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ORIGINAL ARTICLE

The Association of Hospital Volume of Percutaneous Coronary Intervention with Cardiac Mortality

Jae-Hyun Kim[1,2], Jang-Mook Kim[1,2], Eun-Cheol Park[3,4]

[1]Department of Health Administration, Dankook University College of Health Science; [2]Institute of Health Promotion and Policy, Dankook University, Cheonan; [3]Department of Preventive Medicine, Yonsei University College of Medicine; [4]Institute of Health Services Research, Yonsei University, Seoul, Korea

Background: This study investigates the potential volume and outcome association of coronary heart disease (CHD) patients who have undergone percutaneous coronary intervention (PCI) using a large and representative sample.
Methods: We used a National Health Insurance Service-Cohort Sample Database from 2002 to 2013 released by the Korean National Health Insurance Service. A total of 8,908 subjects were analyzed. The primary analysis was based on Cox proportional hazards models to examine our hypothesis.
Results: After adjusting for confounders, the hazard ratio of thirty-day and 1-year mortality in hospitals with a low volume of CHD patients with PCI was 2.8 and 2.2 times higher ($p=0.00$) compared to hospitals with a high volume of CHD patients with PCI, respectively. Thirty-day and 1-year mortality of CHD patients with PCI in low-volume hospitals admitted through the emergency room were 3.101 ($p=0.00$) and 2.8 times higher ($p=0.01$) than those in high-volume hospitals, respectively. Only 30-day mortality in low-volume hospitals of angina pectoris and myocardial infarction patients with PCI was 5.3 and 2.4 times those in high-volume hospitals with PCI, respectively.
Conclusion: Mortality was significantly lower when PCI was performed in a high-volume hospital than in a low-volume hospital. Among patients admitted through the emergency room and diagnosed with angina pectoris, total PCI volume (low vs. high) was associated with significantly greater cardiac mortality risk of CHD patients. Thus, There is a need for better strategic approaches from both clinical and health policy standpoints for treatment of CHD patients.

Keywords: Coronary heart disease; Mortality; Percutaneous coronary intervention

INTRODUCTION

There is considerable evidence to conclude that high-volume hospitals have lower mortality rates compared with low-volume hospitals following complex surgical procedures [1,2]. Since the first volume-outcome relation was reported by Luft et al. [3] in 1979 in cardiology, the association between a hospital's percutaneous coronary intervention (PCI) volume and in-hospital mortality has been extensively investigated [1,3,4]. Furthermore, many earlier studies demonstrated that patients with acute myocardial infarction (AMI) at hospitals performing many primary PCI procedures had lower mortality rates than those at hospitals performing less primary PCI procedures [5], and an inverse volume-outcome relationship for PCI was reported in many studies [6,7].

The introduction of PCI using a balloon catheter by Gruentzig et al. [8] in 1977 revolutionized the treatment of coronary artery disease. Coronary restenosis, a common complication in the early years, was reduced with the implantation of coronary stents used since 1986 [9], a procedure that became standard. In 2001, initially employed uncoated stents were replaced with drug-eluting stents, first eluting sirolimus [10], followed by paclitaxel [11], and subsequently by other drugs [12,13] which, though they failed to abolish restenosis and the need for re-intervention, have made these occurrences less frequent.

Correspondence to: Eun-Cheol Park
Department of Preventive Medicine and Institute of Health Services Research, Yonsei University College of Medicine, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea
Tel: +82-2-2228-1862, Fax: +82-2-392-8133, E-mail: ecpark@yuhs.ac
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Primary PCI is now established as a first-line therapeutic strategy for patients with AMI. Several reports from the United States and France regarding patients undergoing primary PCI have demonstrated an inverse relationship between the hospital volume of primary PCI and in-hospital mortality [5,14].

There is growing interest in the use of procedure volume as a means of identifying hospital quality of care [15]. Based on this evidence, the updated American College of Cardiology/American Heart Association/Society for Cardiovascular Angioplasty and Intervention (ACC/AHA/SCAI) PCI clinical practice guidelines recommend that the minimum annual institutional volume requirement for hospitals offering PCI for ST-segment elevation myocardial infarction (STEMI) be at least 400 elective and 36 primary PCI procedures [16]. In addition, matching current ACC/AHA PCI clinical practice guidelines [17], Leapfrog has established a minimum institutional volume requirement of 400 cases per year for hospitals offering PCI [18]. In contrast, a recent report from Tsuchihashi et al. [19] demonstrates that low-volume hospitals and high-volume hospitals have similar in-hospital outcomes for primary PCI.

However, detailed data regarding the relationships among hospital primary PCI volume, angiographic results, and in-hospital prognosis are still lacking in South Korea. In addition, there have been recent changes in PCI practice, with PCI with stent placement being performed more often than balloon angioplasty as coronary stent technology has progressed (e.g., drug-eluting stents) [20]. We therefore felt it important to reassess this potential volume and outcome association using a large and representative sample.

METHODS

1. Data sources and study design

This study used a National Health Insurance Service-Cohort Sample Database (NHIS-CSD) from 2002 to 2013 released by the Korean National Health Insurance Service.

Initial NHIS-CSD cohort members (n = 1,025,340) were established by stratified random sampling using a systematic sampling method to generate a representative sample of the 46,605,433 Korean residents recorded in 2002. These members were followed up on in 2013. The data comprise a nationally representative random sample of 1,025,340 individuals, approximately 2.2% of the entire 2002 population.

The health care utilization claims include information on prescription drugs, medical procedures, and diagnostic codes based on the International Classification of Diseases, tenth revision (ICD-10), and health care costs. If a member was censored due to death or emigration, a new member was recruited among newborns of the same calendar year. Detailed methods for establishing and ensuring the representativeness of the NHIS-CSD cohort are published on the Korean National Health Insurance Service website [21].

In order to analyze the relationship between volume and outcome association of patients with coronary heart disease (CHD) on mortality, we included the ICD-10 code with I20–I25 in our data for main diagnosis and cardiac mortality records.

We analyzed a unique database of representative individual samples for hospitalized CHD patients with PCI. We linked each PCI patient according to license number to a separate licensure hospital database that included the calendar years. Linkage between each CHD patient with PCI and hospital allowed us to study the association of hospital volume and outcome during a 12-year follow-up sample.

2. Study variables

1) Independent variables

The number of CHD patients with PCI per year was ranked from low to high using SAS Rank function ver. 9.4 (SAS Institute Inc., Cary, NC, USA). Thus, the number of CHD patients with PCI per year was categorized into four groups: low, middle low, middle high, and high.

2) Dependent variables

In this study, our main outcome measures were 30-day and 1-year mortality. The primary end point for this study was 30-day and 1-year mortality after the PCI procedure.

3) Control variables

Individual level (age, sex, household, residential region, patient clinical complexity level [PCCL], inpatient type, diagnosis code, and type of procedure) and hospital level (proportion of PCI per year, organization type, region, beds, doctors, magnetic resonance imaging [MRI], and positron emission tomography [PET]) were included as variables that could affect mortality in the analysis, and all covariate variables were categorical. In order to adjust for clinical severity condition in each patient, PCCL, inpatient type,

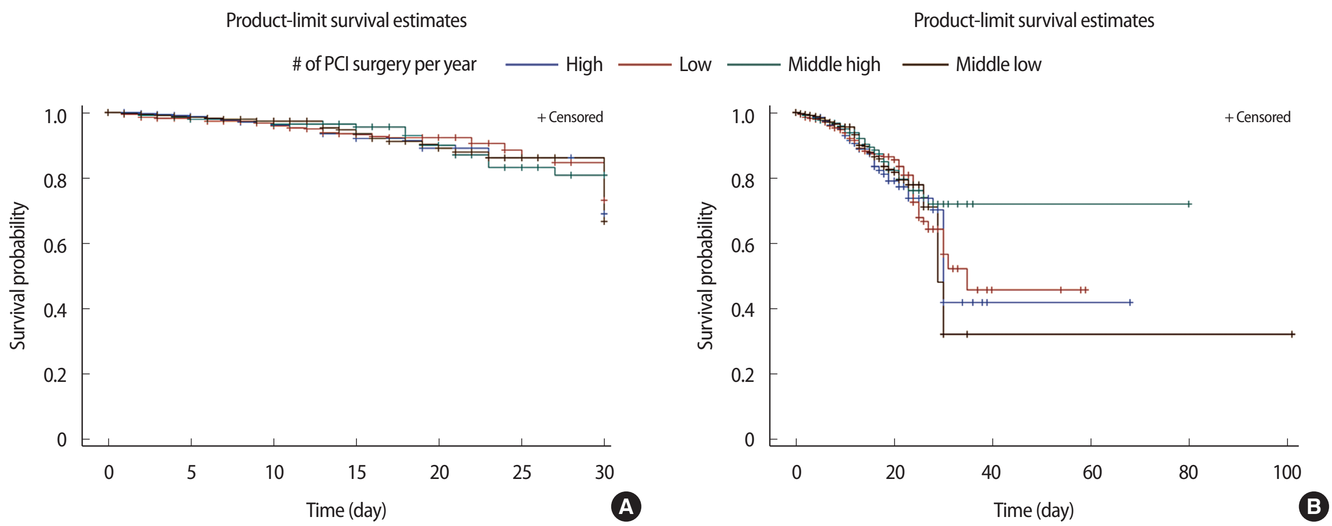

Figure 1. (A) Adjusted effect of hospital volume on 30-day cardiac mortality. (B) Adjusted effect of hospital volume on 1-year cardiac mortality. PCI, percutaneous coronary intervention.

diagnosis code, and type of procedure was used at the individual level.

Age groups were divided into five categories: ≤39, 40–49, 50–59, 60–69, and ≥70 years. Residential regions and region (hospital level) were categorized as metropolitan (Seoul), urban (Daejeon, Daegu, Busan, Incheon, Gwangju, or Ulsan), or rural (not classified as a city). The proportion of PCI per year was divided into four categories using SAS Rank function (SAS Institute Inc.): low, mid low, mid high, and high.

3. Statistical analysis

The primary analysis was based on Cox proportional hazards (PH) models and survival time was calculated as the time between 30 days or 1 year after the PCI procedure and the date of death. The Kaplan-Meier method was used to plot crude survival curves according to time following PCI procedure. In Figure 1, we plot a survival curve for mortality and a cumulative curve for 30-day or 1-year mortality. The modeling of long-term outcomes is affected by the statistical model applied. Considering that critical illness has an effect on outcomes, the Cox PH model, which is the most frequently used model, may be accurate because it relies on the assumption that the prognostic factors have constant hazard ratios over time.

For all analyses, the criterion for significance was $p \leq 0.05$, two-tailed. All analyses were conducted using the SAS statistical software package ver. 9.4 (SAS Institute Inc.).

RESULTS

1. Prevalence of 30-day and 1-year cardiac morality

Of the 8,908 research subjects included in our study, the prevalence of 30-day mortality was 2.4% (212 participants) and the 1-year mortality was 3.9% (349 participants) (Table 1). Of the total sample, 2.9% of 30-day mortality and 4.5% of 1-year mortality were from hospitals with a low volume of PCI per year, while 1.7% of 30-day mortality and 3.1% of 1-year mortality were from hospitals with a high volume of PCI per year (Table 1).

2. Inverse association between volume and outcome of coronary heart disease patients with percutaneous coronary intervention

Table 2 adjusted for age, sex, residential region, PCCL, inpatient type, diagnosis code, type of surgery, proportion of PCI per year, organization type, region, beds, doctors, MRI, and PET. After adjusting for all of these confounders, the hazard ratio of 30-day mortality in a low-volume CHD with PCI patient hospital was 2.8 times higher ($p = 0.00$) compared with those with a high volume of CHD patients with PCI. The hazard ratio of 1-year mortality in a low-volume CHD with PCI patient hospital was 2.187 times higher compared with those in a high-volume CHD with PCI patient hospital (Table 2).

Table 3 illustrates a subgroup analysis conducted according to inpatient type after adjusting for all confounders. Thirty-day mortality in a low-volume CHD patient with PCI hospital admitted

Table 1. General characteristics of subjects included for analysis at baseline

Characteristic	Total no. (%)	30-day cardiac mortality		1-year cardiac mortality	
		Yes (%)	*p*-value	Yes (%)	*p*-value
# of PCI per year			0.06		0.14
Low	2,388 (26.8)	69 (2.9)		107 (4.5)	
Mid low	2,292 (25.7)	58 (2.5)		93 (4.1)	
Mid high	2,123 (23.8)	50 (2.4)		83 (3.9)	
High	2,105 (23.6)	35 (1.7)		66 (3.1)	
Individual					
Sex			0.00		0.00
Male	6,024 (67.6)	122 (2.0)		208 (3.5)	
Female	2,884 (32.4)	90 (3.1)		141 (4.9)	
Age (yr)			<0.001		<0.001
≤39	987 (11.1)	8 (0.8)		10 (1.0)	
40–49	1,986 (22.3)	16 (0.8)		27 (1.4)	
50–59	2,954 (33.2)	47 (1.6)		75 (2.5)	
60–69	2,376 (26.7)	88 (3.7)		149 (6.3)	
≥70	605 (6.8)	53 (8.8)		88 (14.6)	
Residential region			0.05		0.01
Metropolitan	1,756 (19.7)	43 (2.5)		62 (3.5)	
Urban	2,275 (25.5)	39 (1.7)		69 (3.0)	
Rural	4,877 (54.8)	130 (2.7)			
Patient clinical complexity level			<0.001		<0.001
0	5,193 (58.3)	43 (0.8)		81 (1.6)	
1	2,658 (29.8)	134 (5.0)		188 (7.1)	
≥2	1,057 (11.9)	35 (3.3)		80 (7.6)	
Inpatient type			<0.001		<0.001
Emergency room	3,553 (39.9)	147 (4.1)		220 (6.2)	
Outpatient department	5,355 (60.1)	65 (1.2)		129 (2.4)	
Diagnosed code (ischemic heart diseases)			<0.001		<0.001
Angina pectoris	4,690 (52.7)	23 (0.5)		77 (1.6)	
Myocardial infarction	2,791 (31.3)	156 (5.6)		209 (7.5)	
Others	1,427 (16.0)	33 (2.3)		63 (4.4)	
Type of procedure			<0.001		<0.001
Percutaneous transluminal coronary angioplasty	1,002 (11.3)	42 (4.2)		67 (6.7)	
Percutaneous transcatheter placement of intracoronary stent	7,906 (88.8)	170 (2.2)		282 (3.6)	
Hospital					
Proportion of PCI per year			0.24		0.21
Low	2,473 (27.8)	57 (2.3)		96 (3.9)	
Mid low	2,249 (25.3)	43 (1.9)		74 (3.3)	
Mid high	2,138 (24.0)	54 (2.5)		86 (4.0)	
High	2,048 (23.0)	58 (2.8)		93 (4.5)	
Organization type			0.89		0.56
Public	76 (0.9)	2 (2.6)		2 (2.6)	
Private	8,832 (99.2)	210 (2.4)		347 (3.9)	
Region			0.00		<0.001
Metropolitan	2,455 (27.6)	43 (1.8)		66 (2.7)	
Urban	2,979 (33.4)	62 (2.1)		105 (3.5)	
Rural	3,474 (39.0)	107 (3.1)		178 (5.1)	
Bed			0.00		0.00
≤499	1,003 (11.3)	20 (2.0)		27 (2.7)	
500–699	1,311 (14.7)	52 (4.0)		77 (5.9)	
700–899	1,359 (15.3)	33 (2.4)		54 (4.0)	
≥900	5,235 (58.8)	107 (2.0)		191 (3.7)	

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Table 1. Continued

Characteristic	Total no. (%)	30-day cardiac mortality		1-year cardiac mortality	
		Yes (%)	*p*-value	Yes (%)	*p*-value
Doctor			0.01		0.00
≤ 99	1,673 (18.8)	40 (2.4)		66 (4.0)	
100–199	1,317 (14.8)	40 (3.0)		65 (4.9)	
200–299	1,527 (17.1)	49 (3.2)		81 (5.3)	
≥ 300	4,391 (49.3)	83 (1.9)		137 (3.1)	
Magnetic resonance imaging			0.68		0.59
No	7 (0.1)	0		0	
Yes	8,901 (99.9)	212 (2.4)		349 (3.9)	
Positron emission tomography			0.81		0.75
No	1,226 (13.8)	28 (2.3)		46 (3.8)	
Yes	7,682 (86.2)	184 (2.4)		303 (3.9)	
Total	8,908 (100.0)	212 (2.4)		349 (3.9)	

PCI, percutaneous coronary intervention.

Table 2. Adjusted effect between # of PCI and cardiac mortality

Variable	30-day cardiac mortality			1-year cardiac mortality		
	HR	SE	*p*-value	HR	SE	*p*-value
# of PCI per year						
Low	2.8	0.3	0.00	2.2	0.2	0.00
Mid low	2.3	0.2	0.00	1.8	0.2	0.00
Mid high	1.9	0.2	0.00	1.5	0.2	0.01
High	1.0			1.0		
Individual						
Sex						
Male	1.2	0.1	0.11	1.5	0.1	< 0.001
Female	1.0			1.0		
Age (yr)						
≤ 39	0.2	0.4	< 0.001	0.2	0.3	< 0.001
40–49	0.3	0.2	< 0.001	0.2	0.2	< 0.001
50–59	0.6	0.2	0.01	0.4	0.1	< 0.001
60–69	1.0	0.2	0.95	0.8	0.1	0.04
≥ 70	1.0			1.0		
Residential region						
Metropolitan	1.3	0.2	0.19	1.2	0.2	0.23
Urban	0.7	0.2	0.06	0.8	0.1	0.14
Rural	1.0			1.0		
Patient clinical complexity level						
0	0.2	0.3	< 0.001	0.3	0.2	< 0.001
1	0.7	0.2	0.06	0.7	0.2	0.01
≥ 2	1.0			1.0		
Inpatient type						
Emergency room	1.4	0.1	0.01	1.2	0.1	0.16
Outpatient department	1.0			1.0		
Diagnosed code (ischemic heart diseases)						
Angina pectoris	1.0			1.0		
Myocardial infarction	8.8	0.2	< 0.001	3.6	0.1	< 0.001
Others	2.4	0.2	0.00	1.4	0.2	0.02
Type of procedure						
Percutaneous transluminal coronary angioplasty	1.5	0.2	0.00	1.5	0.1	0.00
Percutaneous transcatheter placement of intracoronary stent	1.0			1.0		

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Table 2. Continued

Variable	30-day cardiac mortality			1-year cardiac mortality		
	HR	SE	*p*-value	HR	SE	*p*-value
Hospital						
Proportion of PCI per year						
Low	0.5	0.2	0.01	0.6	0.2	0.01
Mid low	0.5	0.2	0.00	0.6	0.2	0.00
Mid high	0.6	0.2	0.01	0.7	0.1	0.00
High	1.0			1.0		
Organization type						
Public	0.9	0.7	0.86	0.6	0.7	0.51
Private	1.0			1.0		
Region						
Metropolitan	0.6	0.2	0.02	0.5	0.2	< 0.001
Urban	0.8	0.2	0.31	0.7	0.1	0.01
Rural	1.0			1.0		
Bed						
≤ 499	0.9	0.4	0.74	0.4	0.3	0.00
500–699	1.0	0.2	0.95	0.6	0.2	0.02
700–899	0.6	0.2	0.01	0.5	0.2	< 0.001
≥ 900	1.0			1.0		
Doctor						
≤ 99	0.9	0.3	0.83	1.5	0.2	0.08
100–199	0.7	0.2	0.18	1.1	0.2	0.55
200–299	0.9	0.2	0.61	1.1	0.1	0.43
≥ 300	1.0			1.0		
Magnetic resonance imaging						
No	0.0	210.6	0.97	0.0	177.5	0.96
Yes	1.0			1.0		
Positron emission tomography						
No	0.8	0.3	0.43	1.1	0.2	0.78
Yes	1.0			1.0		

PCI, percutaneous coronary intervention; HR, hazard ratio; SE, standard error.

Table 3. Adjusted effect between # of PCI and cardiac mortality by inpatient type

# of PCI per year	Emergency room						Outpatient department					
	30-day cardiac mortality			1-year cardiac mortality			30-day cardiac mortality			1-year cardiac mortality		
	HR	SE	*p*-value	HR	SE	*p*-value	HR	SE	*p*-value	HR	SE	*p*-value
Low	3.1	0.4	0.00	2.8	0.3	0.00	1.7	0.5	0.30	1.2	0.4	0.68
Mid low	2.7	0.3	0.00	2.2	0.2	0.00	1.1	0.4	0.75	0.9	0.3	0.86
Mid high	2.4	0.2	0.00	1.7	0.2	0.00	0.6	0.5	0.36	1.0	0.3	0.99
High	1.0			1.0			1.0			1.0		

Adjusted for sex, age, residential region patient clinical complexity level, diagnosed code, type of procedure, proportion of PCI per year, organization type, region bed doctor, magnetic resonance imaging, and positron emission tomography.
PCI, percutaneous coronary intervention; HR, hazard ratio; SE, standard error.

through the emergency room was 2.2 times higher ($p = 0.00$) than hospitals with a high volume of CHD patients with PCI. One-year mortality in a hospital with a low volume of CHD patients with PCI admitted through the emergency room was 2.8 times higher ($p = 0.00$) than hospitals with a high volume of CHD patients with PCI.

We then conducted subgroup analysis according to diagnosis code after adjusting for all confounders. Thirty-day mortality in a hospital with a low volume of angina pectoris patients with PCI was 5.3 times higher ($p = 0.03$) than in a hospital with a high volume of angina pectoris patients with PCI (Table 4).

Thirty-day mortality in a hospital with a low volume of myocar-

Table 4. Adjusted effect between # of PCI and cardiac mortality by diagnosed code

# of PCI per year	Angina pectoris						Myocardial infarction						Others					
	30-day cardiac mortality			1-year cardiac mortality			30-day cardiac mortality			1-year cardiac mortality			30-day cardiac mortality			1-year cardiac mortality		
	HR	SE	*p*-value	HR	SE	*p*-value	HR	SE	*p*-value	HR	SE	*p*-value	HR	SE	*p*-value	HR	SE	*p*-value
Low	5.3	0.7	0.03	1.9	0.5	0.24	2.4	0.3	0.01	2.1	0.3	0.01	2.6	0.8	0.25	1.3	0.5	0.63
Mid low	4.9	0.6	0.00	1.6	0.4	0.23	2.0	0.3	0.01	1.6	0.2	0.03	3.5	0.7	0.07	1.4	0.4	0.38
Mid high	2.9	0.5	0.02	1.4	0.4	0.35	1.6	0.2	0.04	1.4	0.2	0.13	2.8	0.6	0.07	1.6	0.3	0.16
High	1.0			1.0			1.0			1.0			1.0			1.0		

Adjusted for sex, age, residential region patient clinical complexity level, inpatient type, type of procedure, proportion of PCI per year, organization type, region bed doctor, magnetic resonance imaging, and positron emission tomography.
PCI, percutaneous coronary intervention; HR, hazard ratio; SE, standard error.

dial infarction patients with PCI was 2.4 times higher ($p=0.01$) than in hospitals with a high volume of myocardial infarction patients with PCI. One-year mortality in a hospital with a low volume of myocardial infarction patients with PCI was 2.1 times higher ($p=0.01$) than in a hospital with a high volume of myocardial infarction patients with PCI.

DISCUSSION

Our study provides insightful evidence regarding the specificity of volume and outcome (30-day and/or 1-year mortality) in current practice. The significant inverse association between hospital volume and 30-day mortality and 1-year mortality after PCI procedures was evaluated by analyzing the 2002–2013 database of the nationally large representative and longitudinal cohort sample in Korea.

The major findings of our study are as follows: Korean CHD patients treated with primary PCI in high-volume hospitals had lower cardiac mortality rates than those in low-volume hospitals. There was a significant difference between high-volume and low-volume hospitals in both 30-day and 1-year mortality rates. We also found that CHD patients treated at hospitals with relatively low annual PCI cases had the highest 30-day and 1-year mortality rates, followed by patients treated at middle-low PCI volume hospitals, whereas patients treated at high-PCI volume hospitals had the lowest 30-day and 1-year mortality rates.

Additionally, we conducted subgroup analysis according to inpatient type and diagnosed code. Results of our subgroup analysis also showed inverse volume-outcome relationships of CHD patients with PCI. In particular, there was a substantial difference in mortality rate between high-volume and low-volume hospitals for patients admitted through the emergency room and diagnosed with angina pectoris. After adjusting for patient characteristics (sex, age, residential region, PCCL, inpatient type, diagnosis code, and type of surgery) and hospital characteristics (proportion of PCI per year, organization type, beds, doctors, MRI, and PET), the hazard ratio of 30-day and 1-year mortality for patients treated at hospitals with low annual PCI cases were 3.1 ($p=0.01$) and 2.8 ($p=0.00$) times higher than for patients treated at high-PCI volume hospitals admitted through the emergency room. In addition, the hazard ratio of 30-day and 1-year mortality for patients treated at hospitals with relatively low annual PCI cases were higher than for patients treated at hospitals with a high volume of PCI patients with a diagnosis code of angina pectoris and myocardial infarction.

The relationship between the annual hospital volume of primary PCI and mortality has not been fully investigated in Korea. However, several reports from the United States and France demonstrate that low primary PCI-volume hospitals had higher in-hospital mortality than high-volume hospitals [14,22,23]. In this study, our finding is consistent with several previous studies in which an inverse relationship between hospital procedure volume and adverse outcomes was reported [4,24,25].

According to the guidelines for PCI published by the AHA, ACC, and SCAI in 2005, primary PCI for ST-segment elevation AMI should be performed in centers with an annual volume of at least 400 elective and 36 primary PCI procedures [16], and some studies report significant differences in adverse outcomes among hospital volume groups with cutoffs other than the 400 annual PCI case value [6,26,27]. Although our findings do not lend support to the minimum annual hospital PCI volumes of 400 cases recommended by the ACC/AHA clinical practice guidelines [28], our results are in agreement with those [29-31] that show an inverse volume-outcome relationship. However, previous studies that show a decrease in mortality with increasing operator volume have failed to reach statistical significance because of low sample size, large confidence interval, or low procedure-related mortality [4,28].

A potential explanation for our subgroup analysis results according to inpatient type and diagnosis code is that high-volume emergency rooms tend to be located in more urban areas and accommodate more patients with rapid cardiopulmonary resuscitation in progress and these emergency room-admitted patients receive same-day PCI. Previous study indicates that the strongest predictor of same-day PCI use for patients with STEMIs was hospital PCI volume. Patients with a STEMI admitted to hospitals that performed a total of 200 or more PCIs per year were nearly seven times as likely to receive same-day PCI compared with similar patients admitted to low-volume PCI hospitals [32,33]. In addition, several known advantages of high-volume PCI hospitals likely contributed to cardiac catheterization laboratory availability, standard emergency room protocols for the treatment of CHD patients, and standard catheterization laboratory activation protocols [32].

Although the ACC/AHA clinical practice guidelines recommend a minimum annual hospital PCI case volume of 400, various cut-off points were used in the studies. In addition, in our study, it was not possible to exactly define a specific minimum procedure below which the outcome of CHD patients with PCI would be worse than for those patients treated in hospitals meeting this minimum requirement. Therefore, future evaluations of hospital PCI volume thresholds will be needed to assess recent and pending changes in PCI technology and practice. Given this evidence, there is a need for better strategic approaches from clinical and health policy standpoints for the treatment of CHD patients with PCI. These strategies should be based not only on establishing a recommended volume of primary PCI procedures, but also on developing protocols regarding patient safety. These improvements will result in improved care of CHD patients with PCI.

One strength of our study was that the participants in the survey may be representative of the overall population. Indeed, our large and longitudinal sample allowed the results to be generalized to the adult South Korean population. Nevertheless, several limitations that may have affected our results need to be considered in the interpretation of our findings. First, selection of patients for our study relied on ICD coding of principal diagnosis. Variability in coding practices among individuals and institutions may have influenced our results. It is difficult to validate individual ICD codes because our data is a de-identified database, making it susceptible to errors related to coding. Second, as this is a large and longitudinal nationwide sample, there may be significant heterogeneity in the care provided both in the field and at receiving hospitals. We cannot comment on which aspects of patient care most affected survival.

In conclusion, the PCI is a procedure that delivers excellent results, and is employed more and more each year. The present study provides evidence that in Korea, CHD patients treated with primary PCI in high-volume hospitals exhibit lower mortality than those treated at low-volume hospitals, as reported in many studies. In addition, patients admitted through an emergency room and diagnosed with angina pectoris in a hospital with a relatively lower annual PCI volume had higher mortality rates. An improved understanding of the contribution of emergency department care may be useful in advancing our understanding of how best to organize a system of care to ensure optimal outcomes for CHD patients with PCI.

ORCID

Jae-Hyun Kim: https://orcid.org/0000-0002-3531-489X; Jang Mook Kim https://orcid.org/0000-0003-0703-4994; Eun-Cheol Park https://orcid.org/0000-0002-2306-5398

REFERENCES

1. Begg CB, Cramer LD, Hoskins WJ, Brennan MF. Impact of hospital volume on operative mortality for major cancer surgery. JAMA 1998;280(20):1747-1751. DOI: https://doi.org/10.1001/jama.280.20.1747.
2. Birkmeyer JD, Siewers AE, Finlayson EV, Stukel TA, Lucas FL, Batista I, et al. Hospital volume and surgical mortality in the United States. N Engl J Med 2002;346(15):1128-1137. DOI: https://doi.org/10.1056/NEJMsa012337.
3. Luft HS, Bunker JP, Enthoven AC. Should operations be regionalized?: the empirical relation between surgical volume and mortality 1979. Clin Orthop Relat Res 2007;457:3-9. DOI: https://doi.org/10.1097/BLO.0b013e318034285e.
4. McGrath PD, Wennberg DE, Dickens JD Jr, Siewers AE, Lucas FL, Malenka DJ, et al. Relation between operator and hospital volume and outcomes following percutaneous coronary interventions in the era of the coronary stent. JAMA 2000;284(24):3139-3144. DOI: https://doi.org/10.1001/jama.284.24.3139.
5. Magid DJ, Calonge BN, Rumsfeld JS, Canto JG, Frederick PD, Every NR, et al. Relation between hospital primary angioplasty volume and mortality for patients with acute MI treated with primary angioplasty vs thrombolytic therapy. JAMA 2000;284(24):3131-3138. DOI: https://doi.org/

10.1001/jama.284.24.3131.
6. Jollis JG, Peterson ED, DeLong ER, Mark DB, Collins SR, Muhlbaier LH, et al. The relation between the volume of coronary angioplasty procedures at hospitals treating Medicare beneficiaries and short-term mortality. N Engl J Med 1994;331(24):1625-1629. DOI: https://doi.org/10.1056/NEJM199412153312406.
7. Jollis JG, Peterson ED, Nelson CL, Stafford JA, DeLong ER, Muhlbaier LH, et al. Relationship between physician and hospital coronary angioplasty volume and outcome in elderly patients. Circulation 1997;95(11):2485-2491. DOI: https://doi.org/10.1161/01.cir.95.11.2485.
8. Gruentzig AR, Myler RK, Hanna ES, Turina MI. Coronary transluminal angioplasty [abstract]. Circulation 1977;56(Suppl. 3):III-84.
9. Sigwart U, Puel J, Mirkovitch V, Joffre F, Kappenberger L. Intravascular stents to prevent occlusion and restenosis after transluminal angioplasty. N Engl J Med 1987;316(12):701-706. DOI: https://doi.org/10.1056/NEJM198703193161201.
10. Morice MC, Serruys PW, Sousa JE, Fajadet J, Ban Hayashi E, Perin M, et al. Randomized study with the Sirolimus-coated Bx Velocity balloon-expandable stent in the treatment of patients with de novo native coronary artery lesions: a randomized comparison of a sirolimus-eluting stent with a standard stent for coronary revascularization. N Engl J Med 2002;346(23):1773-1780. DOI: https://doi.org/10.1056/NEJMoa012843.
11. Grube E, Silber S, Hauptmann KE, Mueller R, Buellesfeld L, Gerckens U, et al. TAXUS I: six- and twelve-month results from a randomized, double-blind trial on a slow-release paclitaxel-eluting stent for de novo coronary lesions. Circulation 2003;107(1):38-42. DOI: https://doi.org/10.1161/01.cir.0000047700.58683.a1.
12. Kedhi E, Joesoef KS, McFadden E, Wassing J, van Mieghem C, Goedhart D, et al. Second-generation everolimus-eluting and paclitaxel-eluting stents in real-life practice (COMPARE): a randomised trial. Lancet 2010;375(9710):201-209. DOI: https://doi.org/10.1016/S0140-6736(09)62127-9.
13. Serruys PW, Silber S, Garg S, van Geuns RJ, Richardt G, Buszman PE, et al. Comparison of zotarolimus-eluting and everolimus-eluting coronary stents. N Engl J Med 2010;363(2):136-146. DOI: https://doi.org/10.1056/NEJMoa1004130.
14. Canto JG, Every NR, Magid DJ, Rogers WJ, Malmgren JA, Frederick PD, et al. The volume of primary angioplasty procedures and survival after acute myocardial infarction. National Registry of Myocardial Infarction 2 Investigators. N Engl J Med 2000;342(21):1573-1580. DOI: https://doi.org/10.1056/NEJM200005253422106.
15. Phillips KA, Luft HS. The policy implications of using hospital and physician volumes as “indicators” of quality of care in a changing health care environment. Int J Qual Health Care 1997;9(5):341-348. DOI: https://doi.org/10.1093/intqhc/9.5.341.
16. Smith SC Jr, Feldman TE, Hirshfeld JW Jr, Jacobs AK, Kern MJ, King SB 3rd, et al. ACC/AHA/SCAI 2005 guideline update for percutaneous coronary intervention-summary article: a report of the American College of Cardiology/American Heart Association task force on practice guidelines (ACC/AHA/SCAI Writing Committee to update the 2001 guidelines for percutaneous coronary intervention). J Am Coll Cardiol 2006;47(1):216-235. DOI: https://doi.org/10.1016/j.jacc.2005.11.025.
17. Smith SC Jr, Dove JT, Jacobs AK, Kennedy JW, Kereiakes D, Kern MJ, et al. ACC/AHA guidelines for percutaneous coronary intervention (revision of the 1993 PTCA guidelines)-executive summary: a report of the American College of Cardiology/American Heart Association task force on practice guidelines (committee to revise the 1993 guidelines for percutaneous transluminal coronary angioplasty) endorsed by the Society for Cardiac Angiography and Interventions. Circulation 2001;103(24):3019-3041. DOI: https://doi.org/10.1161/01.cir.103.24.3019.
18. Milstein A, Galvin RS, Delbanco SF, Salber P, Buck CR Jr. Improving the safety of health care: the leapfrog initiative. Eff Clin Pract 2000;3(6):313-316.
19. Tsuchihashi M, Tsutsui H, Tada H, Shihara M, Takeshita A, Kono S, et al. Volume-outcome relation for hospitals performing angioplasty for acute myocardial infarction: results from the Nationwide Japanese Registry. Circ J 2004;68(10):887-891. DOI: https://doi.org/10.1253/circj.68.887.
20. Horiguchi H, Yasunaga H, Hashimoto H, Matsuda S. Impact of drug-eluting stents on treatment option mix for coronary artery disease in Japan. Circ J 2010;74(8):1635-1643. DOI: https://doi.org/10.1253/circj.cj-10-0061.
21. Lee JY, Kim KH, Lee JS. Establishment of a nation cohort sample database using national health insurance data. Wonju: National Health Insurance Service; 2014.
22. Spaulding C, Morice MC, Lancelin B, El Haddad S, Lepage E, Bataille S, et al. Is the volume-outcome relation still an issue in the era of PCI with systematic stenting? Results of the greater Paris area PCI registry. Eur Heart J 2006;27(9):1054-1060. DOI: https://doi.org/10.1093/eurheartj/ehi843.
23. Hannan EL, Wu C, Walford G, King SB 3rd, Holmes DR Jr, Ambrose JA, et al. Volume-outcome relationships for percutaneous coronary interventions in the stent era. Circulation 2005;112(8):1171-1179. DOI: https://doi.org/10.1161/CIRCULATIONAHA.104.528455.
24. Dawkins KD, Gershlick T, de Belder M, Chauhan A, Venn G, Schofield P, et al. Percutaneous coronary intervention: recommendations for good practice and training. Heart 2005;91 Suppl 6:vi1-27. DOI: https://doi.org/10.1136/hrt.2005.061457.
25. Vakili BA, Kaplan R, Brown DL. Volume-outcome relation for physicians and hospitals performing angioplasty for acute myocardial infarction in New York state. Circulation 2001;104(18):2171-2176. DOI: https://doi.org/10.1161/hc3901.096668.
26. Kimmel SE, Sauer WH, Brensinger C, Hirshfeld J, Haber HL, Localio AR. Relationship between coronary angioplasty laboratory volume and outcomes after hospital discharge. Am Heart J 2002;143(5):833-840. DOI: https://doi.org/10.1067/mhj.2002.122116.
27. Epstein AJ, Rathore SS, Volpp KG, Krumholz HM. Hospital percutaneous coronary intervention volume and patient mortality, 1998 to 2000: does the evidence support current procedure volume minimums? J Am Coll Cardiol 2004;43(10):1755-1762. DOI: https://doi.org/10.1016/j.jacc.2003.09.070.
28. Smith SC Jr, Dove JT, Jacobs AK, Kennedy JW, Kereiakes D, Kern MJ, et al. ACC/AHA guidelines of percutaneous coronary interventions (revision of the 1993 PTCA guidelines)--executive summary: a report of the American College of Cardiology/American Heart Association task force on practice guidelines (committee to revise the 1993 guidelines for percutaneous transluminal coronary angioplasty). J Am Coll Cardiol 2001;37(8):2215-2239. DOI: https://doi.org/10.1016/s0735-1097(01)01344-4.
29. Kimmel SE, Berlin JA, Strom BL, Laskey WK. Development and validation of simplified predictive index for major complications in contemporary percutaneous transluminal coronary angioplasty practice. The Registry Committee of the Society for Cardiac Angiography and Interventions. J Am Coll Cardiol 1995;26(4):931-938. DOI: https://doi.org/10.1016/0735-1097(95)00294-4.
30. Moscucci M, Eagle KA, Share D, Smith D, De Franco AC, O’Donnell M, et al. Public reporting and case selection for percutaneous coronary interventions: an analysis from two large multicenter percutaneous coronary intervention databases. J Am Coll Cardiol 2005;45(11):1759-1765. DOI: https://doi.org/10.1016/j.jacc.2005.01.055.

31. Zahn R, Gottwik M, Hochadel M, Senges J, Zeymer U, Vogt A, et al. Volume-outcome relation for contemporary percutaneous coronary interventions (PCI) in daily clinical practice: is it limited to high-risk patients?: results from the Registry of Percutaneous Coronary Interventions of the Arbeitsgemeinschaft Leitende Kardiologische Krankenhausarzte (ALKK). Heart 2008;94(3):329-335. DOI: https://doi.org/10.1136/hrt.2007.118737.
32. Smith SC Jr, Feldman TE, Hirshfeld JW Jr, Jacobs AK, Kern MJ, King SB 3rd, et al. ACC/AHA/SCAI 2005 guideline update for percutaneous coronary intervention--summary article: a report of the American College of Cardiology/American Heart Association task force on practice guidelines (ACC/AHA/SCAI Writing Committee to update the 2001 guidelines for percutaneous coronary intervention). Circulation 2006;113(1):156-175. DOI: https://doi.org/10.1161/CIRCULATIONAHA.105.170815.
33. Antman EM, Anbe DT, Armstrong PW, Bates ER, Green LA, Hand M, et al. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association task force on practice guidelines (committee to revise the 1999 guidelines for the management of patients with acute myocardial infarction). Circulation 2004;110(9):e82-e292.