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Practice Variation in Acute Heart Failure Among Hospitals –Influence of the Number of Cardiologists per Facility

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ABSTRACT

Objectives: Burden of acute heart failure (AHF) on healthcare systems are widely known to be increasing in developed countries, yet the impact of centralization of cardiovascular specialist care on the quality of AHF treatment remains unknown. Here, we examine the relationship between the number of cardiologists per hospital and hospital practice variations.

Design, setting and participants: In a retrospective observational study, we analysed 38,668 AHF patients admitted to 546 Japanese acute care hospitals between 2010 and 2011 using the Diagnosis Procedure Combination administrative claims database. Sample hospitals were categorized into four groups according to the number of cardiologists per facility (none, 1 to 4, 5 to 9, and ≥10). To confirm the capability of administrative data to identify AHF patients, the ≥10 cardiologists group was compared with two recent clinical registries in Japan.

Main outcome measures: Using multivariable logistic regression models, patient risk-adjusted in-hospital mortality rates and age-sex-adjusted odds ratios of various AHF therapies were calculated and compared among the four hospital groups.

Results: The ≥10 cardiologists group of hospitals from the administrative database had similar major underlying diseases incidence and therapeutic practices to those of the clinical registry hospitals. Age-sex-adjusted odds ratios of the various AHF therapies in the four hospital groups revealed wide practice variations associated with the number of cardiologists, which may also have affected patient outcomes such as in-hospital mortality. In addition, the different hospital-level distribution patterns of specific therapeutic practices illustrated the diffusion process of therapies across multiple facilities.

Conclusions: Wide practice variations in AHF care were observed to be associated with the number of cardiologists per facility, indicating that the quality of AHF care may be dependent on manpower resources. The provision of recommended therapies increased together with the number of cardiologists, and this relationship may influence outcomes such as patient mortality.

ARTICLE SUMMARY

Article focus

- This study investigates the effects of the number of cardiologists per hospital on processes of care (such as therapeutic interventions and medications) and patient outcomes (such as in-hospital mortality) using a large administrative claims database.

Key messages

- The capability of administrative data to identify AHF patients was confirmed by using two recent clinical registries in Japan.
- Greater use of recommended therapeutic processes of care, measured by sex-age-adjusted odds ratios, was associated with a higher number of cardiologists.
- Even after adjusting for disease severity factors, patients admitted to hospitals with fewer

cardiologists had a higher likelihood of in-hospital mortality.

- Three patterns of hospital distribution of specific therapeutic interventions can be used as a tool to understand the diffusion process of a new therapeutic practice.

Strengths and limitations of this study

- This study uses a large administrative database to provide novel insight into the practice variations in AHF care across Japanese hospitals categorized by the number of cardiologists.
- These findings can support improvements to hospital quality of care for AHF patients from the perspective of health policy.
- Generalizability of the conclusions outside of Japan may be limited due to possible different clinical circumstances across countries.

The high morbidity, mortality, and readmission rates in acute heart failure (AHF) patients have been widely acknowledged to result in an increased burden on healthcare systems, especially in developed countries with aging populations.[1,2] The impact of centralization of cardiovascular specialist care for AHF patients remains unknown, while preserving quality of care. Also the relation between hospital practice variations and the number of cardiologists is still unclear.

Currently, there are only a few clinical registries that have contributed descriptive analyses of AHF cases in Japan[3-6] including the Acute Decompensated Heart Failure Syndromes (ATTEND) registry[3,4] and the Japanese Cardiac Registry of Heart Failure in Cardiology (JCARE-CARD).[5,6] However, the hospitals included in these registries are likely to be biased toward bigger hospitals with larger number of cardiologists, which may not be representative of all AHF patients. Little information exists concerning the hospital management of AHF, based on analyses that encompass wide regions across Japan.

Recently, a code designating "acute exacerbation" of heart failure (HF), which was newly added in 2009 and unique to the Japanese Diagnosis Procedure Combination (DPC) patient case-mix classification system,[7] has enabled researchers to distinguish AHF from chronic heart failure. Yet the reliability of this extracted data for clinical or epidemiological analyses remains unclear because of the complexity of AHF itself.[2]

The objective of our study consisted of two steps. First, we examined whether demographics of AHF patients identified by administrative data using the new code are comparable with those from the aforementioned Japanese registries. These registries were deemed suitable for cross-reference because they were based on clinical data and their data collection period corresponded with that of our study. Second, in order to elucidate the effects of cardiologists on quality of care, we investigated AHF patient characteristics, therapeutic process of care, patient outcomes, and therapeutic practice patterns among hospital groups stratified by the number of cardiologists per facility.

METHODS

Data sources

Data for analysis were extracted from the DPC administrative database. In the DPC system, the code designating "acute exacerbation" of HF and the determination of the New York Heart Association (NYHA) functional class at admission are determined only by attending physicians, and not by other medical or administrative staff; this may provide face validity for the accuracy of these codes. Subsequently, the results of our sample using administrative data and the results of the ATTEND and the JCARE-CARD registries were compared.

The ATTEND registry included AHF patients from 2007 to 2011. This registry contained 4,842 patients from 53 hospitals; patients who met the modified Framingham criteria[8] were included, but those who had acute coronary syndromes were excluded.[3,4] A preliminary report based on 1,110 patients from 32 hospitals of the registry had been previously published,[3] and we utilized the results of both reports because we observed statistically significant differences in patient characteristics between the two.

The JCARE-CARD registry included patients hospitalized with worsening HF, identified using Framingham criteria. This study enrolled 2,675 patients from 164 hospitals between 2004 and 2005,[5,6] and analyzed patients with reduced and preserved ejection fraction (EF).[6]

Study population

AHF cases were identified using DPC administrative database between July 1, 2010 and March 31, 2011, using the patient selection and exclusion criteria documented in Suppl _Figure 1. Data at patient level were collected in relation with the context, use and coding of administrative data. Exclusion criteria for hospitals were also used, because these hospitals were assumed to provide less emergency care and thought to be unsuitable for comparisons with hospitals providing high-quality emergency care. As more than two-thirds of all 8,565 hospitals in Japan have fewer than 200 beds,[9] we took these factors into consideration in order to make valid comparison. The final sample size comprised 38,668 patients from 546 hospitals, ranging from 20 patients to 343 patients per hospital.

In order to perform valid comparisons between the sample hospitals with the clinical registries, our study sample was divided into four groups according to the number of registered cardiologists per hospital (no cardiologist; 1 to 4; 5 to 9; and ≥10 cardiologists); the ≥10 cardiologists group was compared with the registries, as hospitals in both these groups were likely to be similar in both hospital and patient characteristics, as well as medical practice patterns. Subsequently, patient characteristics, outcomes and therapeutic interventions among the four groups in our study sample were examined. To investigate the effects of cardiologist numbers on quality of hospital care, the age-sex-adjusted odds ratios (ORs) of specific clinical practices were calculated for each group, using the 1 to 4 cardiologists group as the reference.

Statistical Analysis

Means and standard deviations were calculated for continuous data, whereas categorical data were expressed as percentages. Comparisons between the ≥10 cardiologists group in our study sample and the registry groups were performed using the chi-squared tests for dichotomous variables.

Age-sex-adjusted ORs and 95% confidence intervals of specific clinical practices among the hospital groups stratified by the number of cardiologists per hospital were analyzed using multivariable logistic regression analyses. Risk-adjusted mortality rate was calculated as the ratio of observed mortality to predicted mortality, multiplied by the overall mean mortality rate of 7.0%. Predicted mortality of each patient was obtained using the predictive model that we had previously reported.[7] Independent variables in this model included 11 patient factors such as age, NYHA functional class, and comorbidities. Two-tailed P values below 0.05 were considered statistically significant. Statistical computations were performed using SPSS software, version 19.0J (SPSS Inc., Chicago, IL, USA).

Results

Baseline characteristics of the hospitals and AHF patients from the two clinical registries and from the study sample based on the administrative database are described in Table 1.[3-6] Our study sample consisted of hospitals from all 47 prefectures in Japan, varying in hospital bed size, case volume, teaching status, and ownership (public/private).

At the overall patient level, the mean age and the proportion of male patients in our sample were 78 years and 51%, respectively. Ischemic heart disease (IHD) was present in approximately 31%, similar to the registries. Observed in-hospital mortality rate was 7.0%, which was within the range reported in several recent AHF registries.[3, 4,10,11] Median LOS was similar to the ATTEND registry (18 and 21 days).

Table 1. Baseline characteristics of hospitals and AHF patients

Characteristics	Clinical Registries			Study Sample (Administrative Database) Hospital subgroups stratified by the number of cardiologists per facility				
	ATTEND Preliminary Report[3]	ATTEND[4]	JCARE-CARD[5,6]	≥10	5-9	1-4	0	Overall
Geographic region (number of prefectures)	20	24	47	27	45	45	22	47
Study duration, years	2.25	4.67	2.40	0.75	0.75	0.75	0.75	0.75
Institutional Level								
Number of hospitals	32	52	164	72	185	263	26	546
Hospital beds, mean (SD)	557(337)	564(332)	NA	712(264)	523(224)	364(154)	204(76)	456(234)
University hospitals, %	41	40.4	NA	63.9	13.0	4.9	0	15.6
Certified*training facilities, %	93.8	90.4	100	100.0	100.0	74.5	0.0	91.9
Number of cardiologists/facility, median	9.5	9	NA	13	6	3	0	4
Total patients	1,110	4,842	2,675	6,509	15,337	15,867	955	38,668
Case volume /year	-	-	-	8,679	20,449	21,556	1,273	51,557
Case volume/facility･year, mean(SD)	-	-	-	120.5(82.6)	110.5(52.1)	80.4(41.6)	49.0(21.1)	94.4(55.0)
Case volume /facility･year･cardiologist, mean(SD)	-	-	-	9.0(6.5)	17.2(7.9)	34.4(22.9)	-	24.8(19.9)
Patient Level								
Age, mean years (SD)	73(14)	73(14)	71(13)	75.3(12.9)	77.2(12.1)	78.9(11.6)	81.3(10.7)	77.7(12.1)
Male, %	59	58.0	60	57.2	51.7	49.1	44.0	51.4
NYHA functional class at admission, %	n=1,092†	n=4,699†	n=2,644†					
II	12.3	16.1	11.5	33.8	29.0	25.6	22.8	28.3
III	39.7	38.9	45.1	38.9	37.6	39.2	35.4	38.4
IV	48.0	45.0	43.4	27.3	33.4	35.2	41.8	33.3
Underlying diseases, %			n=1,692					
Ischemic heart disease	33‡	31.1‡	32.0	34.6	31.0	30.3	21.9	31.1
Atrial fibrillation/flutter	40	39.6	35.0	26.3	27.3	28.2	22.7	27.4
Hypertension	71	69.4	52.6	53.6	55.9	54.8	37.8	54.6
Diabetes mellitus	34	33.8	29.8	24.8	24.3	26.2	19.3	25.0
Previous history of stroke	12	14.0	14.7	4.3	5.3	7.1	7.7	5.9
Renal failure (mild to moderate)	NA	NA	11.7	9.6	10.4	10.8	10.2	10.4
COPD	9	9.5	6.5	5.3	6.6	6.9	5.0	6.5
Outcomes								
Mean (median) length of stay, days	31(21)	30(21)	35.6(NA) /31.2(NA)§	21.7(18.0)	21.7(17.0)	22.2(18.0)	22.9(17.0)	21.9(18.0)
Crude in-hospital mortality, %	7.7	6.4	3.9 / 6.5§	4.4	6.8	7.6	16.4	7.0

AHF, acute heart failure; SD, standard deviation; NA, not available; NYHA, New York Heart Association; COPD, Chronic obstructive pulmonary disease.

*Certified by the Japanese Circulation Society.

†Estimated case volumes were re-calculated.

†The number was re-calculated by subtracting original NYHA class I patients.

‡Without acute coronary syndromes.[3,4]

§Length of hospital stay with reduced left ventricular ejection fraction (EF) / preserved EF.[6]

Comparisons of patient characteristics and therapeutic practices between the administrative database and the two clinical registries

The median number of cardiologists and hospital beds, and the proportion of university hospitals in the ≥10 cardiologists group in our study sample were similar to those of the ATTEND registry (Table 1).

Details of therapeutic practices as process-of-care measures for hospitalized AHF patients are shown in Table 2. Data for these therapies were not available from the JCARE-CARD registry. Although many differences were statistically significant because of the large sample sizes, the proportions of nonpharmacologic interventions and intravenous medications were similar between the ≥10 cardiologists group and the ATTEND registry in many respects. However, the frequencies of percutaneous coronary intervention (PCI), coronary artery bypass grafting (CABG), intraaortic balloon pump (IABP) and pacemaker implantation (PMI) were much lower in our sample. The proportion of discharge medications was similar to that of the registries.

Comparisons among the four hospital groups from the administrative database stratified by the number of cardiologists

AHF case volume per hospital, the proportions of male patients, and underlying IHD were observed to decline together with the number of cardiologists (Table 1). In contrast, case

volume per cardiologist increased with decreasing cardiologist numbers. The ≥10 cardiologists group showed the highest proportion of university hospitals and patients with NYHA class II at admission among the four groups.

With regard to outcome measures, crude in-hospital mortality tended to increase in hospitals with fewer cardiologists, from 4.4% in the ≥10 cardiologists group to 16.4% in the group with no cardiologists. Even after adjusting for patient severity factors mentioned in our previous study,[7] higher likelihood of mortality was still observed in hospitals with fewer cardiologists, from 5.4% in the ≥ 10 cardiologists group to 10.7% in the group with no cardiologists (Figure 1).

All nonpharmacologic interventions during hospitalization showed reductions in relation to decreasing numbers of cardiologists. Also, major intravenous and discharge medications also tended to decline with decreasing numbers of cardiologists (Table 2).

When examining the effects of cardiologist numbers in processes of care such as therapeutic interventions, there were wide practice variations at the cardiologist-stratified hospital group level, as shown by the age-sex-adjusted ORs (Table 3). The group of hospitals with no cardiologists tended to show lower ORs for each therapeutic intervention. In contrast, groups with 5 to 9 and ≥10 cardiologists had generally higher ORs, especially in specific interventions or medications used to treat severe patients such as intubation, RHC, cardiac resynchronization therapy, implantable cardioverter-defibrillator, IABP and intravenous

carperitide use. Conventional care such as intravenous dopamine, intravenous digoxin, and digitalis at discharge were lower in the ≥ 10 cardiologists group, and nitrates and digitalis at discharge were higher in the group with no cardiologists.

In addition, wide therapeutic practice variations at the individual hospital level were observed among and within the four hospital groups. We found three distinct hospital distribution patterns for specific therapeutic interventions (Figure 2). These patterns were (i) a convex inclination pattern representing commonly used therapies for AHF such as intravenous diuretics (A), angiotensin-converting enzyme inhibitors/angiotensin-receptor blockers (ACEI/ARBs) and warfarins; (ii) a concave inclination pattern representing less commonly-used therapies such as intravenous dobutamine (C), intubation, PCI, and oral inotropic agents; and (iii) an inclination with an intermediate gradient or a combination of the former two patterns representing an intermediate distribution stage of specific therapy use such as intravenous carperitide (B), heparin and beta-blockers at discharge.

Table 2. Clinical practices in AHF patients

Therapeutic Interventions	Clinical Registries			Study Sample (Administrative Database) Hospital subgroups stratified by the number of cardiologists per facility				
	ATTEND Preliminary Report[3]	ATTEND[4]	JCARE-CARD[5,6]	≥10	5-9	1-4	0	Overall
(%)	n=1,110	n=4,842	n=1,613	n=6,509	n=15,337	n=15,867	n=955	n=38,668
Nonpharmacologic interventions		(n=4,842)						
Intubation	11.1	7.5	-	12.2	9.9	8.4	6.1	9.6
Right heart catheterization	20.1	16.7	-	17.6	12.9	9.0	2.2	11.7
Percutaneous coronary intervention	9.6	8	-	4.3	3.4	3.2	0.4	3.4
Coronary artery bypass grafting	1.4	1.3	-	0.3	0.1	0.1	-	0.1
Pacemaker	4.7	3.8	-	1.5	1.0	1.1	0.6	1.1
Cardiac resynchronization therapy(CRT or CRT-D)	2.4	2.3	-	1.7	0.7	0.2	-	0.6
Implantable cardioverter-defibrillator	2.6	2.6	-	0.3	0.1	0.1	-	0.1
Intraaortic balloon pump	3.6	2.5	-	0.9	0.7	0.4	0.1	0.6
Percutaneous cardiopulmonary support	0.6	0.7	-	0.4	0.3	0.1	-	0.2
Intravenous medications		(n=4,842)						
Diuretics	80.4	76.3	-	72.3	76.4	75.6	70.9	75.2
Carperitide	69.4	58.2	-	59.0	49.3	41.0	19.1	46.8
Heparin	NA	NA	-	60.1	54.7	44.8	25.7	50.8
Isosorbide dinitrate (ISDN)	9.2	14.5	-	25.8	21.2	18.2	8.3	20.4
Nitroglycerin (NTG)	26.0	20.8	-	16.9	16.3	12.4	9.1	14.6
ISDN or NTG	NA	NA	-	36.8	32.6	27.6	15.9	30.8
Nicorandil	10.6	9.6	-	6.4	5.2	4.3	0.8	4.9
Inotropes								
Dobutamine	12.7	11.3	-	13.1	12.7	8.8	6.0	11.0
Dopamine	11.0	8.8	-	9.9	14.3	13.4	10.9	13.1
Norepinephrine	6.2	4.7	-	6.8	5.9	4.7	4.8	5.5
Milrinone	2.8	3.3	-	2.3	2.3	2.4	0.8	2.3
Olprinone	0.7	0.8	-	1.5	0.6	0.7	0.3	0.8
Digoxin	6.5	6.9	-	6.6	8.1	7.6	7.6	7.7
Calcium-channel blocker	8.2	NA	-	8.5	5.4	3.9	2.6	5.2
Discharge medications		(n=4,530)						
Diuretics	84.5	82.3	87.0	72.0	72.2	69.3	63.7	70.8
ACEIs	26.3	30.6	38.7	23.3	19.2	18.7	8.8	19.4
ARBs	54.5	46.0	46.4	35.2	33.9	31.0	24.6	32.7
ACEIs or ARBs	78.0	74.7	79.1	57.1	51.6	48.1	32.9	50.6
Aldosterone receptor blockers	49.0	43.0*	42.2*	42.6	38.7	34.9	24.6	37.4
Digitalis	27.2	14.7	27.2	11.2	13.2	12.6	14.6	12.7
Beta-blockers	63.6	67.4	57.5	52.3	43.7	36.9	20.9	41.8
Nitrates	25.5	22.4	23.0	14.4	14.4	15.1	20.0	14.8
Calcium channel blockers	29.1	26.8	25.4	23.0	23.3	21.1	19.9	22.3
Statins	37.3	35.6	21.0	26.9	23.6	19.4	10.4	22.1
Warfarin	40.9	43.2	39.8	39.2	34.6	30.3	21.8	33.3
Antiplatelets	51.8†	46.0†	48.4†	40.5	36.8	34.0	22.8	35.9
Oral inotropic agents	6.6‡	5.2‡	NA	7.1	6.5	5.6	3.4	6.2

AHF, acute heart failure; CRT-D, cardiac resynchronization therapy with defibrillator; ACEIs, angiotensin-converting enzyme inhibitors; ARBs, angiotensin-receptor blockers; NA, not available.

The proportions of discharge medication in ATTEND registry were estimated based on reported figures.[3,4]

Only spironolactone,[*] aspirin, [†] and pimobendan [‡] were included.

Table 3. Adjusted odds ratios (95%CIs) of clinical practices in patients with AHF

Variables	Study Sample (Administrative Database) Hospital subgroups by the number of cardiologists			
	≥10	5-9	1-4	0
(%)	n=6,509	n=15,337	n=15,867	n=955
In-hospital managements				
Nonpharmacologic interventions				
Intubation	1.43 (1.30-1.57)	1.16 (1.07-1.25)	ref	0.74 (0.56-0.97)
Right heart catheterization	1.84 (1.69-2.01)	1.34 (1.25-1.45)	ref	0.26 (0.17-0.40)
Percutaneous coronary intervention	1.23 (1.06-1.43)	1.02 (0.90-1.16)	ref	0.14 (0.05-0.38)
Pacemaker	1.47 (1.15-1.89)	0.94 (0.76-1.17)	ref	0.55 (0.24-1.24)
Implantable cardioverter-defibrillator (ICD)	5.19 (2.31-11.69)	2.48 (1.10-5.57)	ref	-
Cardiac resynchronization therapy (CRT or CRT-D)	8.98 (5.81-13.89)	4.08 (2.64-6.31)	ref	-
Coronary artery bypass grafting	4.95 (2.28-10.79)	1.98 (0.89-4.37)	ref	-
Intraaortic balloon pump	1.96 (1.36-2.82)	1.57 (1.14-2.17)	ref	0.33 (0.05-2.36)
Percutaneous cardiopulmonary support	2.47 (1.41-4.31)	1.62 (0.97-2.72)	ref	-
Intravenous drugs				
Diuretics	0.87 (0.82-0.93)	1.06 (1.01-1.12)	ref	0.76 (0.66-0.88)
Carperitide	2.02 (1.91-2.15)	1.39 (1.33-1.45)	ref	0.35 (0.29-0.41)
Heparin	1.73 (1.63-1.84)	1.44 (1.38-1.51)	ref	0.45 (0.39-0.52)
ISDN or NTG	1.41 (1.32-1.50)	1.22 (1.16-1.28)	ref	0.53 (0.44-0.63)
Nicorandil	1.47 (1.30-1.67)	1.20 (1.08-1.34)	ref	0.20 (0.10-0.40)
Inotropes				
Dobutamine	1.49 (1.36-1.63)	1.48 (1.37-1.59)	ref	0.69 (0.52-0.90)
Dopamine	0.71 (0.65-0.78)	1.08 (1.01-1.15)	ref	0.79 (0.64-0.98)
Norepinephrine	1.41 (1.25-1.59)	1.24 (1.12-1.37)	ref	1.09 (0.80-1.48)
Milrinone	0.87 (0.72-1.06)	0.91 (0.79-1.05)	ref	0.36 (0.18-0.74)
Olprinone	1.89 (1.43-2.50)	0.82 (0.62-1.09)	ref	0.50 (0.16-1.58)
Digoxin	0.85 (0.75-0.95)	1.06 (0.98-1.15)	ref	1.01 (0.79-1.29)
Calcium-channel blocker	2.21 (1.96-2.49)	1.39 (1.25-1.55)	ref	0.68 (0.46-1.02)
Discharge medications				
Diuretics	1.51 (1.37-1.66)	1.14 (1.07-1.22)	ref	0.63 (0.53-0.74)
ACEIs	1.24 (1.16-1.33)	1.00 (0.95-1.06)	ref	0.44 (0.35-0.55)
ARBs	1.16 (1.09-1.23)	1.12 (1.06-1.17)	ref	0.75 (0.65-0.87)
ACEI or ARBs	1.35 (1.27-1.43)	1.11 (1.06-1.16)	ref	0.56 (0.48-0.64)
Aldosterone receptor blockers	1.30 (1.23-1.38)	1.15 (1.09-1.20)	ref	0.64 (0.55-0.74)
Digitalis	0.84 (0.77-0.92)	1.03 (0.96-1.10)	ref	1.23 (1.02-1.48)
Beta-blockers	1.68 (1.58-1.78)	1.26 (1.20-1.32)	ref	0.49 (0.42-0.58)
Nitrates	0.99 (0.91-1.07)	0.97 (0.91-1.03)	ref	1.37 (1.16-1.62)
Calcium channel blockers	1.13 (1.05-1.21)	1.14 (1.08-1.20)	ref	0.93(0.79-1.09)
Statins	1.40 (1.31-1.50)	1.23 (1.16-1.29)	ref	0.52(0.42-0.64)
Warfarin	1.35 (1.27-1.44)	1.16 (1.11-1.22)	ref	0.70(0.59-0.82)
Antiplatelets	1.29 (1.22-1.38)	1.12 (1.07-1.18)	ref	0.59(0.50-0.68)
Oral inotropic agents	1.19 (1.06-1.34)	1.13 (1.03-1.24)	ref	0.61(0.43-0.88)

CI, confidence interval; CRT-D, cardiac resynchronization therapy defibrillator; ISDN, Isosorbide dinitrate; NTG, nitrogrycelin; ACEIs, angiotensin-converting enzyme inhibitors; ARBs, angiotensin-receptor blockers; ref, reference.

The odds ratios were adjusted for sex and age-group (< 60, ≥ 60, ≥ 70, ≥ 80, and ≥ 90 years) using multivariable regression analyses.

DISCUSSION

In this study, we confirmed the compatibility of administrative data to properly identify hospitalized AHF patients by cross-referencing the results from recent clinical registries, and further revealed wide practice variations in AHF care among hospitals in association with the number of cardiologists per facility.

Major underlying diseases, major therapeutic interventions and proportions of discharge medications showed approximate similarities between the ≥10 cardiologists group and the clinical registries. These general similarities indicate that our study sample is comparable with the cohorts from the clinical registries. The results were consistent with a prior study that compared CABG cases between administrative data and registry data, which demonstrated that major comorbidities were similarly prevalent between the two datasets.[12] Because several disparities were also detected among the three cohorts of the clinical registries, the differences between our sample and the clinical registries appeared to be acceptable. Although the definition and diagnosis of AHF are widely known to be complex even in daily clinical practice,[2] AHF patients were considered to be successfully identified with the code indicating acute exacerbation of HF.

However, the possible causes of the differences observed between our sample and the clinical registries are considered as follows: first, there may be a difference in the types of patients between the two datasets. For example, the higher proportion of NYHA class II at

admission in the ≥10 cardiologists group than in the registries, may largely stem from the fundamental differences in the inclusion criteria of AHF; the clinically-based Framingham criteria may be stricter and include more severe patients when compared with more subjective decision of the attending physicians.

Second, although a clinical registry database may be thought to be the "gold standard" for many epidemiological studies, these registries tend to be heavily represented by large medical centers. This can result in some selection bias, as large medical centers generally treat more difficult and unusual cases associated with higher mortality or requirements for intensive care. Because approximately 74% of acute care hospitals have fewer than 300 hospital beds in Japan,[9] it is crucial to utilize administrative data to shed light on the quality of care provided in hospitals groups that include smaller hospitals. In consideration of the large number of hospitals and patients included, administrative data is likely to exhibit more diverse patients from various hospitals, and may be suitable to describe inter-hospital differences of quality in provided care. In addition, the low proportion of major intensive procedures (such as PCI, CABG and PMI) in the administrative data may be due to the payment system that makes physicians to record the primary diagnoses (such as angina or arrhythmia) directly related to the procedures other than AHF.

Next, greater use of recommended therapeutic processes of care, measured by sex-age-adjusted ORs, was observed to be associated with a higher number of cardiologists. When

compared with the 1 to 4 cardiologists group, hospitals with no cardiologists were less likely to provide these treatments, whereas the 5 to 9 cardiologists group and the ≥10 cardiologists group were more likely to provide specialty procedures or new drugs, and less likely to provide conventional drugs (e.g., intravenous dopamine or digoxin, digitalis at discharge). Furthermore, the outcome measure of patient risk-adjusted mortality also decreased with increasing numbers of cardiologists. These results support those of prior studies where the case volume was shown to be associated with better care processes and outcomes in congestive heart failure patients,[13] and high physician volume, especially with cardiologists, was shown to be associated with lower mortality rates.[14]

Additionally, our results showed that lower case volume per cardiologist was related with lower adjusted mortality. The result initially seemed to be contrary to the frequently reported relationship between case volume and outcomes per specialist in major surgeries and cardiovascular interventions.[15,16] These previous studies have used hospital case volume or case volume per physician as a measure of experience with managing diseases. However, the total number of cardiologists per hospital may be better suited to describe the quality of care in specific diseases that require teams of specialists. Our findings both here and in a previous study[17] are therefore not necessarily contradictory to these prior reports.[15,16] Moreover, the quality of care shown by the total number of cardiologists may expand the contents of new draft guidelines from National Institute for Health and Care Excellence (NICE)[18], in which

AHF patients are recommended to be seen by specialist teams.[19]

The number of cardiologists is very important in medical emergencies such as AHF or AMI which require immediate intervention and the integrated teamwork of cardiovascular specialists and medical staff with 24-hour coverage. The results from our study may lead to the concept of "resource dependency" as a source of practice variation. This type of care may be considered to be directly affected by the presence and quantity of resources available, and is distinct from individual physicians' skill or experience. Resource dependency can well explain practice variations before supplier-inducement or patient preferences can influence variations. In other words, the availability of manpower resources may affect the quality of care, leading to practice variations among hospitals.

Finally, we found that the three hospital distribution patterns for specific interventions can be used as a tool to capture diffusion process of a new therapeutic practice. The concept of individual hospital distribution patterns related to the proportion of therapeutic intervention can be illustrated as Suppl_Figure 2. Therapies that are not widely used may show the concave distribution pattern (type C) at first, and would shift from types C to B, finally to type A, when they gradually become more familiar and widespread.

By referring to these three distribution patterns during analyses of cross-sectional data, we may discern how much and how widely a certain therapy is currently adopted among hospitals at a particular time. For example, intravenous carperitide, a recombinant form of atrial natriuretic peptide, which exhibited the intermediate-distribution-stage pattern has been believed to expand in daily practice in Japan,[3,4] yet the characteristics of hospitals that had used this drug remained unclear. Interestingly, the results from our study revealed that the drug had been much less used among hospitals with fewer cardiologists when compared with the ATTEND registry, which included hospitals with larger number of cardiologists. In the context of widely known "innovation diffusion theories",[20, 21] this intermediate-distribution-stage pattern may represent a snapshot of the diffusion process of a new therapeutic practice across multiple facilities over time. Furthermore, these results may be utilized to improve currently provided care from the viewpoint of practice guideline adherence or policymaking perspectives.

Study Limitations

There are several limitations in this study. First, hospitals in this study are restricted to some part of those who actively adopt the DPC system. In addition, the clinical circumstances including the use of drugs may differ across the countries. These may limit the generalizability of our results in worldwide clinical settings. Second, when adjusting outcome measures, we did not consider hospital-level factors such as teaching status, urban location, and the presence of a cardiac intensive care unit, which may also have affected the quality of care. Finally, we could not identify the number of cardiologists who were actually treating

AHF patients, differences in competency among individual cardiologists, and the area of cardiovascular subspecialty of each cardiologist. Further studies are required to examine the effect of these issues on quality of care.

CONCLUSIONS

We revealed wide therapeutic practice variations of AHF in association with the number of cardiologists per facility using an administrative database. Recommended therapeutic practices tended to be provided more frequently in hospitals with more cardiologists. Quality of AHF care may be dependent on manpower resources and may influence outcomes such as risk-adjusted mortality.

Contributors NS and YI had full access to all the data in the study and take responsibility for the analysis and interpretation. Conception and design:NS,YY,YI; acquisition of data:NS,HI,KF,YI; analysis and interpretation of data:NS,SK,HI,YI; drafting of the manuscript:NS,YI; statistical analysis:NS,SK,HI,YI; obtaining funding:KF,YI. All the authors were involved in critical revisions and approving the final manuscript for publication.

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Ethics approval This study was approved by the Ethics Committee of Kyoto University Graduate School and Faculty of Medicine, Japan.

Provenance and peer review Not commissioned; externally peer reviewed.

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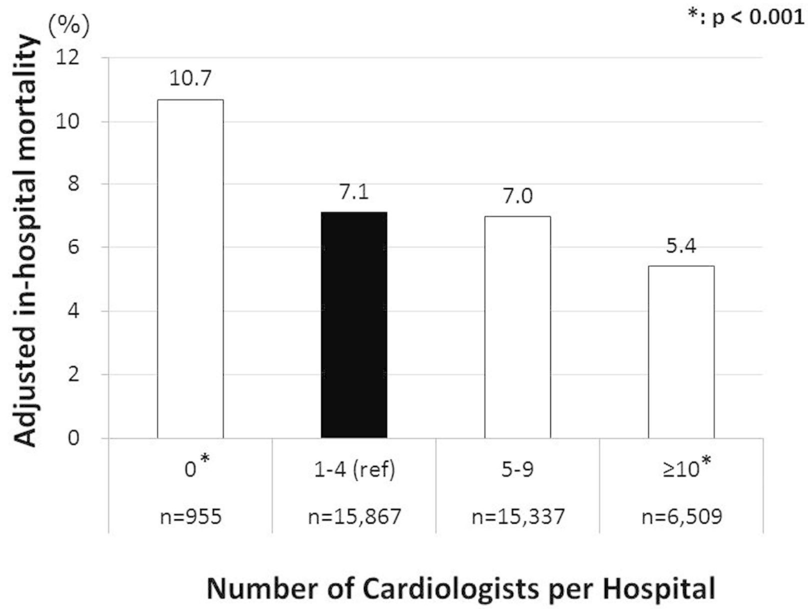
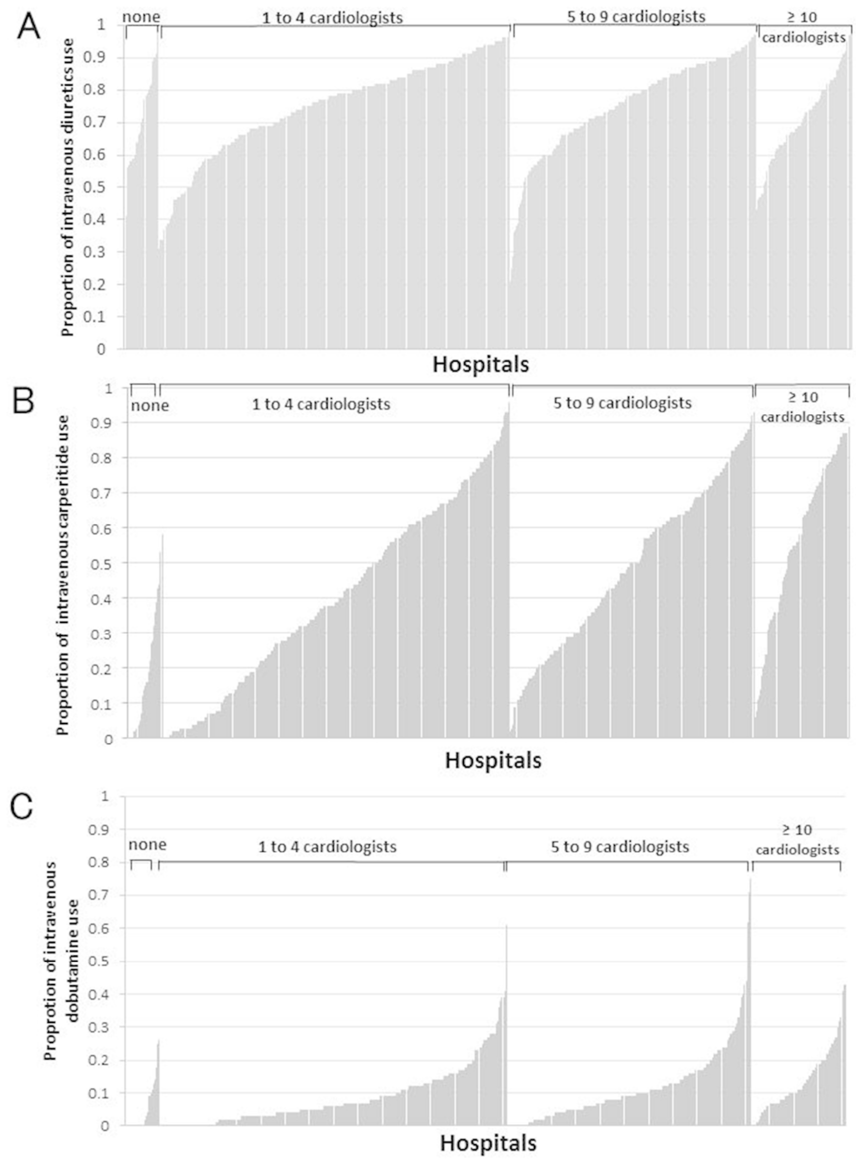


Adjusted in-hospital mortality in AHF stratified by the number of cardiologists per hospital.
254x190mm (300 x 300 DPI)



Hospital distribution patterns for specific practices, categorized by the number of cardiologists.
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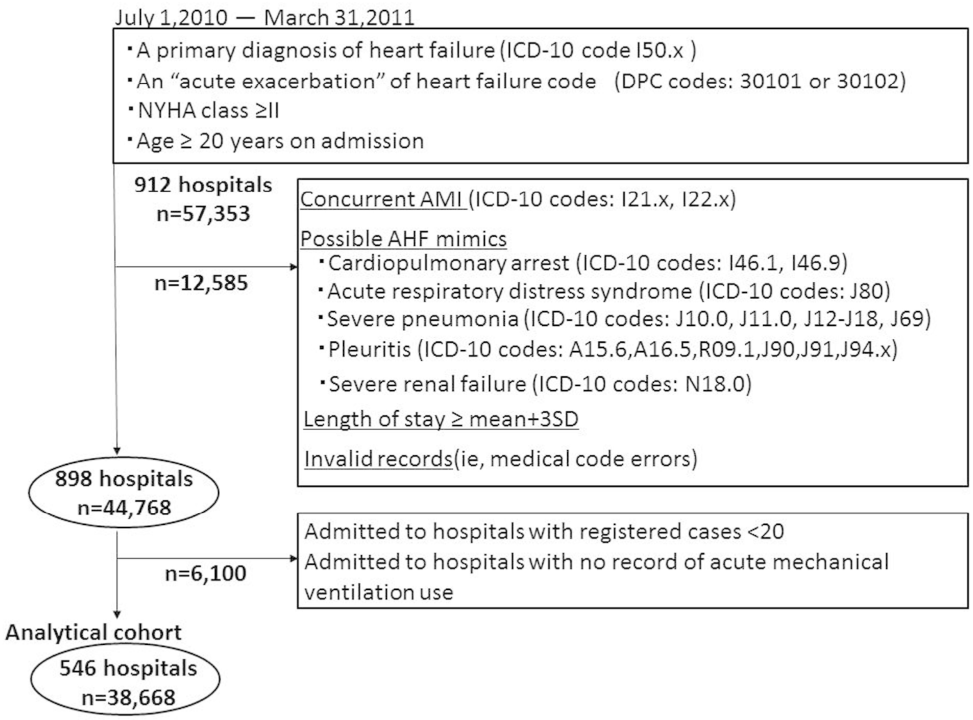
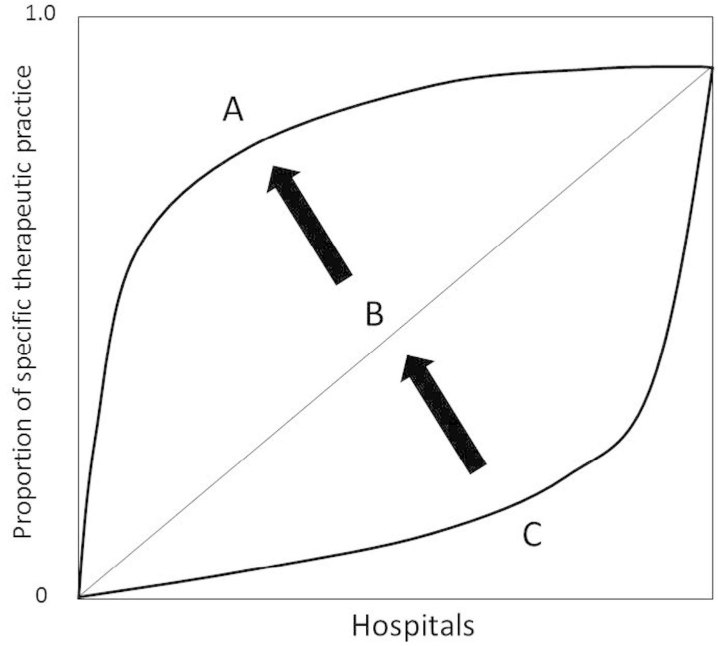


Diagram showing patient selection.
ICD-10, International Classification of Disease, 10th version; DPC, Diagnosis Procedure Combination; NYHA, New York Heart Association; AMI, acute myocardial infarction; SD, standard deviation.
254x190mm (300 x 300 DPI)



A conceptual diagram of clinical practice diffusion.
254x190mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	✔	Recommendation
Title and abstract	1	✔	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		✔	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction			
Background/rationale	2	✔	Explain the scientific background and rationale for the investigation being reported
Objectives	3	✔	State specific objectives, including any prespecified hypotheses
Methods			
Study design	4	✔	Present key elements of study design early in the paper
Setting	5	✔	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	-	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		-	*Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls
		✔	*Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		-	(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed
		-	*Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	✔	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	✔	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	✔	Describe any efforts to address potential sources of bias
Study size	10	✔	Explain how the study size was arrived at
Quantitative variables	11	✔	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	✔	(*a*) Describe all statistical methods, including those used to control for confounding
		✔	(*b*) Describe any methods used to examine subgroups and interactions
		✔	(*c*) Explain how missing data were addressed
		-	(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed
		-	*Case-control study*—If applicable, explain how matching of cases and controls was addressed
		-	*Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		-	(*e*) Describe any sensitivity analyses

Continued on next page

Results			
Participants	13*	✔	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		✔	(b) Give reasons for non-participation at each stage
		✔	(c) Consider use of a flow diagram
Descriptive data	14*	✔	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		-	(b) Indicate number of participants with missing data for each variable of interest
		-	(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	-	*Cohort study*—Report numbers of outcome events or summary measures over time
		-	*Case-control study*—Report numbers in each exposure category, or summary measures of exposure
		✔	*Cross-sectional study*—Report numbers of outcome events or summary measures
Main results	16	✔	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		✔	(*b*) Report category boundaries when continuous variables were categorized
		-	(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	✔	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion			
Key results	18	✔	Summarise key results with reference to study objectives
Limitations	19	✔	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	✔	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	✔	Discuss the generalisability (external validity) of the study results
Other information			
Funding	22	✔	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The Relationship between the Number of Cardiologists and Clinical Practice Patterns in Acute Heart Failure — A Cross-sectional Observational Study

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ABSTRACT

Objectives: Despite the increasing burden of acute heart failure (AHF) on healthcare systems, the association between centralized cardiovascular specialist care and the quality of AHF care remains unknown. Here, we examine the relationship between the number of cardiologists per hospital and hospital practice variations.

Design, setting and participants: In a retrospective observational study, we analysed 38,668 AHF patients admitted to 546 Japanese acute care hospitals between 2010 and 2011 using the Diagnosis Procedure Combination administrative claims database. Sample hospitals were categorized into four groups according to the number of cardiologists per facility (none, 1 to 4, 5 to 9, and ≥10). To confirm the capability of administrative data to identify AHF patients, the ≥10 cardiologists group was compared with two recent clinical registries in Japan.

Main outcome measures: Using multivariable logistic regression models, patient risk-adjusted in-hospital mortality rates and age-sex-adjusted odds ratios of various AHF therapies were calculated and compared among the four hospital groups.

Results: The ≥10 cardiologists group of hospitals from the administrative database had similar major underlying disease incidence and therapeutic practices to those of the clinical registry hospitals. Age-sex-adjusted odds ratios of the various AHF therapies in the four hospital groups revealed wide practice variations associated with the number of cardiologists. Adjusted in-hospital mortality demonstrated a negative association with the number of

cardiologists. In addition, the different hospital-level distribution patterns of specific therapeutic practices illustrated the diffusion process of therapies across facilities.

Conclusions: Wide practice variations in AHF care were associated with the number of cardiologists per facility, indicating a possible relationship between the quality of AHF care and manpower resources. The provision of recommended therapies increased together with the number of cardiologists.

ARTICLE SUMMARY

Article focus

- This study investigates the relationship between the number of cardiologists per hospital and processes of care (such as therapeutic interventions and medications) using a large administrative claims database.

Key messages

- The capability of administrative data to identify AHF patients was confirmed using two recent clinical registries in Japan.
- Greater use of recommended therapeutic processes of care, measured by sex-age-adjusted odds ratios, was associated with a higher number of cardiologists.
- Even after adjusting for disease severity factors, patients admitted to hospitals with fewer cardiologists had a higher likelihood of in-hospital mortality.

- Three patterns of hospital distribution of specific therapeutic interventions were discovered, and may shed light on the diffusion process of new therapeutic practices.

Strengths and limitations of this study

- This study uses a large administrative database to provide novel insight into the practice variations in AHF care across Japanese hospitals categorized by the number of cardiologists.
- These findings can support improvements to hospital quality of care for AHF patients from the perspective of health policy.
- Generalizability of the conclusions outside of Japan may be limited due to different clinical circumstances across countries.

The high morbidity, mortality, and readmission rates in acute heart failure (AHF) patients place a heavy burden on healthcare systems, especially in developed countries with aging populations.[1,2] The association between centralized cardiovascular specialist care and the quality of AHF care remains unknown. Also the relation between hospital practice variations and the number of cardiologists is still unclear.

Currently, there are only a few clinical registries that have contributed descriptive analyses of AHF cases in Japan[3-6] including the Acute Decompensated Heart Failure Syndromes (ATTEND) registry[3,4] and the Japanese Cardiac Registry of Heart Failure in Cardiology (JCARE-CARD).[5,6] However, the hospitals included in these registries are likely to be biased toward bigger hospitals with larger number of cardiologists, which may not be representative of all AHF patients. Little information exists concerning the hospital management of AHF, based on analyses that encompass wide regions across Japan.

Recently, a code designating “acute exacerbation” of heart failure (HF), which was newly added in 2009 and unique to the Japanese Diagnosis Procedure Combination (DPC) patient case-mix classification system,[7,8] has enabled researchers to distinguish AHF from chronic HF. Yet the reliability of this extracted data for clinical or epidemiological analyses remains unclear because of the complexity of AHF itself.[2]

The objective of our study consisted of two steps. First, we examined whether demographics of AHF patients identified by administrative data using the new code are comparable with those from the aforementioned Japanese registries. These registries were deemed suitable for cross-reference because they were based on clinical data and their data collection period corresponded with that of our study. Second, in order to elucidate the relationship between cardiologists and quality of care, we investigated AHF patient characteristics, therapeutic process of care, patient outcomes, and therapeutic practice patterns among hospital groups stratified by the number of cardiologists per facility.

METHODS

Data sources

Data for analysis were extracted from the DPC administrative database,[7,8] which contains inpatient information such as patient case-mix, processes of care, medical charges, and patient outcomes including mortality. In the DPC system, the code designating "acute exacerbation" of HF and the determination of the New York Heart Association (NYHA) functional class at admission are determined only by attending physicians, and not by other medical or administrative staff; this may provide face validity for the accuracy of these codes. Subsequently, the results of our sample using administrative data and the results of the ATTEND and the JCARE-CARD registries were compared.

The ATTEND registry included AHF patients from 2007 to 2011. This registry contained 4,842 patients from 53 hospitals; patients who met the modified Framingham criteria[9] were included, but those who had acute coronary syndromes were excluded.[3,4] A preliminary report based on 1,110 patients from 32 hospitals of the registry had been previously published,[3] and we utilized the results of both reports because we observed statistically significant differences in patient characteristics between the two.

The JCARE-CARD registry included patients hospitalized with worsening HF, identified using Framingham criteria. This study enrolled 2,675 patients from 164 hospitals between 2004 and 2005,[5,6] and analyzed patients with reduced and preserved ejection fraction (EF).[6] The number of cardiologists per hospital was obtained from the Japanese Circulation Society (JCS) website,[10] which gives detailed information on JCS-certified cardiologists.

Study population

Using the DPC administrative database, we identified a total of 57,353 AHF cases who had been admitted to 912 hospitals between July 1, 2010 and March 31, 2011. The selection criteria were i) a primary diagnosis of heart failure (ICD-10 code I50.x), ii) a DPC system code designating an “acute exacerbation” of heart failure, iii) NYHA functional class II or higher, and iv) older than 20 years of age. The exclusion criteria are described in Supplementary Figure 1. Data at patient level were collected in relation with the context, use and coding of administrative data. Exclusion criteria for hospitals were also used, because these hospitals were assumed to provide less emergency care and thought to be unsuitable for comparisons with hospitals providing high-quality emergency care. As more than two-thirds of all 8,565 hospitals in Japan have fewer than 200 beds,[11] we took these factors into consideration in order to make valid comparison. The final sample size comprised 38,668 patients from 546 hospitals, ranging from 20 patients to 343 patients per hospital.

In order to perform valid comparisons between the sample hospitals with the clinical registries, our study sample was divided into four groups according to the number of registered cardiologists per hospital (no cardiologist; 1 to 4; 5 to 9; and ≥10 cardiologists); the ≥10 cardiologists group was compared with the registries, as hospitals in both these groups were likely to be similar in both hospital and patient characteristics, as well as medical practice patterns. Subsequently, patient characteristics, outcomes and therapeutic interventions among the four groups in our study sample were examined. To investigate the relationship between cardiologist numbers and quality of hospital care, the age-sex-adjusted odds ratios (ORs) of specific clinical practices were calculated for each group, using the 1 to 4 cardiologists group as the reference.

Statistical Analysis

Means and standard deviations were calculated for continuous data, whereas categorical data were expressed as percentages. Comparisons between the ≥10 cardiologists group in our study sample and the registry groups were performed using the chi-squared tests for dichotomous variables.

Age-sex-adjusted ORs and 95% confidence intervals of specific clinical practices among the hospital groups stratified by the number of cardiologists per hospital were analyzed using multivariable logistic regression analyses. Risk-adjusted mortality rate was calculated as the ratio of observed mortality to predicted mortality, multiplied by the overall mean mortality rate of 7.0%. Predicted mortality of each patient was obtained using the predictive model that we had previously reported.[7] Independent variables in this model included 11 patient factors such as age, NYHA functional class, and comorbidities. Two-tailed P values below 0.05 were considered statistically significant. Statistical computations were performed using SPSS software, version 19.0J (SPSS Inc., Chicago, IL, USA).

Results

Baseline characteristics of the hospitals and AHF patients from the two clinical registries and from the study sample based on the administrative database are described in Table 1.[3-6] Our study sample consisted of hospitals from all 47 prefectures in Japan, varying in hospital bed size, case volume, teaching status, and ownership (public/private).

At the overall patient level, the mean age and the proportion of male patients in our sample were 78 years and 51%, respectively. Ischemic heart disease (IHD) was present in approximately 31%, similar to the registries. Observed in-hospital mortality rate was 7.0%, which was within the range reported in several recent AHF registries.[3, 4,12,13] Median LOS was similar to the ATTEND registry (18 and 21 days).

Table 1. Baseline characteristics of hospitals and AHF patients

Characteristics	Clinical Registries			Study Sample (Administrative Database) Hospital subgroups stratified by the number of cardiologists per facility				
	ATTEND Preliminary Report[3]	ATTEND[4]	JCARE-CARD[5,6]	≥10	5-9	1-4	0	Overall
Geographic region (number of prefectures)	20	24	47	27	45	45	22	47
Study duration, years	2.25	4.67	2.40	0.75	0.75	0.75	0.75	0.75
Institutional Level								
Number of hospitals	32	52	164	72	185	263	26	546
Hospital beds, mean (SD)	557(337)	564(332)	NA	712(264)	523(224)	364(154)	204(76)	456(234)
University hospitals, %	41	40.4	NA	63.9	13.0	4.9	0	15.6
Certified*training facilities, %	93.8	90.4	100	100.0	100.0	74.5	0.0	91.9
Number of cardiologists*/facility, median	9.5	9	NA	13	6	3	0	4
Total patients	1,110	4,842	2,675	6,509	15,337	15,867	955	38,668
Case volume /year	-	-	-	8,679	20,449	21,556	1,273	51,557
Case volume/facility・year, mean(SD)	-	-	-	120.5(82.6)	110.5(52.1)	80.4(41.6)	49.0(21.1)	94.4(55.0)
Case volume /facility・year・cardiologist, mean(SD)	-	-	-	9.0(6.5)	17.2(7.9)	34.4(22.9)	-	24.8(19.9)
Patient Level								
Age, mean years (SD)	73(14)	73(14)	71(13)	75.3(12.9)	77.2(12.1)	78.9(11.6)	81.3(10.7)	77.7(12.1)
Male, %	59	58.0	60	57.2	51.7	49.1	44.0	51.4
NYHA functional class at admission, %	n=1,092[†]	n=4,699[†]	n=2,644[†]					
II	12.3	16.1	11.5	33.8	29.0	25.6	22.8	28.3
III	39.7	38.9	45.1	38.9	37.6	39.2	35.4	38.4
IV	48.0	45.0	43.4	27.3	33.4	35.2	41.8	33.3
Underlying diseases, %			n=1,692					
Ischemic heart disease	33[‡]	31.1[‡]	32.0	34.6	31.0	30.3	21.9	31.1
Atrial fibrillation/flutter	40	39.6	35.0	26.3	27.3	28.2	22.7	27.4
Cardiomyopathy	NA	12.7	26.2	8.8	7.1	5.5	2.5	6.6
Valvular heart disease	NA	19.4	NA	16.7	16.3	15.4	9.1	15.8
Hypertension	71	69.4	52.6	53.6	55.9	54.8	37.8	54.6
Diabetes mellitus	34	33.8	29.8	24.8	24.3	26.2	19.3	25.0
Previous history of stroke	12	14.0	14.7	4.3	5.3	7.1	7.7	5.9
Renal failure (mild to moderate)	NA	NA	11.7	9.6	10.4	10.8	10.2	10.4
COPD	9	9.5	6.5	5.3	6.6	6.9	5.0	6.5
Outcomes								
Mean (median) length of stay, days	31(21)	30(21)	35.6(NA) /31.2(NA)[§]	21.7(18.0)	21.7(17.0)	22.2(18.0)	22.9(17.0)	21.9(18.0)
Crude in-hospital mortality, %	7.7	6.4	3.9 / 6.5[§]	4.4	6.8	7.6	16.4	7.0

AHF, acute heart failure; SD, standard deviation; NA, not available; NYHA, New York Heart Association; COPD, Chronic obstructive pulmonary disease.

*Certified by the Japanese Circulation Society.

†Estimated case volumes were re-calculated.

†The number was re-calculated by subtracting original NYHA class I patients.

‡Without acute coronary syndromes.[3,4]

§Length of hospital stay with reduced left ventricular ejection fraction (EF) / preserved EF.[6]

Comparisons of patient characteristics and therapeutic practices between the administrative database and the two clinical registries

The median number of cardiologists and hospital beds, and the proportion of university hospitals in the ≥10 cardiologists group in our study sample were similar to those of the ATTEND registry (Table 1).

Details of therapeutic practices as process-of-care measures for hospitalized AHF patients are shown in Table 2. Data for these therapies were not available from the JCARE-CARD registry. Although many differences were statistically significant because of the large sample sizes, the proportions of nonpharmacologic interventions and intravenous medications were similar between the ≥10 cardiologists group and the ATTEND registry in many respects. However, the frequencies of percutaneous coronary intervention (PCI), coronary artery bypass grafting (CABG), intraaortic balloon pump (IABP) and pacemaker implantation (PMI) were much lower in our sample. The proportion of discharge medications was similar to that of the registries.

Comparisons among the four hospital groups from the administrative database stratified by the number of cardiologists

AHF case volume per hospital, the proportions of male patients, and underlying IHD were observed to decline together with the number of cardiologists (Table 1). In contrast, case

volume per cardiologist increased with decreasing cardiologist numbers. The ≥10 cardiologists group showed the highest proportion of university hospitals and patients with NYHA class II at admission among the four groups.

With regard to outcome measures, crude in-hospital mortality tended to increase in hospitals with fewer cardiologists, from 4.4% in the ≥10 cardiologists group to 16.4% in the group with no cardiologists. Even after adjusting for patient severity factors mentioned in our previous study,[7] higher likelihood of mortality was still observed in hospitals with fewer cardiologists, from 5.4% in the ≥ 10 cardiologists group to 10.7% in the group with no cardiologists (Figure 1).

All nonpharmacologic interventions during hospitalization showed reductions in relation to decreasing numbers of cardiologists. Also, major intravenous and discharge medications also tended to decline with decreasing numbers of cardiologists (Table 2).

When examining the effects of cardiologist numbers in processes of care such as therapeutic interventions, there were wide practice variations at the cardiologist-stratified hospital group level, as shown by the age-sex-adjusted ORs (Table 3). The group of hospitals with no cardiologists tended to show lower ORs for each therapeutic intervention. In contrast, groups with 5 to 9 and ≥10 cardiologists had generally higher ORs, especially in specific interventions or medications used to treat severe patients such as intubation, RHC, cardiac resynchronization therapy, implantable cardioverter-defibrillator, IABP and intravenous

carperitide use. Conventional care such as intravenous dopamine, intravenous digoxin, and digitalis at discharge were lower in the ≥ 10 cardiologists group, and nitrates and digitalis at discharge were higher in the group with no cardiologists.

In addition, wide therapeutic practice variations at the individual hospital level were observed among and within the four hospital groups. We found three distinct hospital distribution patterns for specific therapeutic interventions (Figure 2). These patterns were (i) a convex inclination pattern representing commonly used therapies for AHF such as intravenous diuretics (A), angiotensin-converting enzyme inhibitors/angiotensin-receptor blockers (ACEI/ARBs) and warfarins; (ii) a concave inclination pattern representing less commonly-used therapies such as intravenous dobutamine (C), intubation, PCI, and oral inotropic agents; and (iii) an inclination with an intermediate gradient or a combination of the former two patterns representing an intermediate distribution stage of specific therapy use such as intravenous carperitide (B), heparin and beta-blockers at discharge.

Table 2. Clinical practices in AHF patients

Therapeutic Interventions	Clinical Registries			Study Sample (Administrative Database) Hospital subgroups stratified by the number of cardiologists per facility				
	ATTEND Preliminary Report[3]	ATTEND[4]	JCARE-CARD[5,6]	≥10	5-9	1-4	0	Overall
(%)	n=1,110	n=4,842	n=1,613	n=6,509	n=15,337	n=15,867	n=955	n=38,668
Nonpharmacologic interventions		(n=4,842)						
Intubation	11.1	7.5	-	12.2	9.9	8.4	6.1	9.6
Right heart catheterization	20.1	16.7	-	17.6	12.9	9.0	2.2	11.7
Percutaneous coronary intervention	9.6	8	-	4.3	3.4	3.2	0.4	3.4
Coronary artery bypass grafting	1.4	1.3	-	0.3	0.1	0.1	-	0.1
Pacemaker	4.7	3.8	-	1.5	1.0	1.1	0.6	1.1
Cardiac resynchronization therapy(CRT or CRT-D)	2.4	2.3	-	1.7	0.7	0.2	-	0.6
Implantable cardioverter-defibrillator	2.6	2.6	-	0.3	0.1	0.1	-	0.1
Intraaortic balloon pump	3.6	2.5	-	0.9	0.7	0.4	0.1	0.6
Percutaneous cardiopulmonary support	0.6	0.7	-	0.4	0.3	0.1	-	0.2
Intravenous medications		(n=4,842)						
Diuretics	80.4	76.3	-	72.3	76.4	75.6	70.9	75.2
Carperitide	69.4	58.2	-	59.0	49.3	41.0	19.1	46.8
Heparin	NA	NA	-	60.1	54.7	44.8	25.7	50.8
Isosorbide dinitrate (ISDN)	9.2	14.5	-	25.8	21.2	18.2	8.3	20.4
Nitroglycerin (NTG)	26.0	20.8	-	16.9	16.3	12.4	9.1	14.6
ISDN or NTG	NA	NA	-	36.8	32.6	27.6	15.9	30.8
Nicorandil	10.6	9.6	-	6.4	5.2	4.3	0.8	4.9
Inotropes								
Dobutamine	12.7	11.3	-	13.1	12.7	8.8	6.0	11.0
Dopamine	11.0	8.8	-	9.9	14.3	13.4	10.9	13.1
Norepinephrine	6.2	4.7	-	6.8	5.9	4.7	4.8	5.5
Milrinone	2.8	3.3	-	2.3	2.3	2.4	0.8	2.3
Olprinone	0.7	0.8	-	1.5	0.6	0.7	0.3	0.8
Digoxin	6.5	6.9	-	6.6	8.1	7.6	7.6	7.7
Calcium-channel blocker	8.2	NA	-	8.5	5.4	3.9	2.6	5.2
Discharge medications		(n=4,530)						
Diuretics	84.5	82.3	87.0	72.0	72.2	69.3	63.7	70.8
ACEIs	26.3	30.6	38.7	23.3	19.2	18.7	8.8	19.4
ARBs	54.5	46.0	46.4	35.2	33.9	31.0	24.6	32.7
ACEIs or ARBs	78.0	74.7	79.1	57.1	51.6	48.1	32.9	50.6
Aldosterone receptor blockers	49.0	43.0[*]	42.2[*]	42.6	38.7	34.9	24.6	37.4
Digitalis	27.2	14.7	27.2	11.2	13.2	12.6	14.6	12.7
Beta-blockers	63.6	67.4	57.5	52.3	43.7	36.9	20.9	41.8
Nitrates	25.5	22.4	23.0	14.4	14.4	15.1	20.0	14.8
Calcium channel blockers	29.1	26.8	25.4	23.0	23.3	21.1	19.9	22.3
Statins	37.3	35.6	21.0	26.9	23.6	19.4	10.4	22.1
Warfarin	40.9	43.2	39.8	39.2	34.6	30.3	21.8	33.3
Antiplatelets	51.8[†]	46.0[†]	48.4[†]	40.5	36.8	34.0	22.8	35.9
Oral inotropic agents	6.6[‡]	5.2[‡]	NA	7.1	6.5	5.6	3.4	6.2

AHF, acute heart failure; CRT-D, cardiac resynchronization therapy with defibrillator; ACEIs, angiotensin-converting enzyme inhibitors; ARBs, angiotensin-receptor blockers; NA, not available.

The proportions of discharge medication in ATTEND registry were estimated based on reported figures.[3,4]

Only spironolactone,[*] aspirin, [†] and pimobendan [‡] were included.

Table 3. Adjusted odds ratios (95%CIs) of clinical practices in patients with AHF

Variables	Study Sample (Administrative Database) Hospital subgroups by the number of cardiologists			
(%)	≥10 n=6,509	5-9 n=15,337	1-4 n=15,867	0 n=955
In-hospital managements				
Nonpharmacologic interventions				
Intubation	1.43 (1.30-1.57)	1.16 (1.07-1.25)	ref	0.74 (0.56-0.97)
Right heart catheterization	1.84 (1.69-2.01)	1.34 (1.25-1.45)	ref	0.26 (0.17-0.40)
Percutaneous coronary intervention	1.23 (1.06-1.43)	1.02 (0.90-1.16)	ref	0.14 (0.05-0.38)
Pacemaker	1.47 (1.15-1.89)	0.94 (0.76-1.17)	ref	0.55 (0.24-1.24)
Implantable cardioverter-defibrillator (ICD)	5.19 (2.31-11.69)	2.48 (1.10-5.57)	ref	-
Cardiac resynchronization therapy (CRT or CRT-D)	8.98 (5.81-13.89)	4.08 (2.64-6.31)	ref	-
Coronary artery bypass grafting	4.95 (2.28-10.79)	1.98 (0.89-4.37)	ref	-
Intraaortic balloon pump	1.96 (1.36-2.82)	1.57 (1.14-2.17)	ref	0.33 (0.05-2.36)
Percutaneous cardiopulmonary support	2.47 (1.41-4.31)	1.62 (0.97-2.72)	ref	-
Intravenous drugs				
Diuretics	0.87 (0.82-0.93)	1.06 (1.01-1.12)	ref	0.76 (0.66-0.88)
Carperitide	2.02 (1.91-2.15)	1.39 (1.33-1.45)	ref	0.35 (0.29-0.41)
Heparin	1.73 (1.63-1.84)	1.44 (1.38-1.51)	ref	0.45 (0.39-0.52)
ISDN or NTG	1.41 (1.32-1.50)	1.22 (1.16-1.28)	ref	0.53 (0.44-0.63)
Nicorandil	1.47 (1.30-1.67)	1.20 (1.08-1.34)	ref	0.20 (0.10-0.40)
Inotropes				
Dobutamine	1.49 (1.36-1.63)	1.48 (1.37-1.59)	ref	0.69 (0.52-0.90)
Dopamine	0.71 (0.65-0.78)	1.08 (1.01-1.15)	ref	0.79 (0.64-0.98)
Norepinephrine	1.41 (1.25-1.59)	1.24 (1.12-1.37)	ref	1.09 (0.80-1.48)
Milrinone	0.87 (0.72-1.06)	0.91 (0.79-1.05)	ref	0.36 (0.18-0.74)
Olprinone	1.89 (1.43-2.50)	0.82 (0.62-1.09)	ref	0.50 (0.16-1.58)
Digoxin	0.85 (0.75-0.95)	1.06 (0.98-1.15)	ref	1.01 (0.79-1.29)
Calcium-channel blocker	2.21 (1.96-2.49)	1.39 (1.25-1.55)	ref	0.68 (0.46-1.02)
Discharge medications				
Diuretics	1.51 (1.37-1.66)	1.14 (1.07-1.22)	ref	0.63 (0.53-0.74)
ACEIs	1.24 (1.16-1.33)	1.00 (0.95-1.06)	ref	0.44 (0.35-0.55)
ARBs	1.16 (1.09-1.23)	1.12 (1.06-1.17)	ref	0.75 (0.65-0.87)
ACEI or ARBs	1.35 (1.27-1.43)	1.11 (1.06-1.16)	ref	0.56 (0.48-0.64)
Aldosterone receptor blockers	1.30 (1.23-1.38)	1.15 (1.09-1.20)	ref	0.64 (0.55-0.74)
Digitalis	0.84 (0.77-0.92)	1.03 (0.96-1.10)	ref	1.23 (1.02-1.48)
Beta-blockers	1.68 (1.58-1.78)	1.26 (1.20-1.32)	ref	0.49 (0.42-0.58)
Nitrates	0.99 (0.91-1.07)	0.97 (0.91-1.03)	ref	1.37 (1.16-1.62)
Calcium channel blockers	1.13 (1.05-1.21)	1.14 (1.08-1.20)	ref	0.93(0.79-1.09)
Statins	1.40 (1.31-1.50)	1.23 (1.16-1.29)	ref	0.52(0.42-0.64)
Warfarin	1.35 (1.27-1.44)	1.16 (1.11-1.22)	ref	0.70(0.59-0.82)
Antiplatelets	1.29 (1.22-1.38)	1.12 (1.07-1.18)	ref	0.59(0.50-0.68)
Oral inotropic agents	1.19 (1.06-1.34)	1.13 (1.03-1.24)	ref	0.61(0.43-0.88)

CI, confidence interval; CRT-D, cardiac resynchronization therapy defibrillator; ISDN, Isosorbide dinitrate; NTG, nitrogrycelin; ACEIs, angiotensin-converting enzyme inhibitors; ARBs, angiotensin-receptor blockers; ref, reference.

The odds ratios were adjusted for sex and age-group (< 60, ≥ 60, ≥ 70, ≥ 80, and ≥ 90 years) using multivariable regression analyses.

DISCUSSION

In this study, we confirmed the compatibility of administrative data to properly identify hospitalized AHF patients by cross-referencing the results from recent clinical registries, and further revealed wide practice variations in AHF care among hospitals in association with the number of cardiologists per facility.

Major underlying diseases, major therapeutic interventions and proportions of discharge medications showed approximate similarities between the ≥10 cardiologists group and the clinical registries. These general similarities indicate that our study sample is comparable with the cohorts from the clinical registries. The results were consistent with a prior study that compared CABG cases between administrative data and registry data, which demonstrated that major comorbidities were similarly prevalent between the two datasets.[14] Because several disparities were also detected among the three cohorts of the clinical registries, the differences between our sample and the clinical registries appeared to be acceptable. Although the definition and diagnosis of AHF are widely known to be complex even in daily clinical practice,[2] AHF patients were considered to be successfully identified with the code indicating acute exacerbation of HF.

However, the possible causes of the differences observed between our sample and the clinical registries are considered as follows: first, there may be a difference in the types of patients between the two datasets. For example, the higher proportion of NYHA class II at

admission in the ≥10 cardiologists group than in the registries, may largely stem from the fundamental differences in the inclusion criteria of AHF; the clinically-based Framingham criteria may be stricter and include more severe patients when compared with more subjective decision of the attending physicians.

Second, although a clinical registry database may be thought to be the “gold standard” for many epidemiological studies, these registries tend to be heavily represented by large medical centers. This can result in some selection bias, as large medical centers generally treat more difficult and unusual cases associated with higher mortality or requirements for intensive care. Because approximately 74% of acute care hospitals have fewer than 300 hospital beds in Japan,[9] it is crucial to utilize administrative data to shed light on the quality of care provided in hospitals groups that include smaller hospitals. In consideration of the large number of hospitals and patients included, administrative data is likely to exhibit more diverse patients from various hospitals, and may be suitable to describe inter-hospital differences of quality in provided care. In addition, the low proportion of major intensive procedures (such as PCI, CABG and PMI) in the administrative data may be due to the payment system that makes physicians to record the primary diagnoses (such as angina or arrhythmia) directly related to the procedures other than AHF.

Next, greater use of recommended therapeutic processes of care, measured by sex-age-adjusted ORs, was observed to be associated with a higher number of cardiologists. When

compared with the 1 to 4 cardiologists group, hospitals with no cardiologists were less likely to provide these treatments, whereas the 5 to 9 cardiologists group and the ≥10 cardiologists group were more likely to provide specialty procedures or new drugs, and less likely to provide conventional drugs (e.g., intravenous dopamine or digoxin, digitalis at discharge). Furthermore, the outcome measure of patient risk-adjusted mortality also decreased with increasing numbers of cardiologists. These results support those of prior studies where the case volume was shown to be associated with better care processes and outcomes in congestive HF patients,[15] and high physician volume, especially with cardiologists, was shown to be associated with lower mortality rates.[16] However, it should be noted that these results do not unequivocally indicate that a higher number of cardiologists induces higher quality of care. Elderly patients or terminally ill patients are more likely to undergo less invasive treatment, which can be provided in smaller hospitals with fewer cardiologists. Due to Japan's rapidly aging population, our results may also be indicative of this treatment style.

Additionally, our results showed that lower case volume per cardiologist was related with lower adjusted mortality. The result initially seemed to be contrary to the frequently reported relationship between case volume and outcomes per specialist in major surgeries and cardiovascular interventions.[17,18] These previous studies have used hospital case volume or case volume per physician as a measure of experience with managing diseases. However, the total number of cardiologists per hospital may be better suited to describe the quality of care in specific diseases that require teams of specialists. Our findings both here and in a previous study[19] are therefore not necessarily contradictory to these prior reports.[17,18] Moreover, the quality of care shown by the total number of cardiologists may expand the contents of new draft guidelines from National Institute for Health and Care Excellence (NICE)[20], in which AHF patients are recommended to be seen by specialist teams.[21]

The number of cardiologists is very important in medical emergencies such as AHF or AMI which require immediate intervention and the integrated teamwork of cardiovascular specialists and medical staff with 24-hour coverage. The results from our study may lead to the concept of "resource dependency" as a source of practice variation. This type of care may be considered to be directly affected by the presence and quantity of resources available, and is distinct from individual physicians' skill or experience. Resource dependency can well explain practice variations before supplier-inducement or patient preferences can influence variations. In other words, the availability of manpower resources may affect the quality of care, leading to practice variations among hospitals.

Finally, we found that the three hospital distribution patterns for specific interventions can be used as a tool to capture diffusion process of a new therapeutic practice. The concept of individual hospital distribution patterns related to the proportion of therapeutic intervention can be illustrated as Supplementary Figure 2. Therapies that are not widely used may show the concave distribution pattern (type C) at first, and would shift from types C to B, finally to type A, when they gradually become more familiar and widespread.

By referring to these three distribution patterns during analyses of cross-sectional data, we may discern how much and how widely a certain therapy is currently adopted among hospitals at a particular time. For example, intravenous carperitide, a recombinant form of atrial natriuretic peptide, which exhibited the intermediate-distribution-stage pattern has been believed to expand in daily practice in Japan,[3,4] yet the characteristics of hospitals that had used this drug remained unclear. Interestingly, the results from our study revealed that the drug had been much less used among hospitals with fewer cardiologists when compared with the ATTEND registry, which included hospitals with larger number of cardiologists. In the context of widely known "innovation diffusion theories",[22, 23] this intermediate-distribution-stage pattern may represent a snapshot of the diffusion process of a new therapeutic practice across multiple facilities over time. Furthermore, these results may be utilized to improve currently provided care from the viewpoint of practice guideline adherence or policymaking perspectives.

Study Limitations

There are several limitations in this study. First, hospitals in this study are restricted to some part of those who actively adopt the DPC system. In addition, the clinical circumstances including the use of drugs may differ across the countries. These may limit the generalizability of our results in worldwide clinical settings. Second, when adjusting outcome measures, we did not consider hospital-level factors such as teaching status, urban location, and the presence of a cardiac intensive care unit, which may also have affected the quality of care. Finally, we could not identify the number of cardiologists who were actually treating AHF patients, differences in competency among individual cardiologists, and the area of cardiovascular subspecialty of each cardiologist. Further studies are required to examine the effect of these issues on quality of care.

CONCLUSIONS

We revealed wide therapeutic practice variations of AHF in association with the number of cardiologists per facility using an administrative database. Recommended therapeutic practices tended to be provided more frequently in hospitals with more cardiologists. Quality of AHF care may be dependent on manpower resources, and further studies are needed to clarify their relationship.

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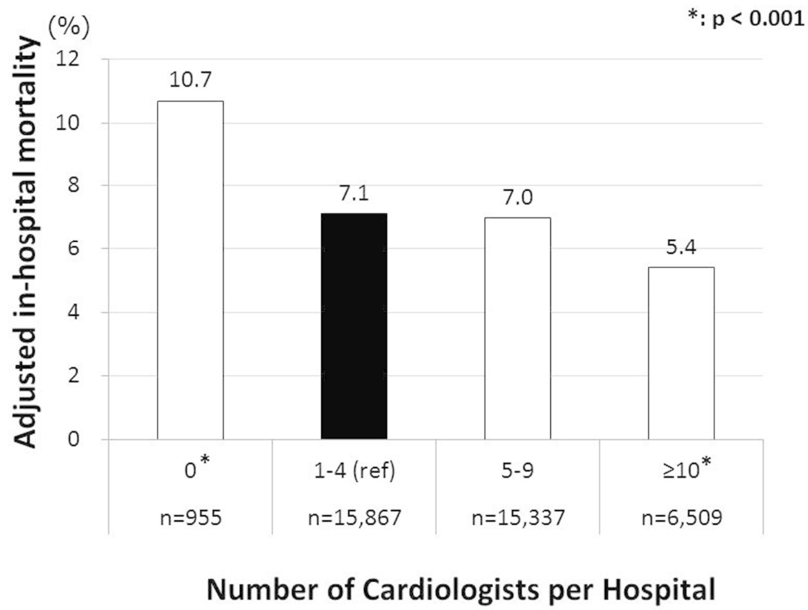

Adjusted in-hospital mortality in AHF stratified by the number of cardiologists per hospital.
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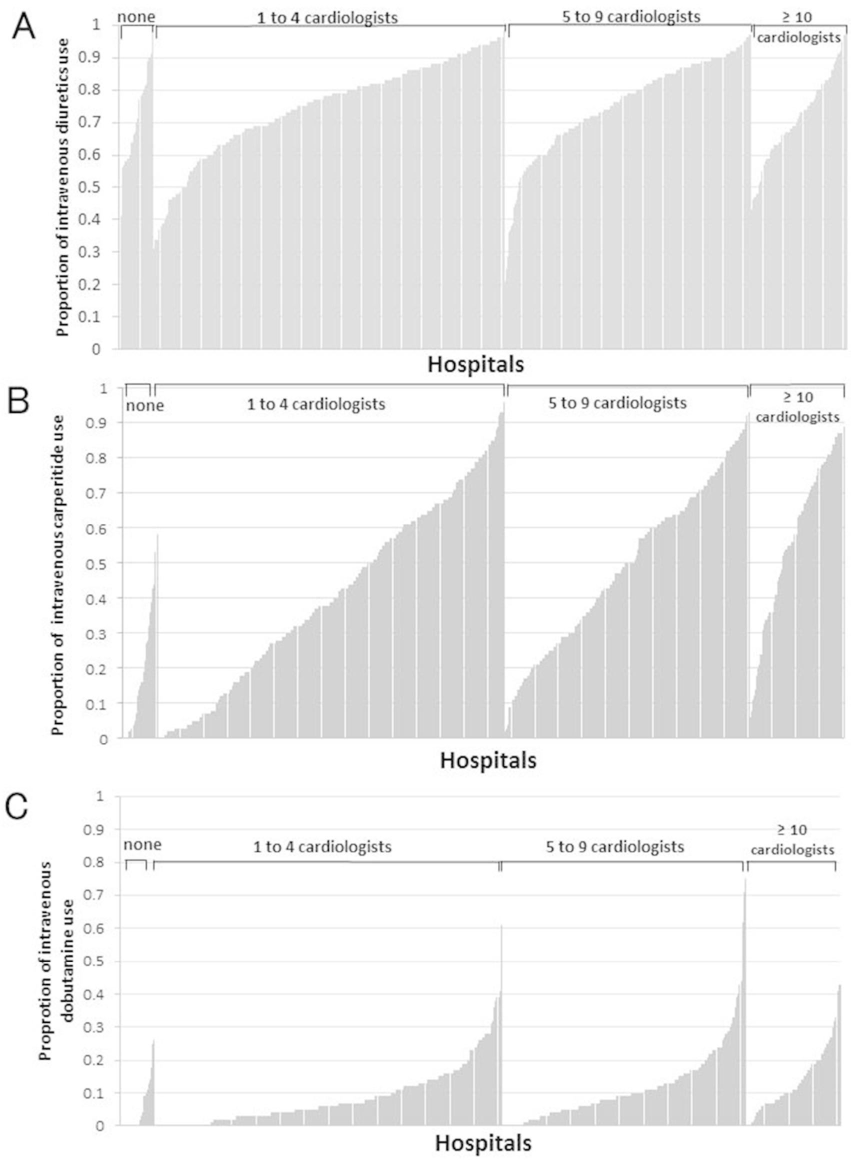

Hospital distribution patterns for specific practices, categorized by the number of cardiologists.
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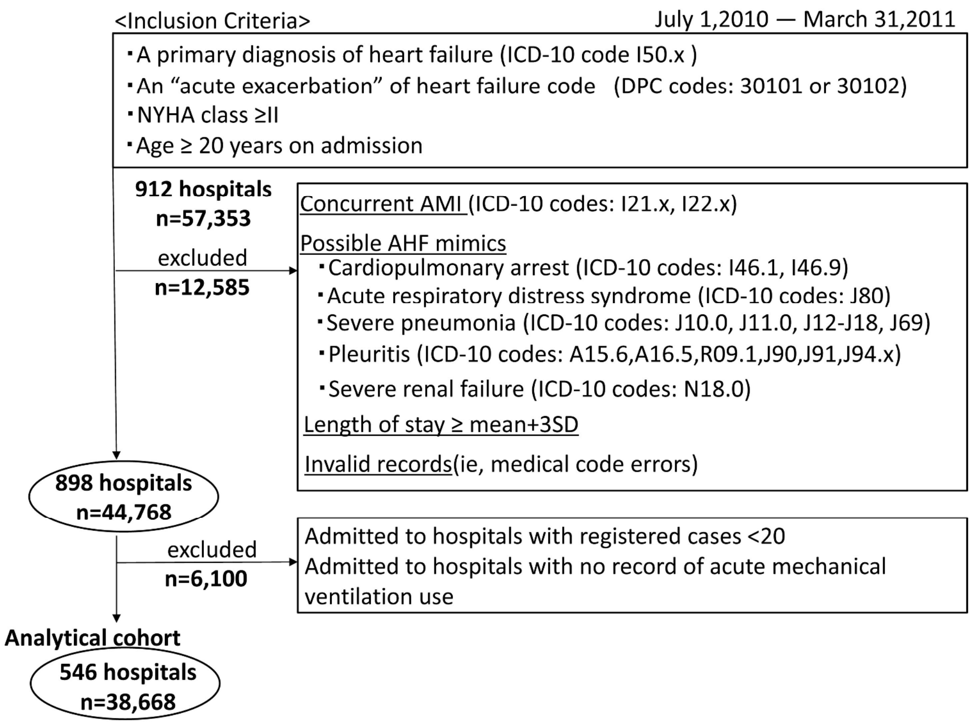

Diagram showing patient selection.
ICD-10, International Classification of Disease, 10th version; DPC, Diagnosis Procedure Combination; NYHA, New York Heart Association; AMI, acute myocardial infarction; SD, standard deviation.

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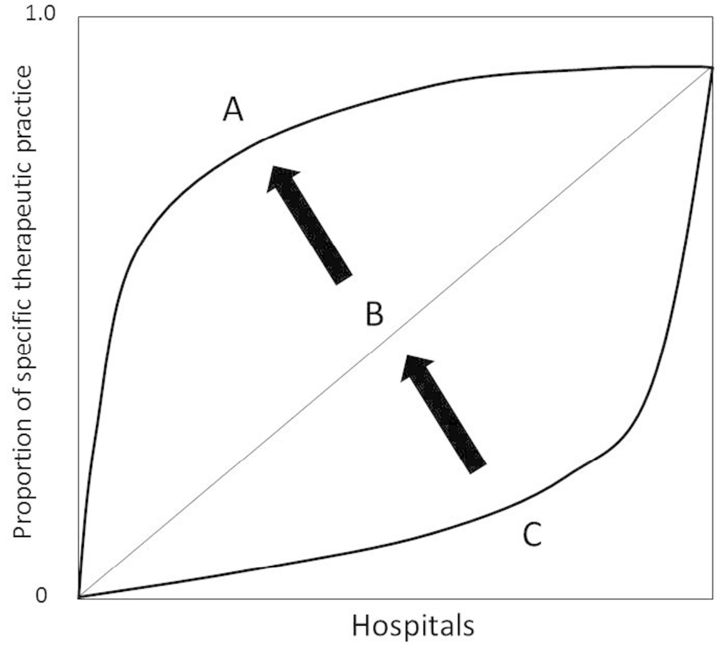

A conceptual diagram of clinical practice diffusion.
254x190mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	✔	Recommendation
Title and abstract	1	✔	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		✔	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction			
Background/rationale	2	✔	Explain the scientific background and rationale for the investigation being reported
Objectives	3	✔	State specific objectives, including any prespecified hypotheses
Methods			
Study design	4	✔	Present key elements of study design early in the paper
Setting	5	✔	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	-	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		-	*Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls
		✔	*Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		-	(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed
		-	*Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	✔	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	✔	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	✔	Describe any efforts to address potential sources of bias
Study size	10	✔	Explain how the study size was arrived at
Quantitative variables	11	✔	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	✔	(*a*) Describe all statistical methods, including those used to control for confounding
		✔	(*b*) Describe any methods used to examine subgroups and interactions
		✔	(*c*) Explain how missing data were addressed
		-	(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed
		-	*Case-control study*—If applicable, explain how matching of cases and controls was addressed
		-	*Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		-	(*e*) Describe any sensitivity analyses

Continued on next page

Results			
Participants	13*	✔	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		✔	(b) Give reasons for non-participation at each stage
		✔	(c) Consider use of a flow diagram
Descriptive data	14*	✔	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		-	(b) Indicate number of participants with missing data for each variable of interest
		-	(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	-	*Cohort study*—Report numbers of outcome events or summary measures over time
		-	*Case-control study*—Report numbers in each exposure category, or summary measures of exposure
		✔	*Cross-sectional study*—Report numbers of outcome events or summary measures
Main results	16	✔	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		✔	(*b*) Report category boundaries when continuous variables were categorized
		-	(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	✔	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion			
Key results	18	✔	Summarise key results with reference to study objectives
Limitations	19	✔	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	✔	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	✔	Discuss the generalisability (external validity) of the study results
Other information			
Funding	22	✔	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

The Relationship between the Number of Cardiologists and Clinical Practice Patterns in Acute Heart Failure — A Cross-sectional Observational Study

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Short title: **Acute Heart Failure Practice Variations**

Total word count: 3,144

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ABSTRACT

Objectives: Despite the increasing burden of acute heart failure (AHF) on healthcare systems, the association between centralized cardiovascular specialist care and the quality of AHF care remains unknown. Here, we examine the relationship between the number of cardiologists per hospital and hospital practice variations.

Design, setting and participants: In a retrospective observational study, we analysed 38,668 AHF patients admitted to 546 Japanese acute care hospitals between 2010 and 2011 using the Diagnosis Procedure Combination administrative claims database. Sample hospitals were categorized into four groups according to the number of cardiologists per facility (none, 1 to 4, 5 to 9, and ≥10). To confirm the capability of administrative data to identify AHF patients, the ≥10 cardiologists group was compared with two recent clinical registries in Japan.

Main outcome measures: Using multivariable logistic regression models, patient risk-adjusted in-hospital mortality rates and age-sex-adjusted odds ratios of various AHF therapies were calculated and compared among the four hospital groups.

Results: The ≥10 cardiologists group of hospitals from the administrative database had similar major underlying disease incidence and therapeutic practices to those of the clinical registry hospitals. Age-sex-adjusted odds ratios of the various AHF therapies in the four hospital groups revealed wide practice variations associated with the number of cardiologists. Adjusted in-hospital mortality demonstrated a negative association with the number of

cardiologists. In addition, the different hospital-level distribution patterns of specific therapeutic practices illustrated the diffusion process of therapies across facilities.

Conclusions: Wide practice variations in AHF care were associated with the number of cardiologists per facility, indicating a possible relationship between the quality of AHF care and manpower resources. The provision of recommended therapies increased together with the number of cardiologists.

ARTICLE SUMMARY

Article focus

- This study investigates the relationship between the number of cardiologists per hospital and processes of care (such as therapeutic interventions and medications) using a large administrative claims database.

Key messages

- The capability of administrative data to identify AHF patients was confirmed using two recent clinical registries in Japan.
- Greater use of recommended therapeutic processes of care, measured by sex-age-adjusted odds ratios, was associated with a higher number of cardiologists.
- Even after adjusting for disease severity factors, patients admitted to hospitals with fewer cardiologists had a higher likelihood of in-hospital mortality.

- Three patterns of hospital distribution of specific therapeutic interventions were discovered, and may shed light on the diffusion process of new therapeutic practices.

Strengths and limitations of this study

- This study uses a large administrative database to provide novel insight into the practice variations in AHF care across Japanese hospitals categorized by the number of cardiologists.
- These findings can support improvements to hospital quality of care for AHF patients from the perspective of health policy.
- Generalizability of the conclusions outside of Japan may be limited due to different clinical circumstances across countries.

The high morbidity, mortality, and readmission rates in acute heart failure (AHF) patients place a heavy burden on healthcare systems, especially in developed countries with aging populations.[1,2] The association between centralized cardiovascular specialist care and the quality of AHF care remains unknown. Also the relation between hospital practice variations and the number of cardiologists is still unclear.

Currently, there are only a few clinical registries that have contributed descriptive analyses of AHF cases in Japan[3-6] including the Acute Decompensated Heart Failure Syndromes (ATTEND) registry[3,4] and the Japanese Cardiac Registry of Heart Failure in Cardiology (JCARE-CARD).[5,6] However, the hospitals included in these registries are likely to be biased toward bigger hospitals with larger number of cardiologists, which may not be representative of all AHF patients. Little information exists concerning the hospital management of AHF, based on analyses that encompass wide regions across Japan.

Recently, a code designating "acute exacerbation" of heart failure (HF), which was newly added in 2009 and unique to the Japanese Diagnosis Procedure Combination (DPC) patient case-mix classification system,[7,8] has enabled researchers to distinguish AHF from chronic HF. Yet the reliability of this extracted data for clinical or epidemiological analyses remains unclear because of the complexity of AHF itself.[2]

The objective of our study consisted of two steps. First, we examined whether demographics of AHF patients identified by administrative data using the new code are comparable with those from the aforementioned Japanese registries. These registries were deemed suitable for cross-reference because they were based on clinical data and their data collection period corresponded with that of our study. Second, in order to elucidate the relationship between cardiologists and quality of care, we investigated AHF patient characteristics, therapeutic process of care, patient outcomes, and therapeutic practice patterns among hospital groups stratified by the number of cardiologists per facility.

METHODS

Data sources

Data for analysis were extracted from the DPC administrative database,[7,8] which contains inpatient information such as patient case-mix, processes of care, medical charges, and patient outcomes including mortality. In the DPC system, the code designating "acute exacerbation" of HF and the determination of the New York Heart Association (NYHA) functional class at admission are determined only by attending physicians, and not by other medical or administrative staff; this may provide face validity for the accuracy of these codes. Subsequently, the results of our sample using administrative data and the results of the ATTEND and the JCARE-CARD registries were compared.

The ATTEND registry included AHF patients from 2007 to 2011. This registry contained 4,842 patients from 53 hospitals; patients who met the modified Framingham criteria[9] were included, but those who had acute coronary syndromes were excluded.[3,4] A preliminary report based on 1,110 patients from 32 hospitals of the registry had been previously published,[3] and we utilized the results of both reports because we observed statistically significant differences in patient characteristics between the two.

The JCARE-CARD registry included patients hospitalized with worsening HF, identified using Framingham criteria. This study enrolled 2,675 patients from 164 hospitals between 2004 and 2005,[5,6] and analyzed patients with reduced and preserved ejection fraction (EF).[6] The number of cardiologists per hospital was obtained from the Japanese Circulation Society (JCS) website,[10] which gives detailed information on JCS-certified cardiologists.

Study population

Using the DPC administrative database, we identified a total of 57,353 AHF cases who had been admitted to 912 hospitals between July 1, 2010 and March 31, 2011. The selection criteria were i) a primary diagnosis of heart failure (ICD-10 code I50.x), ii) a DPC system code designating an "acute exacerbation" of heart failure, iii) NYHA functional class II or higher, and iv) older than 20 years of age. The exclusion criteria are described in Supplementary Figure 1. Data at patient level were collected in relation with the context, use and coding of administrative data. Exclusion criteria for hospitals were also used, because these hospitals were assumed to provide less emergency care and thought to be unsuitable for comparisons with hospitals providing high-quality emergency care. As more than two-thirds of all 8,565 hospitals in Japan have fewer than 200 beds,[11] we took these factors into consideration in order to make valid comparison. The final sample size comprised 38,668 patients from 546 hospitals, ranging from 20 patients to 343 patients per hospital.

In order to perform valid comparisons between the sample hospitals with the clinical registries, our study sample was divided into four groups according to the number of registered cardiologists per hospital (no cardiologist; 1 to 4; 5 to 9; and ≥10 cardiologists); the ≥10 cardiologists group was compared with the registries, as hospitals in both these groups were likely to be similar in both hospital and patient characteristics, as well as medical practice patterns. Subsequently, patient characteristics, outcomes and therapeutic interventions among the four groups in our study sample were examined. To investigate the relationship between cardiologist numbers and quality of hospital care, the age-sex-adjusted odds ratios (ORs) of specific clinical practices were calculated for each group, using the 1 to 4 cardiologists group as the reference.

Statistical Analysis

Means and standard deviations were calculated for continuous data, whereas categorical data were expressed as percentages. Comparisons between the ≥10 cardiologists group in our study sample and the registry groups were performed using the chi-squared tests for dichotomous variables.

Age-sex-adjusted ORs and 95% confidence intervals of specific clinical practices among the hospital groups stratified by the number of cardiologists per hospital were analyzed using multivariable logistic regression analyses. Risk-adjusted mortality rate was calculated as the ratio of observed mortality to predicted mortality, multiplied by the overall mean mortality rate of 7.0%. Predicted mortality of each patient was obtained using the predictive model that we had previously reported.[7] Independent variables in this model included 11 patient factors such as age, NYHA functional class, and comorbidities. Two-tailed P values below 0.05 were considered statistically significant. Statistical computations were performed using SPSS software, version 19.0J (SPSS Inc., Chicago, IL, USA).

Results

Baseline characteristics of the hospitals and AHF patients from the two clinical registries and from the study sample based on the administrative database are described in Table 1.[3-6] Our study sample consisted of hospitals from all 47 prefectures in Japan, varying in hospital bed size, case volume, teaching status, and ownership (public/private).

At the overall patient level, the mean age and the proportion of male patients in our sample were 78 years and 51%, respectively. Ischemic heart disease (IHD) was present in approximately 31%, similar to the registries. Observed in-hospital mortality rate was 7.0%, which was within the range reported in several recent AHF registries.[3, 4,12,13] Median LOS was similar to the ATTEND registry (18 and 21 days).

Table 1. Baseline characteristics of hospitals and AHF patients

Characteristics	Clinical Registries			Study Sample (Administrative Database) Hospital subgroups stratified by the number of cardiologists per facility				
	ATTEND Preliminary Report[3]	ATTEND[4]	JCARE-CARD[5,6]	≥10	5-9	1-4	0	Overall
Geographic region (number of prefectures)	20	24	47	27	45	45	22	47
Study duration, years	2.25	4.67	2.40	0.75	0.75	0.75	0.75	0.75
Institutional Level								
Number of hospitals	32	52	164	72	185	263	26	546
Hospital beds, mean (SD)	557(337)	564(332)	NA	712(264)	523(224)	364(154)	204(76)	456(234)
University hospitals, %	41	40.4	NA	63.9	13.0	4.9	0	15.6
Certified*training facilities, %	93.8	90.4	100	100.0	100.0	74.5	0.0	91.9
Number of cardiologists*/facility, median	9.5	9	NA	13	6	3	0	4
Total patients	1,110	4,842	2,675	6,509	15,337	15,867	955	38,668
Case volume /year	-	-	-	8,679	20,449	21,556	1,273	51,557
Case volume/facility･year, mean(SD)	-	-	-	120.5(82.6)	110.5(52.1)	80.4(41.6)	49.0(21.1)	94.4(55.0)
Case volume /facility･year･cardiologist, mean(SD)	-	-	-	9.0(6.5)	17.2(7.9)	34.4(22.9)	-	24.8(19.9)
Patient Level								
Age, mean years (SD)	73(14)	73(14)	71(13)	75.3(12.9)	77.2(12.1)	78.9(11.6)	81.3(10.7)	77.7(12.1)
Male, %	59	58.0	60	57.2	51.7	49.1	44.0	51.4
NYHA functional class at admission, %	n=1,092[†]	n=4,699[†]	n=2,644[†]					
II	12.3	16.1	11.5	33.8	29.0	25.6	22.8	28.3
III	39.7	38.9	45.1	38.9	37.6	39.2	35.4	38.4
IV	48.0	45.0	43.4	27.3	33.4	35.2	41.8	33.3
Underlying diseases, %			n=1,692					
Ischemic heart disease	33[‡]	31.1[‡]	32.0	34.6	31.0	30.3	21.9	31.1
Atrial fibrillation/flutter	40	39.6	35.0	26.3	27.3	28.2	22.7	27.4
Cardiomyopathy	NA	12.7	26.2	8.8	7.1	5.5	2.5	6.6
Valvular heart disease	NA	19.4	NA	16.7	16.3	15.4	9.1	15.8
Hypertension	71	69.4	52.6	53.6	55.9	54.8	37.8	54.6
Diabetes mellitus	34	33.8	29.8	24.8	24.3	26.2	19.3	25.0
Previous history of stroke	12	14.0	14.7	4.3	5.3	7.1	7.7	5.9
Renal failure (mild to moderate)	NA	NA	11.7	9.6	10.4	10.8	10.2	10.4
COPD	9	9.5	6.5	5.3	6.6	6.9	5.0	6.5
Outcomes								
Mean (median) length of stay, days	31(21)	30(21)	35.6(NA) /31.2(NA)[§]	21.7(18.0)	21.7(17.0)	22.2(18.0)	22.9(17.0)	21.9(18.0)
Crude in-hospital mortality, %	7.7	6.4	3.9 / 6.5[§]	4.4	6.8	7.6	16.4	7.0

AHF, acute heart failure; SD, standard deviation; NA, not available; NYHA, New York Heart Association; COPD, Chronic obstructive pulmonary disease.

*Certified by the Japanese Circulation Society.

†Estimated case volumes were re-calculated.

†The number was re-calculated by subtracting original NYHA class I patients.

‡Without acute coronary syndromes.[3,4]

§Length of hospital stay with reduced left ventricular ejection fraction (EF) / preserved EF.[6]

Comparisons of patient characteristics and therapeutic practices between the administrative database and the two clinical registries

The median number of cardiologists and hospital beds, and the proportion of university hospitals in the ≥10 cardiologists group in our study sample were similar to those of the ATTEND registry (Table 1).

Details of therapeutic practices as process-of-care measures for hospitalized AHF patients are shown in Table 2. Data for these therapies were not available from the JCARE-CARD registry. Although many differences were statistically significant because of the large sample sizes, the proportions of nonpharmacologic interventions and intravenous medications were similar between the ≥10 cardiologists group and the ATTEND registry in many respects. However, the frequencies of percutaneous coronary intervention (PCI), coronary artery bypass grafting (CABG), intraaortic balloon pump (IABP) and pacemaker implantation (PMI) were much lower in our sample. The proportion of discharge medications was similar to that of the registries.

Comparisons among the four hospital groups from the administrative database stratified by the number of cardiologists

AHF case volume per hospital, the proportions of male patients, and underlying IHD were observed to decline together with the number of cardiologists (Table 1). In contrast, case

volume per cardiologist increased with decreasing cardiologist numbers. The ≥10 cardiologists group showed the highest proportion of university hospitals and patients with NYHA class II at admission among the four groups.

With regard to outcome measures, crude in-hospital mortality tended to increase in hospitals with fewer cardiologists, from 4.4% in the ≥10 cardiologists group to 16.4% in the group with no cardiologists. Even after adjusting for patient severity factors mentioned in our previous study,[7] higher likelihood of mortality was still observed in hospitals with fewer cardiologists, from 5.4% in the ≥ 10 cardiologists group to 10.7% in the group with no cardiologists (Figure 1).

All nonpharmacologic interventions during hospitalization showed reductions in relation to decreasing numbers of cardiologists. Also, major intravenous and discharge medications also tended to decline with decreasing numbers of cardiologists (Table 2).

When examining the effects of cardiologist numbers in processes of care such as therapeutic interventions, there were wide practice variations at the cardiologist-stratified hospital group level, as shown by the age-sex-adjusted ORs (Table 3). The group of hospitals with no cardiologists tended to show lower ORs for each therapeutic intervention. In contrast, groups with 5 to 9 and ≥10 cardiologists had generally higher ORs, especially in specific interventions or medications used to treat severe patients such as intubation, RHC, cardiac resynchronization therapy, implantable cardioverter-defibrillator, IABP and intravenous

carperitide use. Conventional care such as intravenous dopamine, intravenous digoxin, and digitalis at discharge were lower in the ≥ 10 cardiologists group, and nitrates and digitalis at discharge were higher in the group with no cardiologists.

In addition, wide therapeutic practice variations at the individual hospital level were observed among and within the four hospital groups. We found three distinct hospital distribution patterns for specific therapeutic interventions (Figure 2). These patterns were (i) a convex inclination pattern representing commonly used therapies for AHF such as intravenous diuretics (A), angiotensin-converting enzyme inhibitors/angiotensin-receptor blockers (ACEI/ARBs) and warfarins; (ii) a concave inclination pattern representing less commonly-used therapies such as intravenous dobutamine (C), intubation, PCI, and oral inotropic agents; and (iii) an inclination with an intermediate gradient or a combination of the former two patterns representing an intermediate distribution stage of specific therapy use such as intravenous carperitide (B), heparin and beta-blockers at discharge.

Table 2. Clinical practices in AHF patients

Therapeutic Interventions	Clinical Registries			Study Sample (Administrative Database) Hospital subgroups stratified by the number of cardiologists per facility				
	ATTEND Preliminary Report[3]	ATTEND[4]	JCARE -CARD[5,6]	≥10	5-9	1-4	0	Overall
(%)	n=1,110	n=4,842	n=1,613	n=6,509	n=15,337	n=15,867	n=955	n=38,668
Nonpharmacologic interventions		(n=4,842)						
Intubation	11.1	7.5	-	12.2	9.9	8.4	6.1	9.6
Right heart catheterization	20.1	16.7	-	17.6	12.9	9.0	2.2	11.7
Percutaneous coronary intervention	9.6	8	-	4.3	3.4	3.2	0.4	3.4
Coronary artery bypass grafting	1.4	1.3	-	0.3	0.1	0.1	-	0.1
Pacemaker	4.7	3.8	-	1.5	1.0	1.1	0.6	1.1
Cardiac resynchronization therapy(CRT or CRT-D)	2.4	2.3	-	1.7	0.7	0.2	-	0.6
Implantable cardioverter-defibrillator	2.6	2.6	-	0.3	0.1	0.1	-	0.1
Intraaortic balloon pump	3.6	2.5	-	0.9	0.7	0.4	0.1	0.6
Percutaneous cardiopulmonary support	0.6	0.7	-	0.4	0.3	0.1	-	0.2
Intravenous medications		(n=4,842)						
Diuretics	80.4	76.3	-	72.3	76.4	75.6	70.9	75.2
Carperitide	69.4	58.2	-	59.0	49.3	41.0	19.1	46.8
Heparin	NA	NA	-	60.1	54.7	44.8	25.7	50.8
Isosorbide dinitrate (ISDN)	9.2	14.5	-	25.8	21.2	18.2	8.3	20.4
Nitroglycerin (NTG)	26.0	20.8	-	16.9	16.3	12.4	9.1	14.6
ISDN or NTG	NA	NA	-	36.8	32.6	27.6	15.9	30.8
Nicorandil	10.6	9.6	-	6.4	5.2	4.3	0.8	4.9
Inotropes								
Dobutamine	12.7	11.3	-	13.1	12.7	8.8	6.0	11.0
Dopamine	11.0	8.8	-	9.9	14.3	13.4	10.9	13.1
Norepinephrine	6.2	4.7	-	6.8	5.9	4.7	4.8	5.5
Milrinone	2.8	3.3	-	2.3	2.3	2.4	0.8	2.3
Olprinone	0.7	0.8	-	1.5	0.6	0.7	0.3	0.8
Digoxin	6.5	6.9	-	6.6	8.1	7.6	7.6	7.7
Calcium-channel blocker	8.2	NA	-	8.5	5.4	3.9	2.6	5.2
Discharge medications		(n=4,530)						
Diuretics	84.5	82.3	87.0	72.0	72.2	69.3	63.7	70.8
ACEIs	26.3	30.6	38.7	23.3	19.2	18.7	8.8	19.4
ARBs	54.5	46.0	46.4	35.2	33.9	31.0	24.6	32.7
ACEIs or ARBs	78.0	74.7	79.1	57.1	51.6	48.1	32.9	50.6
Aldosterone receptor blockers	49.0	43.0*	42.2*	42.6	38.7	34.9	24.6	37.4
Digitalis	27.2	14.7	27.2	11.2	13.2	12.6	14.6	12.7
Beta-blockers	63.6	67.4	57.5	52.3	43.7	36.9	20.9	41.8
Nitrates	25.5	22.4	23.0	14.4	14.4	15.1	20.0	14.8
Calcium channel blockers	29.1	26.8	25.4	23.0	23.3	21.1	19.9	22.3
Statins	37.3	35.6	21.0	26.9	23.6	19.4	10.4	22.1
Warfarin	40.9	43.2	39.8	39.2	34.6	30.3	21.8	33.3
Antiplatelets	51.8†	46.0†	48.4†	40.5	36.8	34.0	22.8	35.9
Oral inotropic agents	6.6‡	5.2‡	NA	7.1	6.5	5.6	3.4	6.2

AHF, acute heart failure; CRT-D, cardiac resynchronization therapy with defibrillator; ACEIs, angiotensin-converting enzyme inhibitors; ARBs, angiotensin-receptor blockers; NA, not available.

The proportions of discharge medication in ATTEND registry were estimated based on reported figures.[3,4]

Only spironolactone,[*] aspirin,[†] and pimobendan[‡] were included.

Table 3. Adjusted odds ratios (95%CIs) of clinical practices in patients with AHF

Variables (%)	Study Sample (Administrative Database) Hospital subgroups by the number of cardiologists ≥10 n=6,509	5-9 n=15,337	1-4 n=15,867	0 n=955
In-hospital managements				
Nonpharmacologic interventions				
Intubation	1.43 (1.30-1.57)	1.16 (1.07-1.25)	ref	0.74 (0.56-0.97)
Right heart catheterization	1.84 (1.69-2.01)	1.34 (1.25-1.45)	ref	0.26 (0.17-0.40)
Percutaneous coronary intervention	1.23 (1.06-1.43)	1.02 (0.90-1.16)	ref	0.14 (0.05-0.38)
Pacemaker	1.47 (1.15-1.89)	0.94 (0.76-1.17)	ref	0.55 (0.24-1.24)
Implantable cardioverter-defibrillator (ICD)	5.19 (2.31-11.69)	2.48 (1.10-5.57)	ref	-
Cardiac resynchronization therapy (CRT or CRT-D)	8.98 (5.81-13.89)	4.08 (2.64-6.31)	ref	-
Coronary artery bypass grafting	4.95 (2.28-10.79)	1.98 (0.89-4.37)	ref	-
Intraaortic balloon pump	1.96 (1.36-2.82)	1.57 (1.14-2.17)	ref	0.33 (0.05-2.36)
Percutaneous cardiopulmonary support	2.47 (1.41-4.31)	1.62 (0.97-2.72)	ref	-
Intravenous drugs				
Diuretics	0.87 (0.82-0.93)	1.06 (1.01-1.12)	ref	0.76 (0.66-0.88)
Carperitide	2.02 (1.91-2.15)	1.39 (1.33-1.45)	ref	0.35 (0.29-0.41)
Heparin	1.73 (1.63-1.84)	1.44 (1.38-1.51)	ref	0.45 (0.39-0.52)
ISDN or NTG	1.41 (1.32-1.50)	1.22 (1.16-1.28)	ref	0.53 (0.44-0.63)
Nicorandil	1.47 (1.30-1.67)	1.20 (1.08-1.34)	ref	0.20 (0.10-0.40)
Inotropes				
Dobutamine	1.49 (1.36-1.63)	1.48 (1.37-1.59)	ref	0.69 (0.52-0.90)
Dopamine	0.71 (0.65-0.78)	1.08 (1.01-1.15)	ref	0.79 (0.64-0.98)
Norepinephrine	1.41 (1.25-1.59)	1.24 (1.12-1.37)	ref	1.09 (0.80-1.48)
Milrinone	0.87 (0.72-1.06)	0.91 (0.79-1.05)	ref	0.36 (0.18-0.74)
Olprinone	1.89 (1.43-2.50)	0.82 (0.62-1.09)	ref	0.50 (0.16-1.58)
Digoxin	0.85 (0.75-0.95)	1.06 (0.98-1.15)	ref	1.01 (0.79-1.29)
Calcium-channel blocker	2.21 (1.96-2.49)	1.39 (1.25-1.55)	ref	0.68 (0.46-1.02)
Discharge medications				
Diuretics	1.51 (1.37-1.66)	1.14 (1.07-1.22)	ref	0.63 (0.53-0.74)
ACEIs	1.24 (1.16-1.33)	1.00 (0.95-1.06)	ref	0.44 (0.35-0.55)
ARBs	1.16 (1.09-1.23)	1.12 (1.06-1.17)	ref	0.75 (0.65-0.87)
ACEI or ARBs	1.35 (1.27-1.43)	1.11 (1.06-1.16)	ref	0.56 (0.48-0.64)
Aldosterone receptor blockers	1.30 (1.23-1.38)	1.15 (1.09-1.20)	ref	0.64 (0.55-0.74)
Digitalis	0.84 (0.77-0.92)	1.03 (0.96-1.10)	ref	1.23 (1.02-1.48)
Beta-blockers	1.68 (1.58-1.78)	1.26 (1.20-1.32)	ref	0.49 (0.42-0.58)
Nitrates	0.99 (0.91-1.07)	0.97 (0.91-1.03)	ref	1.37 (1.16-1.62)
Calcium channel blockers	1.13 (1.05-1.21)	1.14 (1.08-1.20)	ref	0.93(0.79-1.09)
Statins	1.40 (1.31-1.50)	1.23 (1.16-1.29)	ref	0.52(0.42-0.64)
Warfarin	1.35 (1.27-1.44)	1.16 (1.11-1.22)	ref	0.70(0.59-0.82)
Antiplatelets	1.29 (1.22-1.38)	1.12 (1.07-1.18)	ref	0.59(0.50-0.68)
Oral inotropic agents	1.19 (1.06-1.34)	1.13 (1.03-1.24)	ref	0.61(0.43-0.88)

CI, confidence interval; CRT-D, cardiac resynchronization therapy defibrillator; ISDN, Isosorbide dinitrate; NTG, nitrogrycelin; ACEIs, angiotensin-converting enzyme inhibitors; ARBs, angiotensin-receptor blockers; ref, reference.

The odds ratios were adjusted for sex and age-group (< 60, ≥ 60, ≥ 70, ≥ 80, and ≥ 90 years) using multivariable regression analyses.

DISCUSSION

In this study, we confirmed the compatibility of administrative data to properly identify hospitalized AHF patients by cross-referencing the results from recent clinical registries, and further revealed wide practice variations in AHF care among hospitals in association with the number of cardiologists per facility.

Major underlying diseases, major therapeutic interventions and proportions of discharge medications showed approximate similarities between the ≥10 cardiologists group and the clinical registries. These general similarities indicate that our study sample is comparable with the cohorts from the clinical registries. The results were consistent with a prior study that compared CABG cases between administrative data and registry data, which demonstrated that major comorbidities were similarly prevalent between the two datasets.[14] Because several disparities were also detected among the three cohorts of the clinical registries, the differences between our sample and the clinical registries appeared to be acceptable. Although the definition and diagnosis of AHF are widely known to be complex even in daily clinical practice,[2] AHF patients were considered to be successfully identified with the code indicating acute exacerbation of HF.

However, the possible causes of the differences observed between our sample and the clinical registries are considered as follows: first, there may be a difference in the types of patients between the two datasets. For example, the higher proportion of NYHA class II at

admission in the ≥10 cardiologists group than in the registries, may largely stem from the fundamental differences in the inclusion criteria of AHF; the clinically-based Framingham criteria may be stricter and include more severe patients when compared with more subjective decision of the attending physicians.

Second, although a clinical registry database may be thought to be the “gold standard” for many epidemiological studies, these registries tend to be heavily represented by large medical centers. This can result in some selection bias, as large medical centers generally treat more difficult and unusual cases associated with higher mortality or requirements for intensive care. Because approximately 74% of acute care hospitals have fewer than 300 hospital beds in Japan,[9] it is crucial to utilize administrative data to shed light on the quality of care provided in hospitals groups that include smaller hospitals. In consideration of the large number of hospitals and patients included, administrative data is likely to exhibit more diverse patients from various hospitals, and may be suitable to describe inter-hospital differences of quality in provided care. In addition, the low proportion of major intensive procedures (such as PCI, CABG and PMI) in the administrative data may be due to the payment system that makes physicians to record the primary diagnoses (such as angina or arrhythmia) directly related to the procedures other than AHF.

Next, greater use of recommended therapeutic processes of care, measured by sex-age-adjusted ORs, was observed to be associated with a higher number of cardiologists. When

compared with the 1 to 4 cardiologists group, hospitals with no cardiologists were less likely to provide these treatments, whereas the 5 to 9 cardiologists group and the ≥10 cardiologists group were more likely to provide specialty procedures or new drugs, and less likely to provide conventional drugs (e.g., intravenous dopamine or digoxin, digitalis at discharge). Furthermore, the outcome measure of patient risk-adjusted mortality also decreased with increasing numbers of cardiologists. These results support those of prior studies where the case volume was shown to be associated with better care processes and outcomes in congestive HF patients,[15] and high physician volume, especially with cardiologists, was shown to be associated with lower mortality rates.[16] However, it should be noted that these results do not unequivocally indicate that a higher number of cardiologists induces higher quality of care. Elderly patients or terminally ill patients are more likely to undergo less invasive treatment, which can be provided in smaller hospitals with fewer cardiologists. Due to Japan's rapidly aging population, our results may also be indicative of this treatment style.

Additionally, our results showed that lower case volume per cardiologist was related with lower adjusted mortality. The result initially seemed to be contrary to the frequently reported relationship between case volume and outcomes per specialist in major surgeries and cardiovascular interventions.[17,18] These previous studies have used hospital case volume or case volume per physician as a measure of experience with managing diseases. However, the total number of cardiologists per hospital may be better suited to describe the quality of care in specific diseases that require teams of specialists. Our findings both here and in a previous study[19] are therefore not necessarily contradictory to these prior reports.[17,18] Moreover, the quality of care shown by the total number of cardiologists may expand the contents of new draft guidelines from National Institute for Health and Care Excellence (NICE)[20], in which AHF patients are recommended to be seen by specialist teams.[21]

The number of cardiologists is very important in medical emergencies such as AHF or AMI which require immediate intervention and the integrated teamwork of cardiovascular specialists and medical staff with 24-hour coverage. The results from our study may lead to the concept of “resource dependency” as a source of practice variation. This type of care may be considered to be directly affected by the presence and quantity of resources available, and is distinct from individual physicians’ skill or experience. Resource dependency can well explain practice variations before supplier-inducement or patient preferences can influence variations. In other words, the availability of manpower resources may affect the quality of care, leading to practice variations among hospitals.

Finally, we found that the three hospital distribution patterns for specific interventions can be used as a tool to capture diffusion process of a new therapeutic practice. The concept of individual hospital distribution patterns related to the proportion of therapeutic intervention can be illustrated as Supplementary Figure 2. Therapies that are not widely used may show the concave distribution pattern (type C) at first, and would shift from types C to B, finally to type A, when they gradually become more familiar and widespread.

By referring to these three distribution patterns during analyses of cross-sectional data, we may discern how much and how widely a certain therapy is currently adopted among hospitals at a particular time. For example, intravenous carperitide, a recombinant form of atrial natriuretic peptide, which exhibited the intermediate-distribution-stage pattern has been believed to expand in daily practice in Japan,[3,4] yet the characteristics of hospitals that had used this drug remained unclear. Interestingly, the results from our study revealed that the drug had been much less used among hospitals with fewer cardiologists when compared with the ATTEND registry, which included hospitals with larger number of cardiologists. In the context of widely known "innovation diffusion theories",[22, 23] this intermediate-distribution-stage pattern may represent a snapshot of the diffusion process of a new therapeutic practice across multiple facilities over time. Furthermore, these results may be utilized to improve currently provided care from the viewpoint of practice guideline adherence or policymaking perspectives.

Study Limitations

There are several limitations in this study. First, hospitals in this study are restricted to some part of those who actively adopt the DPC system. In addition, the clinical circumstances including the use of drugs may differ across the countries. These may limit the generalizability of our results in worldwide clinical settings. Second, when adjusting outcome measures, we did not consider hospital-level factors such as teaching status, urban location, and the presence of a cardiac intensive care unit, which may also have affected the quality of care. Finally, we could not identify the number of cardiologists who were actually treating AHF patients, differences in competency among individual cardiologists, and the area of cardiovascular subspecialty of each cardiologist. Further studies are required to examine the effect of these issues on quality of care.

CONCLUSIONS

We revealed wide therapeutic practice variations of AHF in association with the number of cardiologists per facility using an administrative database. Recommended therapeutic practices tended to be provided more frequently in hospitals with more cardiologists. Quality of AHF care may be dependent on manpower resources, and further studies are needed to clarify their relationship.

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