

# Changes in the Practice of Coronary Revascularization between 2006 and 2010 in the Republic of Korea

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interest.

**Purpose:** Evidence suggests that technological innovations and reimbursement schemes of the National Health Insurance Service may have impacted the management of coronary artery disease. Thus, we investigated changes in the practice patterns of coronary revascularization. **Materials and Methods:** Revascularization and in-hospital mortality among Koreans  $\geq 20$  years old were identified from medical claims filed between 2006 and 2010. The age- and sex-standardized procedure rate per 100000 person-years was calculated directly from the distribution of the 2008 Korean population. **Results:** The coronary revascularization rate increased from 116.1 (95% confidence interval, 114.9–117.2) in 2006 to 131.0 (129.9–132.1) in 2010. Compared to the rate ratios in 2006, the rate ratios for percutaneous coronary intervention (PCI) and coronary artery bypass graft (CABG) surgery in 2010 were 1.16 (1.15–1.17) and 0.80 (0.76–0.84), respectively. Among patients who received PCI, the percentage with drug-eluting stents increased from 89.1% in 2006 to 93.0% in 2010. In-hospital mortality rates from PCI significantly increased during the study period ( $p=0.03$ ), whereas those from CABG significantly decreased ( $p=0.01$ ). The in-hospital mortality rates for PCI and CABG were higher in elderly and female patients and at the lowest-volume hospitals. **Conclusion:** The annual volume of coronary revascularization continuously increased between 2006 and 2010 in Korea, although this trend differed according to procedure type. A high percentage of drug-eluting stent procedures and a high rate of in-hospital mortality at low-volume hospitals were noted.

**Key Words:** Myocardial revascularization, percutaneous coronary intervention, insurance, reimbursement

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## INTRODUCTION

Most percutaneous coronary intervention (PCI) procedures are electively performed in patients with stable coronary artery disease.<sup>1</sup> However, recent advancements in catheter-based technology, radiographic imaging, and stent composition and deployment have allowed PCI to be performed in patients with diffuse lesions, multi-

vessel disease, and left-main disease.<sup>2-8</sup> Bare-metal stents (BMS) and drug-eluting stents (DES) improve outcomes from angioplasty by providing mechanical support.

Compared to BMS, DES release immunosuppressive and anti-proliferative drugs and consequently prevent neointimal hyperplasia, which is a leading cause of restenosis in patients with BMS.<sup>9,10</sup>

Several clinical studies have shown that, compared with the previous era when BMS were used, the use of DES has had relatively lower rates of restenosis, relieving concerns about technical problems.<sup>11,12</sup> However, since 2006, several studies have reported that the use of PCI as an initial treatment for stable coronary artery disease does not reduce the risk of major cardiovascular events.<sup>13</sup> Furthermore, these reports show that the use of DES increases the risk of stent thrombosis.<sup>14,15</sup> Consequently, there have been changes in the management of coronary disease in Western countries.<sup>16</sup>

In the Republic of Korea (ROK), all Koreans are required to participate in the National Health Insurance (NHI) program. Thus, in addition to differences in the clinical characteristics of coronary artery disease in different individuals, the practice patterns for coronary revascularization in the ROK might differ from those in other countries due to reimbursement policies. However, there have been no studies on this issue. Therefore, in this study, we investigated changes in the practice patterns of coronary revascularization and the risk of in-hospital mortality after coronary revascularization.

## MATERIALS AND METHODS

Medical claims data reported to the Health Insurance Review and Assessment Service (HIRA) between 2006 and 2010 were used to identify cases of coronary revascularization. Due to the NHI program, all clinics and hospitals must submit medical utilization data to HIRA, including disease codes [International Classification of Diseases, 10th revision (ICD10)], diagnostic and treatment procedures, drug prescriptions, outcomes of hospitalization, and medical costs.

We identified cases of coronary revascularization among patients admitted with cardiovascular diseases (I21–I25) who were  $\geq 20$  years old. Thus, all patients who received elective, urgent, and emergency coronary revascularization procedures were included. However, due to the lack clinical data for patients, we could not provide further differentiation in the analysis.

In-hospital mortality was defined as deaths from all causes

during hospitalization for coronary revascularization. PCI procedures were classified as BMS or DES based on the medical device codes in the HIRA system; the types of DES were further classified as first, second, or third generation.<sup>17</sup> PCI procedures that did not include BMS or DES were designated as angioplasties. Hospitals were divided into tertiles based on the annual number of PCI or coronary artery bypass graft (CABG) procedures each year.

The proportional differences in sex, age, stent type, and in-hospital mortality from 2006 to 2010 were investigated using the chi-square test. The age- and sex-standardized procedure rate per 100000 person-years was directly calculated from the distribution of the 2008 Korean population. The rate ratios (RRs) of coronary revascularization and the 95% confidence intervals were estimated with the Poisson regression model after adjusting for age and gender, and a trend test in which ordinal scores were assigned to calendar years was also performed. In the Poisson regression model, the specific number of procedures according to each calendar year, age, and gender was used as a dependent variable, and the size of the population at risk (mid-year population in each year) was used as an offset term. An event of coronary revascularization was considered a unit of analysis.

The risk of in-hospital mortality was estimated with a generalized linear mixed-effects model for binomial data using a logit link function; stratified analyses by age, gender, and procedure volume in each hospital were performed. A linear trend test was also performed after including ordinal scores for each calendar year in the generalized linear mixed-effects model. Due to the potential effects of annual procedure volumes, we included tertiles of procedure volume as a random effect and sex, age group, and year of procedure as independent variables in the generalized linear mixed-effects model.

To explore the pattern of repeated coronary revascularization after PCI, we constructed a procedure cohort consisting of patients who received PCI from 2007 to 2009 and did not have prior revascularization within the preceding 12 months. The procedure cohort was followed for 12 months.

All statistical analyses were performed with SAS version 9.1.3 (SAS Institute Inc., Cary, NC, USA).

## RESULTS

### Utilization of coronary revascularization

Among 210914 patients, 247325 coronary revascularization procedures were reported between 2006 and 2010. Table 1

shows the annual number of coronary revascularization procedures from 2006 to 2010 by sex, age, and type of revascularization. The number of PCI procedures increased by 35%, whereas the number of CABG procedures decreased by 6.5%. The increase in PCI was observed in each age and sex group. The proportion of patients who received DES continuously increased from 89.1% in 2006 to 93.0% in 2010 (Table 1). Fig. 1 shows the quarterly distribution of PCI according to the type of stent.

A reduced number of CABG procedures was observed in both genders and in each age strata, with the exception of the  $\geq 75$ -year-old group. The percentages of male and elderly

( $\geq 65$  years old) patients who received PCI or CABG increased over the 5-year period. The number of hospitals that provided PCI and CABG increased by 23.5% and 13.0%, respectively.

#### Age- and sex-adjusted coronary revascularization rate

The age- and sex-standardized rate of PCI per 100000 person-years increased during the 5-year study period. The rate of PCI increased from 106.5 in 2006 to 123.4 in 2010. However, the rate of CABG decreased from 9.5 in 2006 to 7.6 in 2010 (Table 2). The rates for PCI and CABG were highest among men and elderly patients (55–74 years old).

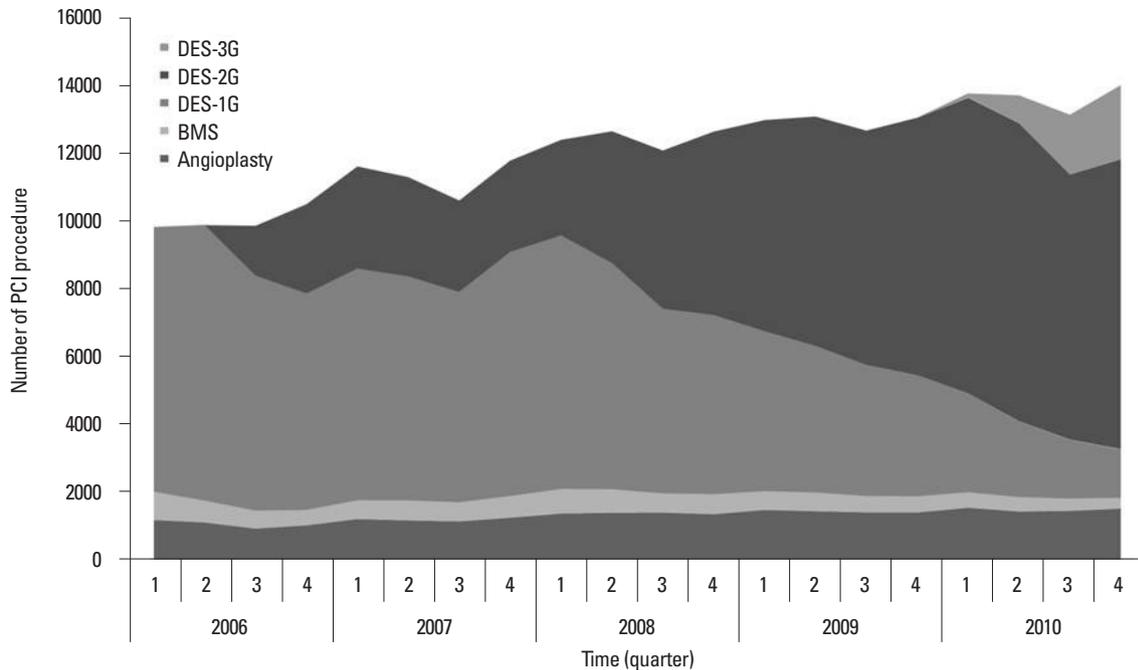
**Table 1.** Annual Number of Coronary Revascularizations According to Sex, Age, and Stent Type from 2006 to 2010 in the Republic of Korea

	2006 (n=40653)	2007 (n=45025)	2008 (n=48963)	2009 (n=50662)	2010 (n=53589)	p value
<b>PCI</b>						
Total	37323 (91.8)	41565 (92.3)	45444 (92.8)	47405 (93.6)	50489 (94.2)	
Sex						<0.0001
Men	24571 (65.8)	27272 (65.6)	29632 (65.2)	31599 (66.7)	33939 (67.2)	
Women	12752 (34.2)	14293 (34.4)	15812 (34.8)	15806 (33.3)	16550 (32.8)	
Age, yrs						<0.0001
20–49	4837 (13.0)	5223 (12.6)	5432 (12.0)	5358 (11.3)	5566 (11.0)	
50–64	14923 (40.0)	16092 (38.7)	17135 (37.7)	17664 (37.3)	18644 (36.9)	
65–74	12393 (33.2)	14150 (34.0)	15582 (34.3)	16268 (34.3)	16863 (33.4)	
$\geq 75$	5170 (13.9)	6100 (14.7)	7295 (16.1)	8115 (17.1)	9416 (18.6)	
Stent type <sup>†</sup>						<0.0001*
Angioplasty	4197 (11.2)	4727 (11.4)	5480 (12.1)	5693 (12.0)	6101 (12.1)	
BMS	2467 (6.6)	2349 (5.7)	2569 (5.7)	2059 (4.3)	1550 (3.1)	
1st-gen DES	29145 (78.1)	26751 (64.4)	24797 (54.6)	16393 (34.6)	8268 (16.4)	
2nd-gen DES	4101 (11.0)	11314 (27.2)	16756 (36.9)	27470 (57.9)	33827 (67.0)	
3rd-gen DES	-	-	-	-	4860 (9.6)	
In-hospital mortality	544 (1.5)	615 (1.5)	707 (1.6)	748 (1.6)	909 (1.8)	<0.0001
No. of hospitals providing procedure	119	125	135	140	147	
<b>CABG</b>						
Total	3330 (8.2)	3460 (7.7)	3519 (7.2)	3257 (6.4)	3100 (5.8)	
Sex						0.1
Men	2295 (68.9)	2458 (71.0)	2433 (69.1)	2304 (70.7)	2208 (71.2)	
Women	1035 (31.1)	1002 (29.0)	1086 (30.9)	953 (29.3)	892 (28.8)	
Age, yrs						<0.0001
20–49	276 (8.3)	301 (8.7)	255 (7.2)	260 (8.0)	204 (6.6)	
50–64	1400 (42.0)	1432 (41.4)	1383 (39.3)	1266 (38.9)	1175 (37.9)	
65–74	1317 (39.5)	1363 (39.4)	1482 (42.1)	1358 (41.7)	1293 (41.7)	
$\geq 75$	337 (10.1)	364 (10.5)	399 (11.3)	373 (11.5)	428 (13.8)	
In-hospital mortality	130 (3.9)	104 (3.0)	111 (3.2)	90 (2.8)	96 (3.1)	0.095
No. of hospitals providing procedure	69	73	73	75	78	

PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; DES, drug-eluting stent; BMS, bare-metal stents.

\*First-, second-, and third-generation DES were categorized into DES.

<sup>†</sup>Values may not add up to the total due to multiple cases.



**Fig. 1.** Quarterly distribution of the number of percutaneous coronary intervention (PCI) procedures according to the type of procedure from 2006 to 2010 in the Republic of Korea. BMS, bare-metal stent; DES-1G, first-generation drug-eluting stent; DES-2G, second-generation drug-eluting stent; DES-3G, third-generation drug-eluting stent.

The adjusted RR for PCI in 2010 was significantly higher than that in 2006 for all age and sex strata. The linear trend for the RR was also statistically significant (Table 2). The adjusted RR for CABG in 2010 was significantly lower than that in 2006 for age and sex strata, with the exception of the  $\geq 75$ -year-old group.

#### In-hospital mortality rates from PCI and CABG

In-hospital mortality after PCI significantly increased from 1.5% in 2006 to 1.8% in 2010. Although in-hospital mortality due to CABG decreased during the study period, this change was not statistically significant in men or women (Table 1).

In a generalized linear mixed-effects model, the risk of in-hospital mortality from PCI or CABG was higher among women and the older-age group than among men and the younger-age group (Table 3); the risk of in-hospital mortality from CABG continuously decreased from 2006 to 2010, whereas the risk increased for PCI ( $p$  for trend=0.03). The risks of in-hospital mortality from PCI and CABG were significantly higher in hospitals with low procedure volumes than in hospitals with the highest procedure volumes.

Stratified analyses by age, sex, and hospital procedure volume indicated that the risk of in-hospital mortality was significantly higher in 2010 than in 2006 among women, elderly patients, and the highest-volume hospitals; the linear

trends were also statistically significant (Table 4). In contrast, the in-hospital mortality rates for CABG decreased in 2010 in all strata, with the exception of Tertile 1 of procedure volume; statistical significance was observed only in  $< 65$ -year-old patients and Tertile 2 of procedure volume.

#### Recurrent PCI and CABG

Among 210914 patients, 194291 (92.1%) received PCI only (172458 received one, 19720 received two, and 2113 received three or more PCIs), 13579 (6.4%) received CABG only (13556 received one and 23 received two CABGs), and 3044 (1.4%) received both PCI and CABG (Supplementary Table 1, only online).

Among the 121575 cases who received PCI between 2007 and 2009 and who did not have histories of revascularization during the previous 12 months, 10949 (9.0%) received a repeat revascularization procedure within 12 months. There were 10166 (8.4%) patients who received PCI and 783 (0.6%) who received CABG as their second revascularization procedure. The proportion of follow-up PCI procedures was high between 7 and 10 months after the first PCI procedure, whereas the peak time for CABG was within 2 months of the first PCI procedure (Supplementary Fig. 1, only online).

**Table 2.** Standardized Rates and Rate Ratios (95% Confidence Interval)\* of Coronary Revascularization by Sex and Age

	Rate per 100000/rate ratio (95% CI)					<i>p</i> for linear trend
	2006	2007	2008	2009	2010	
<b>Total</b>	116.1	123.5	128.9	128.6	131.0	<0.0001
	1	1.06 (1.05–1.08)	1.11 (1.10–1.12)	1.11 (1.09–1.12)	1.13 (1.11–1.14)	
<b>PCI</b>						
<b>Total</b>	106.5	114.0	119.7	120.3	123.4	<0.0001
	1	1.07 (1.05–1.08)	1.12 (1.11–1.14)	1.13 (1.11–1.14)	1.16 (1.15–1.17)	
<b>Sex</b>						
<b>Men</b>	143.0	152.6	159.2	163.6	169.3	<0.0001
	1	1.07 (1.05–1.08)	1.11 (1.10–1.13)	1.14 (1.13–1.16)	1.18 (1.17–1.20)	
<b>Women</b>	71.4	76.9	81.7	78.6	79.3	<0.0001
	1	1.08 (1.05–1.1)	1.14 (1.12–1.17)	1.10 (1.08–1.12)	1.11 (1.09–1.13)	
<b>Age, yrs</b>						
<b>20–49</b>	20.0	21.6	22.6	22.5	23.6	<0.0001
	1	1.08 (1.05–1.12)	1.13 (1.09–1.17)	1.13 (1.09–1.17)	1.18 (1.14–1.22)	
<b>50–64</b>	203.0	209.9	212.8	209.0	209.9	0.0514
	1	1.03 (1.01–1.06)	1.05 (1.03–1.07)	1.03 (1.01–1.05)	1.03 (1.01–1.06)	
<b>65–74</b>	406.4	445.1	474.3	484.6	493.9	<0.0001
	1	1.10 (1.07–1.12)	1.17 (1.14–1.19)	1.19 (1.17–1.22)	1.22 (1.19–1.24)	
<b>≥75</b>	228.6	251.6	280.1	288.6	309.8	<0.0001
	1	1.1 (1.06–1.14)	1.23 (1.19–1.26)	1.26 (1.23–1.3)	1.36 (1.32–1.39)	
<b>CABG</b>						
<b>Total</b>	9.5	9.5	9.3	8.3	7.6	<0.0001
	1	1.00 (0.95–1.05)	0.97 (0.93–1.02)	0.87 (0.83–0.91)	0.80 (0.76–0.84)	
<b>Sex</b>						
<b>Men</b>	13.4	13.8	13.1	11.9	11.0	<0.0001
	1	1.03 (0.97–1.08)	0.97 (0.92–1.03)	0.89 (0.83–0.94)	0.82 (0.76–0.88)	
<b>Women</b>	5.8	5.4	5.6	4.76	4.3	<0.0001
	1	0.93 (0.85–1.02)	0.97 (0.89–1.06)	0.83 (0.74–0.91)	0.75 (0.66–0.84)	
<b>Age, yrs</b>						
<b>20–49</b>	1.1	1.3	1.1	1.1	0.9	0.0197
	1	1.1 (0.93–1.26)	0.93 (0.76–1.1)	0.96 (0.79–1.13)	0.76 (0.58–0.94)	
<b>50–64</b>	19.1	18.7	17.2	15.0	13.2	0.0009
	1	0.98 (0.91–1.05)	0.9 (0.83–0.98)	0.79 (0.71–0.86)	0.69 (0.62–0.77)	
<b>65–74</b>	143.3	42.9	45.1	40.4	37.8	0.0001
	1	0.99 (0.92–1.07)	1.04 (0.97–1.12)	0.93 (0.86–1.01)	0.87 (0.80–0.95)	
<b>≥75</b>	15.0	15.1	15.3	13.2	14.0	0.12
	1	1.01 (0.86–1.15)	1.02 (0.88–1.17)	0.89 (0.74–1.03)	0.94 (0.80–1.08)	

PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; CI, confidence interval.

\*Rates were standardized by a direct method to sex and age according to the distribution of the Korean population in 2008. Rate ratios and the corresponding 95% CIs were estimated by Poisson regression analysis after adjusting for age and sex.

## DISCUSSION

We found that the rate of revascularization continuously increased from 116.1 per 100000 in 2006 to 131.0 in 2010 in the ROK. In contrast to the increased rate of PCI (16%), the rate of CABG decreased (20%) during the study period. Previous studies have reported that the rate of revascularization ranged from 358.0 to 556.9 per 100000 between 2001

and 2008 in the U.S.<sup>16,18</sup> and was 186.7 per 100000 during 2005 in Canada.<sup>19</sup> Compared to these results from Western countries, the coronary revascularization rates in our study were relatively low.

### Trends in coronary revascularization

In our study, the increase in PCI was greater than the decrease in CABG, such that the overall rate of revascularization increased. Our findings were similar to those of a previ-

**Table 3.** The Risk of in-Hospital Mortality after Coronary Revascularization

	Risk ratio (95% confidence interval)*	
	PCI	CABG
Fixed effects		
Women (vs. men)	1.11 (1.04–1.19)	1.24 (1.04–1.49)
Age		
20–49	Reference	Reference
50–64	1.24 (1.04–1.47)	2.20 (1.20–3.89)
65–74	2.75 (2.32–3.25)	3.52 (1.93–6.20)
≥75	6.68 (5.64–7.90)	7.90 (4.43–14.08)
Yr		
2006	Reference	Reference
2007	0.98 (0.87–1.10)	0.77 (0.59–1.00)
2008	1.01 (0.90–1.13)	0.75 (0.58–0.98)
2009	1.00 (0.90–1.12)	0.67 (0.51–0.89)
2010	1.11 (1.00–1.24)*	0.73 (0.56–0.96)
<i>p</i> for trend	0.03	0.01
Random effects		
Procedure volume <sup>†</sup>		
Tertile 1	1.56 (1.40–1.75)	3.62 (2.72–4.82)
Tertile 2	1.42 (1.32–1.52)	2.31 (1.88–2.83)
Tertile 3	Reference	Reference

PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft.

\**p* = 0.05.

<sup>†</sup>Hospitals were divided into tertiles based on the annual number of revascularization procedures.

ous study, which reported an increasing trend in the revascularization rate yet divergent trends according to procedure type.<sup>18</sup> Recent studies in the U.S. show that although the incidence of coronary artery disease is increasing, the revascularization rate, especially the rate of PCI, is decreasing or is unchanged after 2005.<sup>16,20,21</sup> However, the use of the PCI procedure continuously increased during our study period, despite there being no change in health care policy on the use of coronary revascularization procedures.

Although the PCI rate increased in all of the age and sex categories, the increases in the male and elderly (≥65 years old) groups were higher than those in the female and young adult (<65 years old) groups. For elderly patients, in addition to their increased risk of coronary diseases, a history of revascularization might also contribute to the increased rate of PCI. Our findings are consistent with the results from a U.S. study that reported an increasing trend in the rate of PCI between 2000 and 2006, with a greater increase among elderly patients.<sup>18</sup>

A decreased rate of CABG was observed in both genders and in all age groups, with the exception of those ≥75 years

old. There may be several reasons for the reduced rate of CABG. First, practice guidelines for revascularization have changed due to reports on the efficacy of PCI vs. CABG for left-main coronary disease<sup>5,6</sup> and multi-vessel disease.<sup>7,8</sup> Second, patient preference or physician recommendations may contribute to treatment decisions and the decreased rate of CABG. In general, patients and physicians prefer less-invasive treatments that offer equal efficacy.

### Transition of stent type

In our study, changes in the type of stent used were prominent. The older-generation DES were immediately replaced by newer-generation models as soon as they became available, although it is unclear if the newer-generation DES models are truly superior.

In addition to the enthusiasm of physicians for new medical technologies, we believe that a distorted reimbursement pricing policy for stents might affect the rapid changes in PCI stent type. The price of DES was only 20% higher than that of BMS; the difference between BMS and DES is about 300 US dollars (BMS and DES cost \$1500 and \$1800 US dollars, respectively). However, in most countries, the cost difference between BMS and DES is greater than 1200 US dollars, and the price of DES is more than double that of BMS.<sup>22</sup> Therefore, there might be less motivation for physicians in the ROK to choose BMS rather than DES. In our study, more than 90% of PCI procedures involved DES. In addition, NHI covers only three stent implantations (two stents in one vessel) during the lifetime of each patient. Thus, due to the lower restenosis rate of DES compared to that of BMS, both physicians and patients might have strong preferences for DES. Due to the lack of clinical information in our study, further investigations into the suitability and reimbursement criteria for PCI using clinical data are necessary to confirm our findings.

### Recurrent coronary revascularization

We observed a peak in the percentage of CABG within 2 months of PCI and between 7 to 10 months for repeat PCI procedures. Our findings might reflect the general practice of routine coronary angiography after revascularization with PCI. If critical stenosis is confirmed with routine follow-up coronary angiography, repeat PCI or CABG is usually performed and consequently might also increase adverse events after coronary revascularization. However, due to study limitations, we could not distinguish repeated revascularization of the original lesion from revascularization due to disease

**Table 4.** The Risk of in-Hospital Mortality after Coronary Revascularization According to Age, Sex, and Procedure Volume

	Risk ratio (95% confidence interval)					<i>p</i> for trend
	2006	2007	2008	2009	2010	
<b>PCI</b>						
Sex						
Men	1	0.95 (0.81–1.11)	1.05 (0.91–1.23)	1.03 (0.89–1.20)	1.04 (0.89–1.20)	0.35
Women	1	1.02 (0.86–1.21)	0.96 (0.81–1.13)	0.96 (0.81–1.14)	1.21 (1.03–1.42)	0.03
Age, yrs						
<65	1	0.89 (0.71–1.13)	0.96 (0.77–1.21)	0.93 (0.74–1.16)	1.05 (0.84–1.31)	0.56
≥65	1	1.02 (0.89–1.16)	1.05 (0.92–1.20)	1.07 (0.94–1.22)	1.21 (1.07–1.37)	0.001
Procedure volume*/ mean±SD†						
Tertile 1	1	0.68 (0.48–0.96)	0.72 (0.52–1.02)	0.67 (0.48–0.95)	0.78 (0.57–1.07)	0.31
	62.9±43.08	82.6±48.18	75.2±47.63	74.3±49.44	89.4±49.21	
Tertile 2	1	0.98 (0.81–1.22)	1.13 (0.93–1.38)	1.11 (0.91–1.35)	1.06 (0.87–1.29)	0.37
	236.7±56.2	269.1±69.73	253.2±69.5	255.9±60.68	260.9±54.64	
Tertile 3	1	1.04 (0.89–1.21)	1.00 (0.89–1.18)	1.02 (0.88–1.18)	1.22 (1.06–1.40)	0.009
	635.1±274.47	639.9±238.1	681.5±282.49	680±270.65	680±267.11	
<b>CABG</b>						
Sex						
Men	1	0.84 (0.60–1.17)	0.85 (0.61–1.19)	0.65 (0.46–0.94)	0.77 (0.54–1.09)	0.06
Women	1	0.66 (0.43–1.02)	0.60 (0.39–0.91)	0.69 (0.45–1.06)	0.67 (0.43–1.03)	0.09
Age						
<65	1	0.64 (0.40–1.02)	0.72 (0.46–1.15)	0.70 (0.43–1.12)	0.57 (0.34–0.97)	0.05
≥65	1	0.84 (0.61–1.15)	0.79 (0.57–1.08)	0.68 (0.49–0.95)	0.85 (0.62–1.17)	0.09
Procedure volume*/ mean±SD						
Tertile 1	1	1.03 (0.41–2.61)	1.18 (0.51–2.75)	1.06 (0.44–2.56)	1.38 (0.58–3.32)	0.51
	6.1±3.8	6.1±3.5	6.9±3.64	6.3±2.72	4.8±2.57	
Tertile 2	1	0.52 (0.32–0.86)	0.35 (0.20–0.60)	0.38 (0.21–0.66)	0.51 (0.31–0.86)	0.002
	21.3±6.39	20.1±6.96	21.9±5.89	17.9±4.59	18.5±6.54	
Tertile 3	1	0.89 (0.63–1.24)	0.95 (0.69–1.32)	0.81 (0.57–1.14)	0.80 (0.56–1.13)	0.17
	121.8±149.89	116.6±144.88	116.9±139	106.1±122.21	97.0±108	

PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft.

All analyses were performed separately by age and gender with the generalized linear mixed-effects model and procedure volume (tertile) as a random effect after adjusting for age (20–49, 50–64, 65–74, or ≥75 years old) and/or sex.

\*Age and sex were adjusted in a generalized linear model.

†Annual number of procedures.

progression of other lesions or staged procedures.<sup>23–25</sup>

#### In-hospital mortality from coronary revascularization

Several studies in developed countries show that in-hospital mortality rates after coronary revascularization have either remained unchanged or have decreased during the last decade.<sup>24</sup> However, in our study, in-hospital mortality after PCI significantly increased in 2010 from 2006, with the most prominent increases observed among female and elderly patients.

Women and elderly patients are at increased risk of developing major cardiovascular events after coronary revascularization due to non-specific symptoms, co-morbidities,

and repeated treatments, which might delay or prevent appropriate treatment.<sup>26</sup> Considering the decreased number of CABG surgeries in our study, it is also possible that high-risk patients, such as women, the elderly, and patients with co-morbidities, did not receive CABG. This shift of high-risk patients from CABG to PCI might have contributed to the increased rates of in-hospital mortality after PCI and the decreased in-hospital mortality observed with CABG.

In our study, the number of hospitals providing coronary revascularization continuously increased during the 5-year period. Given that low-volume hospitals inherently have worse outcomes for PCI or CABG,<sup>27–29</sup> an increased number

of hospitals with low procedure volumes might have also contributed to the increased in-hospital mortality. Compared to the highest-volume hospitals, in-hospital mortality after PCI or CABG was significantly higher in the lowest-volume hospitals in our study. Interestingly, in-hospital mortality after PCI did not change in low-volume hospitals during the study period. In contrast, in-hospital mortality increased significantly in the highest-volume hospitals. During the study period, although the number of hospitals that provide coronary revascularization procedures increased by 23.5% in our study, the proportion of hospitals that provide CABG surgery decreased from 58.0% in 2006 to 53.1% in 2010. Thus, considering the small number of hospitals that provide CABG surgery compared to PCI, severe cases or cases that follow failed prior procedures, especially PCI, might be referred from low-volume hospitals to high-volume hospitals (or other hospitals that provide CABG surgery). Consequently, this might increase the in-hospital mortality in high-volume hospitals.

Coronary heart disease has increased during the last decade and has become one of the leading causes of death in the ROK.<sup>30,31</sup> Thus, to effectively reduce in-hospital mortality or major adverse cardiovascular events after coronary revascularization, further evaluation of the suitability and performance of coronary revascularization is necessary.

### Limitations and strengths

In the current study, we used national data representing all Koreans to investigate changes in the practice of coronary revascularization. However, there are several limitations that should be considered. First, as we included only inpatient cases of coronary revascularization with ICD10 codes I21–I25, outpatient cases or those with other ICD10 codes were not included in our analyses. However, in the ROK, subjects who receive medical care in the hospital for more than 6 hours are considered inpatient. Reimbursements for coronary revascularization without I21–I25 codes are restricted. Thus, almost all revascularization cases could be included in our study. Second, due to limitations in the medical claims data, we could not distinguish between different causes of coronary revascularization, such as staged procedures, disease progression of the original target lesion or another lesion, and failure of a prior procedure.<sup>23–25</sup> In addition, the revascularization procedures in our study included both first-time and repeat procedures with prior histories of revascularization. Considering that repeat procedures are highly conditional on the prior procedure, our findings

might be confounded by repeat procedures. Finally, similar to other epidemiological studies that use medical claims data,<sup>16,20,21</sup> due to the lack of clinical information, we were unable to determine the causes of in-hospital mortality and patients characteristics such as co-morbidities, nor could we determine whether PCI procedures were elective, acute, or emergent. Acute and emergent coronary revascularizations usually have worse clinical outcomes compared to elective coronary revascularization.<sup>32,33</sup> Our results should be carefully compared to those reported by other studies with elective patients. Additionally, due to the inclusion of non-coronary revascularization-related deaths, in-hospital mortality might also be over-estimated in our study.

In conclusion, the annual volume of coronary revascularization has continuously increased in the ROK between 2006 and 2010. In contrast to an increased rate of PCI, the rate of CABG decreased. A high proportion of PCI procedures involved DES. Furthermore, a higher rate of in-hospital mortality from coronary revascularization was observed in low-volume hospitals. Further evaluation of outcomes and reimbursement policies for coronary revascularization will provide additional information to physicians and patients.

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