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Trends in Percutaneous Coronary Intervention and Coronary Artery Bypass Surgery in Korea

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Background: Coronary angioplasty has been replacing coronary artery bypass grafting (CABG) because of the relative advantage in terms of recovery time and noninvasiveness of the procedure. Compared to other Organization for Economic Cooperation and Development (OECD) countries, Korea has experienced a rapid increase in coronary angioplasty volumes. **Methods:** We analyzed changes in procedure volumes of CABG and of percutaneous coronary intervention (PCI) from three sources: the OECD Health Data, the National Health Insurance Service (NHIS) surgery statistics, and the National Health Insurance claims data. **Results:** We found the ratio of procedure volume of PCI to that of CABG per 100,000 population was 19.12 in 2014, which was more than triple the OECD average of 5.92 for the same year. According to data from NHIS statistics, this ratio was an increase from 11.4 to 19.3 between 2006 and 2013. **Conclusion:** We found that Korea has a higher ratio of total procedure volumes of PCI with respect to CABG and also a more rapid increase of volumes of PCI than other countries. Prospective studies are required to determine whether this increase in absolute volumes of PCI is a natural response to a real medical need or representative of medical overuse.

Key words: 1. Coronary artery bypass
2. Coronary angiography
3. Myocardial infarction
4. Quality of healthcare
5. Administrative claims, healthcare

Introduction

The Korean population is ageing at an alarming speed, and 24.3% of the population is expected to be aged 65 or older by 2030 [1]. The prevalence of cardiovascular disease (CVD) among the elderly population is expected to rise to a level comparable to that of western developed countries. Risk factors associated with CVD, such as diabetes, hypertension, a westernized diet, and obesity, have increased in this population. Before 2013, neurovascular disease was the second-leading cause of death and CVD was the third-leading cause of death in Korea. However, in 2014, a 4.2% decrease in mortality from neurovascular disease and a 4.4% increase in mortality from CVD brought about an unprecedented change in the order

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Table 1. Source and definition of data

	PTCA or coronary atherectomy	Coronary artery bypass graft
Organization for Economic Cooperation and Development health data		
Common	ICD-9-CM (2006): 00.66	Bypass anastomosis for heart revascularization ICD-9-CM (1996): 36.1
Korea	NHIS EDI code PTCA: M6551, M6552, M6571, M6572 PTPIS: M6561, M6562, M6563, M6564	NHIS EDI code Vascular bypass operation Code: O1641, O1642, O1647, OA641, OA642 OA647
NHIS main surgery statistical yearbook	NHIS EDI code PTCA: M6551, M6552, M6571, M6572 PTPIS: M6561, M6562, M6563, M6564	NHIS EDI code Vascular bypass operation Code: O1641, O1642, O1647, OA641, OA642 OA647
NHIS claim data	NHIS EDI code PTCA: M6551, M6552, M6571, M6572 PTPIS: M6561, M6562, M6563, M6564	NHIS EDI code Vascular bypass operation Code: O1641, O1642, O1647, OA641, OA642 OA647

PTCA, percutaneous transluminal coronary angioplasty; ICD, International Classification of Diseases; NHIS, National Health Insurance Service; EDI, electronic data interchange; PTPIS, percutaneous transcatheter placement of intracoronary stent.

of mortality. Of the non-multifactorial disorders and excluding cancer, ischemic heart disease is the leading cause of death [2].

For these reasons, the management of CVD is deserving of increased attention and investment from the government. The government established regional cardiovascular and cerebrovascular disease centers in 2008; there are now 11 participating hospitals [3]. However, the department of thoracic and cardiovascular surgery, which plays major preventative roles for heart disease especially at later stages, was not included in this program.

Recently, percutaneous coronary intervention (PCI) has been replacing coronary artery bypass graft surgery (CABG) for the treatment of heart diseases because of the relative benefits of PCI over CABG. Benefits include the non-invasiveness of procedures (i.e., open incision is not required) and faster patient recovery. So it is not surprising that volumes of PCI have increased among most Organization for Economic Cooperation and Development (OECD) member countries over the past 20 years. The total procedure volumes of PCI surpassed those of CABG by the 1990s, coinciding with the publication of studies outlining the clinical outcomes of the relative benefits of PCI with stenting [4]. However, coronary angiography has been shown through large clinical trials to be as effective as only CABG for single or double vessel diseases. The results of these studies have been reflected in guidelines, such as those devised by the American Heart Association and by the Europe Society of Cardiology, recommending that CABG should be performed for CVD or for left main coronary diseases [5,6]. Recent OECD heath data have shown that the proportion of PCI for coronary artery disease was 78% on average, and its country-specific proportion in Korea exceeded 96%, which is substantially higher than the world average [7].

The rise in volumes of PCI are not expected to cause problems, provided that the surgeries are performed following medical care standards. Previous studies have demonstrated that in the instances where suboptimal PCIs were performed, the surgery was associated with a significantly greater prevalence of postoperative complications related to heart disease, of re-admissions, of re-surgery or of CABG, and of mortality than CABG from the second postoperative year [8]. Healthcare expenses for PCI cost far more than the expenses required for CABG, and so financial burdens borne by the public health sector and the Health and Welfare Service are expected to increase in the long term.

We investigated the trend in procedure volumes of PCI and of CABG over 10 years using a multifaceted approach and evaluated implications of these results.

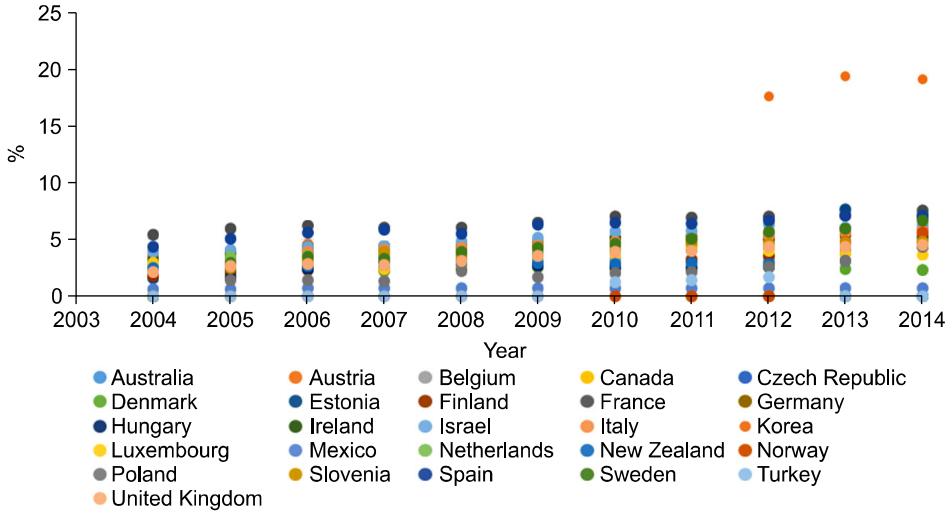

Fig. 1. Ratio of total procedures of percutaneous coronary intervention and stenting vs. coronary artery bypass graft surgery per 100 000 populations. From Organization for Economic Cooperation and Development. Health at a glance 2016. Paris: Organization for Economic Cooperation and Development; 2016 [7].

Table 2. Ratio of total procedures of percutaneous coronary intervention and stenting vs. CABG per 100,000 population [9]

	Year							
	2006	2007	2008	2009	2010	2011	2012	2013
PTCA+stent	74.8	82.9	86.4	98.4	106.2	104.1	113.4	115.3
PTCA	7.9	8.8	9.9	11.3	11.8	11.6	12.7	13.7
Stent	66.9	74.1	76.6	87.1	94.4	92.5	100.7	101.6
CABG	6.55	6.72	6.49	6.94	6.69	6.17	6.46	5.97
(PTCA+stent)/CABG	11.4	12.3	13.3	14.2	15.9	16.9	17.5	19.3
PTCA/CABG	1.21	1.31	1.53	1.63	1.76	1.88	1.97	2.29

CABG, coronary artery bypass graft surgery; PTCA, percutaneous transluminal coronary angioplasty.

Methods

We analyzed procedures volumes of PCI and of CABG using three data sets: the OECD health data, the National Health Insurance Service (NHIS) surgery statistics, and the National Health Insurance claims data. Using the OECD health data, we compared the country-specific ratios of procedure volumes of PCI per 100,000 population in relation to CABG between 2004 and 2013. Similarly, using the NHIS surgery statistics, we compared the procedure volumes per 100,000 population between 2006 and 2013 on the basis of procedure numbers and patient numbers in Korea. Using the NHIS claims data, we compared the number of Korean hospitals providing medical services for PCI and for CABG, the hospital-specific procedure volume, and the regional distribution among hospitals in Korea. Sources and definitions for all data are recorded in Table 1.

Results

Using the total procedures of PCI and of CABG from the OECD health data, we calculated the corresponding annual ratios of total procedures of PCI per 100,000 population in relation to CABG by country (Fig. 1). These ratios are summarized in Supplementary Table 1. Although annual figures in Korea have been recorded only since 2012, we can observe that the ratio of total procedures of PCI with respect to CABG is significantly higher than the OECD average of 5.92. The 10-year trends of the other countries have also shown an increasing trend; the ratio has doubled since 2004 from the average ratio of 2.82.

The total number of PCI and of CABG procedures reported in NHIS surgery statistics is based on the same requirements proposed in the OECD health data. Annual total procedures per 100,000 population and the annual ratios of total procedures of PCI in relation to CABG are in Table 2 [9]. We found that

Table 3. Number of hospitals operating PCI and CABG

	Year									
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
(A) PCI	107	113	129	138	147	154	166	178	186	216
(B) PCI ≤75	27	26	31	28	26	33	33	36	34	57
(B)/(A) %	25.2	23.0	24.0	20.3	17.7	21.4	19.9	20.2	18.3	26.4
(C) CABG	75	79	81	89	89	82	83	81	81	84
(D) Without CABG	22	24	30	32	35	38	42	44	46	51
(D)/(C) %	29.9	30.1	37.2	35.5	39.5	46.8	50.0	54.5	56.5	61.1

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

Table 4. Number of hospitals operating percutaneous coronary intervention without coronary artery bypass graft surgery by region

Region	Year											
	2004			2007			2010			2013		
	A	B	A/B (%)	A	B	A/B (%)	A	B	A/B (%)	A	B	A/B (%)
Seoul	6	31	19.4	5	37	13.5	10	36	27.8	19	45	42.2
Busan	5	10	50.0	10	16	62.5	17	23	73.9	24	30	80.0
Incheon/Gyonggi	7	22	31.8	15	33	45.5	20	40	50.0	37	57	64.9
Gangwon	1	4	25.0	2	5	40.0	2	5	40.0	1	5	20.0
Chungbuk	0	1	0.0	2	3	66.7	5	6	83.3	5	6	83.3
Daejeon/Chungnam	1	8	12.5	2	8	25.0	5	11	45.5	12	17	70.6
Chunbuk	2	3	66.7	1	3	33.3	2	4	50.0	2	4	50.0
Gwangju/Chunnam	6	11	54.5	6	13	46.2	7	11	63.6	10	15	66.7
Daegu/Kyungbuk	2	10	20.0	4	11	36.4	10	15	66.7	13	20	65.0
Ulsan/Kyungnam	1	6	16.7	2	6	33.3	6	13	46.2	7	13	53.8
Jeju	0	0	-	1	3	33.3	1	3	33.3	2	4	50.0

A, number of hospitals operating percutaneous coronary intervention without coronary artery bypass graft surgery; B, number of hospitals operating percutaneous coronary intervention.

the ratio of total procedures of PCI in relation to CABG increased from 11.4 to 19.3 between 2006 and 2013. This increase was caused by a reduction in CABG procedures and a concomitant increase in PCI procedures.

Using claim codes from the OECD health data and the NHIS surgery statistics, we assessed the number of hospitals performing PCI and CABG procedures from 2002 to 2013. We found that the number of hospitals performing CABG remained similar across the 10 years (75 in 2004 versus 84 in 2013), whereas the number of hospitals performing PCI almost doubled across the same period (107 in 2004 versus 216 in 2013) (Table 3).

For hospitals operating less than 75 procedures of PCI annually, we found that the yearly statistics were inconsistent, and the ratio of 26.4% was unusually high. In addition, we found that the proportion of hospitals that only performed PCI doubled from 29.9% to 61.1% between 2004 and 2013 (Table 3).

We evaluated the proportion of hospitals performing only PCI by region, and found that the proportions generally increased across all regions after 2004. By 2013, the proportion of hospitals performing only PCI exceeded 60% in the following regions: Busan, Incheon/Geonggi, Chungbuk, and Daejeon/Chungnam (Table 4).

Discussion

We found that Korea, compared to other countries, had a distinctly high ratio of total PCI procedures in relation to CABG through a comparative analysis of the OECD health data by country. Although we cannot make conclusions about medical overuse by medical providers on the basis of this ratio alone, it

would not be surprising if the sudden increase in volumes of PCI is associated with a compromise in the quality of treatment. We believe that compromised quality is likely to be secondary to the increase in the number of healthcare centers, which include those with low procedure volumes and those that perform only PCI procedures.

In 2013, according to the OECD, the countries with the highest PCI volumes were Germany, Hungary, and Austria and those with the lowest volumes were Mexico and Chile. There are several interpretations of the increase in PCI volumes and the inter-country differences. The reasons for the country-dependent differences in volumes include disparities in capacities to perform treatments or to cover the expenses, in clinical practice guidelines and treatment methods, and in disease codes and medical reports [4]. In many OECD member countries, the rate of increase in procedure volumes was steeper between 2000 and 2006 than in the later period (2006 to 2014) [4].

To elucidate the causes of increased volumes of PCI in Korea, we assessed the accuracy of statistical data and changes in policy and legislation. The health insurance data containing information on procedures of PCI and CABG is not based on diseases codes but on claims made by patients themselves, so it is likely that it would be associated with fewer errors. Because the number of allowed stents was limited until 2014, stents used beyond the restricted amount may not have been included in the claim process. However, because any stents used beyond the limit would have been used for the same surgery for which the expenses are being claimed, we believe that it would not have a significant effect on the overall statistics. In addition, data from the Korean registry of acute myocardial infarction showed that the proportion of procedure volumes for ST-segment elevation myocardial infarction increased from 88.6% to 96.3% between 2006 and 2013. Non ST-segment elevation myocardial infarction increased from 72.1% to 81.7% for the same period, an increase of almost 10% [10].

Comparison of data among countries is limited in that many countries do not use administrative data but use data from registries of CVD. Datasets may not be compatible for comparative analyses because of the inconsistencies in the type of data used across countries. Furthermore, procedures of PCI with stenting included in the counts may include procedures for diseases other than acute myocardial infarction and procedures that perform combined widening and stenting. Thus, the procedure volume of PCI in Korea may be an overestimate.

The policies for the coverage of PCI and of CABG in Korea have not changed substantially over the 10-year study period. The upper limit of the number of stents that could be used during PCI decreased by 20% in 2007; in December 2014 the restriction to the number of usable stents was removed. However, these changes did not seem to make a significant contribution to the trend seen in procedure volumes.

The increasing prevalence of PCI procedures, in accord with developments in techniques such as drug-eluting stenting, is a trend seen worldwide. The increase of PCI procedures in Korea has been particularly prominent, which we suggest can be explained as a supplier effect from medical overuse rather than policy effects.

Although we cannot attribute the decrease in the quality of service directly to the increase in volumes of PCI on the basis of our findings alone, we can suggest a few potential indirect connections.

The correlation between prevalence of ischemic heart disease, measured as the mortality of ischemic heart disease, and total procedures of revascularization seems to be nonexistent. For instance, the mortality from ischemic heart disease in Germany is just slightly lower than the OECD average, but the number of total procedures of revascularization is highest in Germany [4]. We found that the proportion of mortality after ischemic heart disease and acute myocardial infarction per 100 000 population decreased by 26.4% between 2004 and 2014 in Korea, which is lower than the average 46.7% decrease among OECD countries for the same period. We compared our mortality values to those of Japan because mortality rates have been shown to be lower among Asians than in Westerners. Japan had a mortality rate of 38.7% for ischemic heart disease and acute myocardial infarction in 2012, which was lower than the corresponding value of 56.4% in Korea. This was a reduction in mortality by 45.8%, which, like other countries, was lower than the corresponding value among Koreans [7]. Thus, even when we take into account that mortality rates are generally lower among Asians than in Westerners, we found that the reduc-

tion in mortality after these diseases was greater Korea than in other countries. The increase in the volumes of revascularization is occurring relatively quickly in Korea, even though it has a slower rate of the reduction in mortality and higher mortality compared to other countries.

The Health Insurance Review and Assessment Service (HIRA)'s quality assessment, begun in 2007, shows in-hospital deaths after PCI and deaths within 30 days of admission have been continually decreasing [11]. In 2012, the in-hospital mortality after PCI was 6.4% and the mortality within 30 days of admission was 7.0%. The country-specific proportion of mortality within 30 days of admission after acute myocardial infarction, reported by the OECD among patients aged 45 and over (adjusted for sex and age), was 8.3% in 2012. Korea was the fourth highest country for this proportion, following Mexico, Austria, and Estonia [4]. According to the Korean registry of acute myocardial infarction, the mortality after acute ST-segment elevation myocardial infarction decreased from 5.7% to 4.8% between 2006 and 2012; the mortality after acute non ST-segment elevation myocardial infarction decreased from 3.8% to 3.1% between 2006 and 2013 [10].

There were 186 healthcare centers eligible for HIRA's quality assessment. In 2013, they excluded 71 centers that did not meet the baseline requirements of 30 annual procedures of PCI and earning at least 10 points per indicator. The present situation of healthcare centers with low volumes and suboptimal quality were not reflected in HIRA's assessment. The data from the registry of acute myocardial infarction similarly represents only the situations of participating hospitals.

Policies and legislation concerning the treatment of cardiovascular and cerebrovascular diseases were enacted in 2016 for patients such as those with CVD like myocardial infarction. Considering that the standard treatment for coronary artery disease, which makes up the bulk of CVDs, is the traditional CABG, the fact that some of the existing cardiovascular and cerebrovascular disease centers do not perform the surgery is of concern.

Based only on the findings of our study, conclusions cannot be drawn concerning problems of appropriateness or of quality of procedures. Still, we cannot exclude that these issues may arise as a direct result of an increase in the number of providers of the medical service. The hospitals in which these issues may be particularly problematic are those that have low procedure volumes or those where CABG is not performed at all. Studies are needed to investigate linking real data to these concerns.

Prospective, in-depth studies based on our findings are required to understand concerns in the healthcare service and their causes. First, an assessment of appropriateness must be prioritized in hospitals in which the number of procedures fails to exceed a certain limit per year or CABG is not performed. Outliers with substandard quality must be identified and the underlying problems in these hospitals must be addressed to enhance the overall quality of healthcare service. This may be especially current and prominent in regions where the number of hospitals performing PCI has increased rapidly, thereby stimulating competition between hospitals that may compromise the provided quality of service.

Second, the accuracy of data for statistical analysis must be improved. Health insurance data are administrative in nature and consists of codes developed for the purpose of making medical expense claims; thus, their disease codes are not as accurate as the ones developed for medical records or for research purposes. To evaluate the appropriateness of the treatment of PCI and CABG, more accurate information on disease codes and severity of disease must be obtained. This information may be derived from the HIRA's Assessment of Appropriateness or from the preexisting Registry of Neurovascular Disease.

In conclusion, we found that Korea showed a higher ratio of volumes of PCI in relation to CABG compared to other countries. We also found that the PCI-specific annual ratios showed a steep increasing trend. Prospective studies are required to discriminate whether or not this increase results from a real medical need because of an absolute increase in PCI patient numbers or from medical overuse by providers. Current data does not lead itself to assessment of appropriateness of medical care or of qualities issues because parameters such as mortality, which is our indirect marker of outcome, are decreasing and those concerning quality are increasing. An assessment of current situations of medical care, especially among healthcare centers with low procedure volumes or those unable to provide CABG, is required.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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Supplementary Table 1. Ratio of total procedures of percutaneous transluminal coronary angioplasty and stenting vs. coronary artery bypass graft surgery per 100,000 populations

Country	Year										
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Australia	2.29	2.44	2.48	2.54	2.62	2.91	3.05	3.09	3.09	-	-
Austria	3.52	4.03	4.50	4.47	4.55	4.83	5.08	5.32	5.48	5.73	5.90
Belgium	-	2.93	3.05	3.07	3.26	3.20	3.28	3.32	3.47	-	-
Canada	-	-	2.44	2.45	2.55	2.58	2.62	2.67	2.81	-	-
Czech Republic	-	2.70	3.04	3.44	3.69	3.73	3.86	4.09	4.24	4.02	4.39
Denmark	1.88	2.27	2.42	2.24	2.42	2.61	2.50	2.43	2.59	2.43	2.34
Estonia	1.63	2.26	2.65	2.86	3.16	3.44	3.86	4.74	6.97	7.62	7.15
Finland	1.74	1.97	2.26	2.35	2.46	2.72	2.53	3.20	3.53	3.85	4.68
France	5.40	5.96	6.19	6.03	6.07	6.44	7.00	6.95	7.05	7.11	7.56
Germany	-	3.50	3.90	3.95	4.27	4.50	4.95	5.18	5.29	5.43	5.79
Hungary	-	1.61	2.37	2.82	2.67	2.67	2.54	2.44	2.57	-	6.96
Ireland	3.21	3.75	4.33	4.39	4.25	4.28	5.13	4.93	4.93	5.42	5.23
Israel	3.94	4.10	4.38	4.40	4.78	5.14	5.72	5.79	6.29	6.02	6.25
Italy	2.75	3.26	3.91	4.07	4.29	4.41	4.79	5.01	5.37	5.62	5.74
Korea	-	-	-	-	-	-	-	-	17.58	19.36	19.12
Luxembourg	2.91	2.89	3.11	2.36	2.66	3.44	3.75	4.32	3.95	3.81	3.63
Mexico	0.65	0.64	0.67	0.66	0.67	0.69	0.67	0.69	0.69	0.68	0.69
Netherlands	-	3.43	3.58	3.64	3.75	4.02	4.43	-	-	-	-
New Zealand	2.49	2.64	2.64	2.71	2.92	2.91	2.83	2.92	2.87	3.09	-
Norway	-	-	-	-	-	-	-	-	-	4.82	5.63
Poland	-	1.45	1.43	1.35	2.18	1.71	2.02	2.12	2.54	3.07	4.33
Slovenia	-	2.49	3.07	3.88	3.54	4.23	4.45	4.64	4.58	4.68	4.77
Spain	4.38	5.07	5.60	5.86	5.51	6.34	6.49	6.40	6.67	7.08	7.08
Sweden	-	2.95	3.46	3.27	3.91	4.25	4.58	5.04	5.69	5.98	6.69
Switzerland	3.31	3.75	3.45	3.41	3.96	-	-	-	-	-	-
Turkey	-	-	-	-	-	-	1.20	1.43	1.70	-	-
United Kingdom	2.16	2.62	2.84	2.77	3.09	3.52	3.88	4.02	4.31	4.34	4.53
Average	2.82	2.99	3.24	3.29	3.47	3.68	3.80	3.95	4.76	5.51	5.92

From Organization for Economic Cooperation and Development. Health at a glance 2015. Paris: Organization for Economic Cooperation and Development; 2015 [4].