	<0.001‡	97	96	97	98	<0.001‡
CCB	60	64	62	56	<0.001‡	72	73	73	71	0.08‡
Statins	91	90	91	92	<0.001‡	89	87	89	90	<0.001‡
Oral anti-diabetic drugs	61	64	62	59	<0.001‡	76	75	77	76	<0.001‡
Device										
IABP	8.9	6.6	9.2	9.6	<0.001‡	37	29	34	44	<0.001‡
PCPS	0.4	0.2	0.4	0.6	<0.001‡	8.3	5.2	7.1	11	<0.001‡
LVAD	0	0	0	0	<0.001‡	0.05	0	0.07	0.05	0.36‡
CRRT	0.7	0.6	0.6	0.8	0.05‡	2.6	1.9	2	3.6	<0.001‡
Respirator	7.7	7.2	7.5	8	0.05‡	50	47	47	54	<0.001‡
LOHS (days)	16 (10–19)	17 (11–21)	16 (10–19)	15 (9–17)	<0.001‡	20 (5–26)	22 (3–26)	19 (4–25)	21 (7–26)	<0.001‡

Data given as mean±SD, median (IQR), n (%) or (%). *ANOVA; †Kruskal-Wallis rank sum test; ‡χ^2 test with Bonferroni correction. Abbreviations as in Tables 1,2.

Prognosis and AMI Severity

In the not-severe group, the AOR for 30-day mortality was 0.87 (95% CI: 0.70–1.05, P=0.15) in the second tertile and 0.81 (95% CI: 0.67–0.97, P=0.02) in the third tertile, and an inverse trend for 30-day mortality was observed between the tertiles (trend test P<0.01). In the severe group, the AOR was 0.86 (95% CI: 0.71–1.03, P=0.10) in the second tertile and 0.71 (95% CI: 0.59–0.85, P<0.001) in the third tertile, and an inverse trend for 30-day mortality was observed between the tertiles (trend test P<0.01). No interaction effect between the number of BCC/50 cardiovascular beds and AMI severity was seen on interaction analysis (**Figure 2**; **Table 5**).

Discussion

In this study, we demonstrated that the number of BCC/50 cardiovascular beds is associated with 30-day in-hospital AMI mortality. In addition, after adjustment for patient and hospital baseline characteristics, we showed that the hospital 30-day mortality rate in the third tertile hospitals is significantly lower than that in the first tertile hospitals. Moreover, this tendency was independent of AMI severity.

The present results are generally consistent with previous studies. O'Neill et al compared 30-day mortality in acute coronary syndrome (ACS) patients between those admitted to non-cardiology services and those admitted to cardiology services. Patients with ACS who were admitted to cardiology services more commonly underwent cardiac catheterization and evidence-based pharmacotherapy and had a significantly lower 30-day mortality than those admitted to non-cardiology services.[14] Badheka et al found that a large operator volume is associated with reduced mortality in patients undergoing PCI.[15] Their study included angina pectoris and AMI,[15] whereas the present study focused on patients with AMI and investigated the number of cardiologists/50 cardiovascular beds, which in turn is considered new.

We infer that the decreased 30-day mortality with the increase in the number of BCC/50 cardiovascular beds could be attributed to the following: (1) increased annual number of coronary angiography, emergency PCI, and CABG per hospital; moreover, the use of circulation devices, such as IABP and PCPS, increased as the number of BCC/50 cardiovascular beds increased, which in turn suggests that the treatment options for AMI are wide and varied and AMI could be treated quickly; and (2) the total number of hospital beds was greater in hospitals with a large number

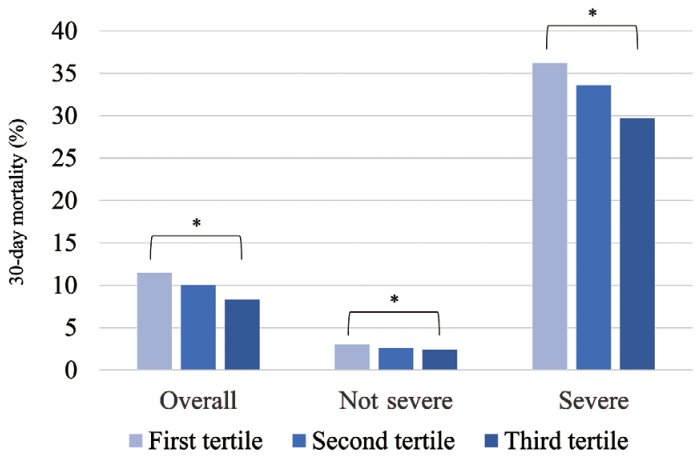

Figure 2. In-hospital 30-day mortality vs. severity of acute myocardial infarction and tertile of number of board-certified cardiologists/50 cardiovascular beds in Japan. *P<0.01.

Table 5. AOR and 95% CI for 30-Day Mortality vs. AMI Severity and Cardiologist Tertile

	No. JCS BCC/ 50 CV beds (range)	Not severe				Severe			
		n	AOR	95% CI	P-value	n	AOR	95% CI	P-value
First tertile	0.63–6.58	8,938	Ref.			3,064	Ref.		
Second tertile	6.63–10.98	18,172	0.87	0.70–1.05	0.15	5,758	0.86	0.71–1.03	0.10
Third tertile	11.05–75.58	21,747	0.81	0.67–0.97	0.02	5,924	0.71	0.59–0.85	<0.001

The model includes age (per 10 years), gender, Charlson comorbidity index, Killip classification, hypertension, hyperlipidemia, diabetes, CKD, atrial fibrillation, and ambulance use. Abbreviations as in Tables 1–3.

of BCC/50 cardiovascular beds than in those with a low number of BCC/50 cardiovascular beds, with the former having several medical staff working and sufficient facilities, and thus cardiologists would more likely receive the needed assistance and cooperation from other departments and medical staff when they encounter problems.

Improvement in the prognosis of AMI requires adherence to treatment guidelines.[16] Differences in the adherence to treatment guidelines for AMI between cardiologists and non-cardiologists exist.[17,18] In the present study, significant differences in the use of medications, such as angiotensin-converting enzyme inhibitors, angiotensin II receptor blocker, β-blockers, and antiplatelets, between tertiles were not found.

New approaches to further improve the acute outcome of AMI treatment are warranted. This study suggests that one of the methods to improve outcome in Japan is to transport patients with AMI to third tertile hospitals. Furthermore, increasing physician volume may be needed to improve treatment outcome.

Study Limitations

This study had several limitations. First, this was an observational study using the JROAD-DPC database, which included approximately 50% of JCS-certified hospitals and 29% of all hospital beds in Japan.[11] Second, the accuracy of the diagnoses and procedures in the DPC database is unclear. Third, the present study could not include some important confounding factors such as door-to-balloon time. Finally, we could not calculate the appropriate number of cardiologists to ensure the best outcome.

Conclusions

Patients with AMI who are admitted to hospitals with a large number of cardiologists/50 cardiovascular beds have a lower 30-day mortality rate. This tendency was independent of patient and hospital characteristics and AMI severity. This study is the first to provide new information about the relationship between the number of BCC and in-hospital AMI-related mortality in Japan.

Acknowledgment

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Disclosures

The authors declare no conflicts of interest.

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Supplementary Files

Supplementary File 1

Table S1. No. JCS BCC/50 CV beds and 30-day AMI mortality with PSM

Please find supplementary file(s);
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