

The Association Between Treatment Frequency and Treatment Outcome for Cardiovascular Surgeries

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Background: This study analyzed the association between the volume of heart surgeries and treatment outcomes for hospitals in the last five years. **Methods:** Hospitals that perform heart surgeries were chosen throughout Korea as subjects using from the Health Insurance Review and Assessment Service. The treatment outcome of the heart surgeries was defined as the mortality within 30 postoperative days, while the annual volume of the surgeries was categorized. Logistic regression was used as the statistical analysis method, and the impacts of the variables on the heart surgery treatment outcomes were then analyzed. **Results:** The chance of death of patients who received surgery in a hospital that performed 50 or more surgeries annually was noticeably lower than patients receiving operations from hospitals that performed fewer than 50 surgeries annually, indicating that the chance of death decreases as the annual volume of heart surgeries in the hospital increases. In particular, the mortality rate in hospitals that performed more than 200 surgeries annually was less than half of that in hospitals that performed 49 or fewer surgeries annually. **Conclusion:** These results indicate that accumulation of a certain level of heart surgery experience is critical in improving or maintaining the quality of heart surgeries. In order to improve the treatment outcomes of small hospitals, a support policy must be implemented that allows for cooperation with experienced professionals.

Key words: 1. Thoracic surgery
2. Volume-outcome relationship
3. Quality of health care

Introduction

Cardiovascular diseases, with their high mortality rates and added burden of disease, are considered a serious health issue that is typically coupled with a

rapidly aging population. In Korea, usage of medical services by patients with cardiovascular disease has increased in the last 5 years by an annual average of 6.1%, indicating that the demand for heart surgeries will increase significantly in the future [1]. Heart sur-

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geries are an important treatment option that can allow patients with cardiovascular disease to recover and improve their symptoms. In particular, the success of the surgery and whether or not the patient is eligible to receive a heart surgery is directly related to the life and death of the patient; hence, it is of utmost importance to provide the heart surgery at the appropriate time.

It is generally accepted that for difficult and intensive surgeries, hospitals with more experience yield better treatment outcomes. Heart surgeries are extremely difficult procedures that require many professionals and corresponding equipment, and are representative of medical services that are highly dependent on professional experience and hospital systems. An analysis regarding the relationship between the annual volume of the hospital and the treatment outcomes is an example of a method to indirectly evaluate the quality of medical services (e.g., heart diseases). The results of such an analysis can be used to improve the quality of the surgery and also to establish standards to maintain a certain surgery quality.

There have been contradicting reports from previous research investigating the relationship between the annual volume of heart surgeries and treatment outcomes. Some studies found that the mortality rate within the hospital decreases as the number of heart surgeries performed increases [2-4], while another study reported that there is no relationship between the mortality rate and the number of surgeries performed by the hospital [5]. Some studies found that the quantity of coronary artery bypass grafts (CABG) performed was not a significant factor in predicting the results of the surgery [5], while other studies found that although mortality rates are lower in hospitals that have performed a greater quantity of CABG surgeries, the relationship weakens as time passes [3].

As the need emerged for the establishment of regional heart centers in Korea, the interest in heart surgery has increased, and the need for maintaining a certain volume of heart surgeries to maintain or improve surgery quality has also surfaced. Previous research conducted in Korea on the relationship between the volume of heart surgeries performed and the treatment outcomes either focused on certain types of heart surgeries such as CABG or analyzed the data from a single hospital for a single year [6,7]. To our knowledge, there is no study that included

analysis on a national scale over a multi-year period. This research analyzed the relationship between the number of surgeries performed and treatment outcomes from hospitals in the last 5 years on a national scale in Korea.

Methods

1) Research subjects

This research utilized the National Health Insurance claims data published by the Health Insurance Review and Assessment Service from the last five years (2010–2014) and analyzed patients who received heart surgeries over the entire country. The type of surgery was identified using the claim data and aid code, which included congenital heart disease surgery (O1671, O1672, O1680, O1701, O1702, O1703, O1704, O1705, O1710, O1711, O1721, O1722, O1723, O1770, O1800, O1810, O1821, O1822, O1825, O1826, O1840, O1841, O1850, O1861, O1873, O1874, O1875, O1878, O1879, O1960), heart valve surgery (O1730, O1740, O1750, O1760, O1781, O1782, O1783, O1791, O1792, O1793, O1794, O1795, O1796, O1797, O1798), coronary artery surgery (O1641, O1642, O1647, O1830, OA641, OA642, OA647), and aorta surgery (O2031, O2032, O2033).

We excluded patients whose residential addresses could not be verified, had received a heart surgery <3 years before this study, received heart valve and coronary artery surgery concurrently, had received a heart transplant, or had undergone multiple heart surgeries. Because a hospital can separate the specification for billing for a patient before release from the hospital, repeated admittance to the hospital shown on the billing data must be combined into a single case. Hence, if the initial day of care for a single patient in the same hospital was within a day of the exit date on the billing specification, the case was treated as a single admittance. The final admittance count was 40,522 cases and 40,236 patients.

2) Definition of variables

The treatment outcome of heart surgery was defined as the mortality rate within 30 days of the surgery. Death was verified through the resident registration electronic database from the Ministry of Interior. The volume of heart surgeries performed by the hospital was defined as the number of heart sur-

geries performed. Volume of heart surgeries must be defined by a suitable standard; however, because there is no agreed upon standard of categorization, the definition varies greatly for each research study. Most studies utilize a standard that is recommended for maintaining surgery quality, or studies categorize based on the distribution of the research subjects so that they are evenly distributed in each category [4,5,8,9]. For this research, in consideration of the distribution of the number of heart surgeries performed annually by hospitals in Korea, the categories were defined as 49 or fewer cases, 50–199, 200–349, and 350 or more cases.

The patient's gender, age, type of healthcare coverage, comorbidity index, and whether or not it was an emergency surgery were treated as independent variables that could affect the treatment outcomes in previous research. In this study we used the Charlson Comorbidity Index, which is commonly used to evaluate a patient's condition using administrative data. Patients were assigned a score of 0 to 3, with a larger number indicating a more severe condition. It is impossible to identify the date of the surgery through claims data, therefore if the patient had a percutaneous coronary intervention (PCI) (treatment code M6551, M6552, M6561, M6562, M6563, M6564, M6571, M6572) within a year of the initial date of treatment, then the patient was defined as having had a PCI less than one year before the heart surgery. If additional night charges were added to the billing specifications in the claims data or if a PCI was performed less than 30 days prior to being admitted into the hospital, the heart surgery was defined as an emergency surgery.

3) Method of analysis

A chi-square test was performed to identify whether or not there is a difference in the number of heart surgeries based on the characteristics of the admitted heart surgery patient. A logistic regression was used to analyze causes that affect the mortality rate in the hospital and within 30 days from surgery. The logistic regression model used in the analysis was as follows:

$$\log it(P_i) = \beta_0 + \beta_1 x_{1,i} + \dots + \beta_m x_{m,i} + \varepsilon, \quad \varepsilon \sim \text{Logistic}(0,1)$$

From the equation,

$\log it(P_i)$: Mortality rate in the hospital or within 30 days of surgery

i : Number of hospital admittances

x_1 – x_3 : Number of surgical procedures (low=0)

x_4 : Gender dummy variable (male=0)

x_5 – x_7 : Age-group dummy variable (less than 49 years=0)

x_8 : Type of Medicare (medical aid=0)

x_9 – x_{12} : Type of heart surgery (congenital heart disease=0)

x_{13} – x_{15} : Charlson Comorbidity Index (0 points=0)

x_{16} : Whether or not a PCI was performed within a year prior to the surgery (no=0)

x_{17} : Whether the surgery was an emergency surgery (no=0)

x_{18} – x_{21} : Year of surgery (2010=0)

In order to analyze the differences in the adjusted mortality rate based on the volume of heart surgeries, logistic regression analysis was performed. The resulting predicted mortality rate of the admitted heart surgery patient was summed up for the number of deaths in each group and divided, then multiplied by the crude mortality rate.

Adjusted mortality rate=

$$\frac{\text{Actual number of deaths}}{\text{Predicted number of deaths}} \times \text{Crude mortality rate}$$

SAS Enterprise Guide ver. 4.3 (SAS Institute Inc., Cary, NC, USA) was used for the analysis, with a verified statistical uncertainty of 5%.

Results

1) Typical characteristics of research subjects

In the last five years (2010–2014), there was a total of 98 heart surgery hospitals nationwide (Table 1). There were 86 heart surgery hospitals as of 2014; 52 hospitals (60.5%) performed 49 or fewer heart surgeries annually and 24 (27.9%) performed 50–199 annually. These two groups make up 88.4% of the total number of hospitals in Korea. There were only 10 hospitals (11.6%) that performed more than 200 heart surgeries annually.

Coronary artery surgery was most common type of heart surgery with 12,980 cases (32.0%), followed by heart valve surgery with 12,606 cases (31.1%), and

Table 1. Basic characteristics of the research subjects

Characteristic	Total	Hospital volume group			
		1-49	50-199	200-349	≥ 350
No. of patients	40,236	5,135	10,371	5,295	19,488
No. of hospitals					
Total (5 yr)	98	73	35	6	6
2010	85 (100.0)	52 (61.2)	24 (28.2)	3 (3.5)	6 (7.1)
2011	86 (100.0)	52 (60.5)	23 (26.7)	5 (5.8)	6 (7.0)
2012	85 (100.0)	50 (58.8)	26 (30.6)	3 (3.5)	6 (7.1)
2013	85 (100.0)	52 (61.2)	23 (27.1)	5 (5.9)	5 (5.9)
2014	86 (100.0)	52 (60.5)	24 (27.9)	5 (5.8)	5 (5.8)
No. of admissions	40,522 (100.0)	5,148 (100.0)	10,391 (100.0)	5,336 (100.0)	19,647 (100.0)
Type of surgery					
Congenital cardiovascular surgery	10,685 (26.4)	794 (15.4)	1,657 (16.0)	2,039 (38.2)	6,195 (31.5)
Valve surgery	12,606 (31.1)	1,797 (34.9)	3,296 (31.7)	1,510 (28.3)	6,003 (30.6)
Coronary artery surgery	12,980 (32.0)	1,983 (38.5)	4,016 (38.7)	1,150 (21.6)	5,831 (29.7)
Aorta surgery	2,733 (6.7)	399 (7.8)	1,022 (9.8)	443 (8.3)	869 (4.4)
Valve and coronary artery surgery	1,518 (3.8)	175 (3.4)	400 (3.9)	194 (3.6)	749 (3.8)
Gender					
Male	23,695 (58.5)	3,039 (59.0)	6,026 (58.0)	3,094 (58.0)	11,536 (58.7)
Female	16,827 (41.5)	2,109 (41.0)	4,365 (42.0)	2,242 (42.0)	8,111 (41.3)
Age (yr)	47.7±28.0	56.0±22.2	55.5±23.2	40.6±30.8	43.3±29.3
< 40	11,544 (28.5)	756 (14.7)	1,653 (15.9)	2,124 (39.8)	7,011 (35.7)
40-64	13,904 (34.3)	2,108 (41.0)	4,050 (39.0)	1,552 (29.1)	6,194 (31.5)
65-74	10,248 (25.3)	1,554 (30.2)	3,123 (30.1)	1,059 (19.9)	4,512 (23.0)
≥ 75	4,826 (11.9)	730 (14.2)	1,565 (15.1)	601 (11.3)	1,930 (9.8)
Health insurance status					
National health insurance	38,216 (94.3)	4,573 (88.8)	9,602 (92.4)	5,059 (94.8)	18,982 (96.6)
Medical aid	2,306 (5.7)	575 (11.2)	789 (7.6)	277 (5.2)	665 (3.4)
Charlson Comorbidity Index (points)					
0	18,150 (44.8)	2,019 (39.2)	4,085 (39.3)	2,724 (51.1)	9,322 (47.5)
1	10,194 (25.2)	1,320 (25.6)	2,728 (26.3)	1,226 (23.0)	4,920 (25.0)
2	5,504 (13.6)	803 (15.6)	1,612 (15.5)	637 (11.9)	2,452 (12.5)
≥ 3	6,674 (16.5)	1,006 (19.5)	1,966 (18.9)	749 (14.0)	2,953 (15.0)
Received a percutaneous coronary intervention within a year prior to surgery	39,648 (97.8)	5,009 (97.3)	10,139 (97.6)	5,255 (98.5)	19,245 (98.0)
Yes					
No	874 (2.2)	139 (2.7)	252 (2.4)	81 (1.5)	402 (2.1)
Emergency surgery	36,962 (91.2)	4,518 (87.8)	8,914 (85.8)	4,896 (91.8)	18,634 (94.8)
Yes					
No	3,560 (8.8)	630 (12.2)	1,477 (14.2)	440 (8.3)	1,013 (5.2)

Values are presented as number (%) or mean±standard deviation.

then by congenital heart disease surgery with 10,685 cases (26.4%). These three surgery types represented 89.5% of all heart surgeries performed. Interestingly, more than half of the patients who had a congenital heart disease surgery underwent surgery in one of the hospitals that perform more than 350 surgeries annually.

The average age of patients who had heart surgeries was 47.7 years. The average age of patients in hospitals that performed 200 or more heart surgeries annually was lower than the average age of patients in hospitals that performed less than 200 heart surgeries annually. Most of the patients who underwent heart surgery had health insurance, and 50% of pa-

Table 2. Factors that affect the mortality rate in the hospital or within 30 days of heart surgery

Variable	Total (N=40,522)	Crude mortality	Odds ratio (95% confidence interval)
Hospital volume			
1-49	5,148 (12.7)	11.4	1.00
50-199	10,391 (25.6)	8.3	0.64 (0.57-0.72)*
200-349	5,336 (13.2)	4.7	0.36 (0.31-0.43)*
≥ 350	19,647 (48.5)	2.6	0.22 (0.20-0.25)*
Gender			
Male	23,695 (58.5)	4.9	1.00
Female	16,827 (41.5)	6.1	1.02 (0.93-1.12)
Age (yr)			
< 40	11,544 (28.5)	3.6	1.00
40-64	13,904 (34.3)	3.6	0.82 (0.67-1.01)
65-74	10,248 (25.3)	6.7	1.58 (1.27-1.96)*
≥ 75	4,826 (11.9)	12.6	2.89 (2.32-3.59)*
Health insurance status			
National health insurance	38,216 (94.3)	5.3	1.03 (0.86-1.22)
Medical aid	2,306 (5.7)	7.5	1.00
Type of surgery			
Congenital cardiovascular surgery	10,685 (26.4)	4.0	1.00
Valve surgery	12,606 (31.1)	4.8	0.66 (0.54-0.81)*
Coronary artery surgery	12,980 (32.0)	4.6	0.41 (0.33-0.51)*
Aorta surgery	2,733 (6.7)	15.4	1.42 (1.14-1.77)*
Valve and coronary artery surgery	1,518 (3.8)	10.2	1.11 (0.85-1.44)
Charlson Comorbidity Index (points)			
0	18,150 (44.8)	4.4	1.00
1	10,194 (25.2)	4.6	0.95 (0.84-1.08)
2	5,504 (13.6)	6.6	1.26 (1.09-1.46)*
≥ 3	6,674 (16.5)	8.5	1.78 (1.55-2.03)*
Received a percutaneous coronary intervention within a year prior to surgery			
Yes	874 (2.2)	7.9	1.42 (1.09-1.86)*
No	39,648 (97.8)	5.4	1.00
Emergency surgery			
Yes	3,560 (8.8)	15.4	2.74 (2.43-3.09)*
No	36,962 (91.2)	4.5	1.00
Year			
2010	8,256 (20.4)	5.2	1.00
2011	8,095 (20.0)	5.4	1.00 (0.87-1.15)
2012	8,154 (20.1)	5.9	1.04 (0.91-1.20)
2013	8,000 (19.7)	5.8	1.01 (0.88-1.17)
2014	8,017 (19.8)	4.9	0.82 (0.71-0.95)*

Values are presented as number (%) or %.

*p < 0.05.

tients with health insurance had surgeries in hospitals that performed 350 heart surgeries or more annually. In contrast, 59.2% of patients with medical aid had surgery in hospitals that performed fewer than 200 heart surgeries annually.

Most patients did not receive a PCI within one

year prior to surgery (97.8%), and in cases where the patient did, most underwent surgery in hospitals that perform 350 or more heart surgeries annually. Emergency surgeries accounted for 8.8% of the total cases, and most had surgeries in hospitals that perform 50-199 surgeries annually.

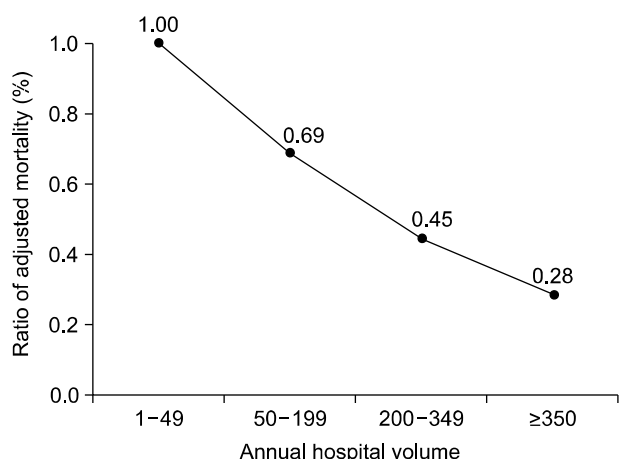


Fig. 1. Adjusted mortality rate against annual hospital volume, ratio for low treatment volume hospitals.

2) Factors that affect the treatment outcomes for different volumes of heart surgeries

Statistically, the mortality rate of patients was significantly lower in hospitals that performed a high number of heart surgeries annually, and the mortality rate of patients who were 65 years and older was significantly higher than that of patients who were under 40 years. Patients with a Charlson Comorbidity Index of 2 or greater had much higher mortality rates than those who had an index of zero (Table 2). The mortality rate of patients who had a PCI within one year of the surgery, or who underwent an emergency surgery, was significantly higher than the rate of those who did not.

3) Relationship between the volume of heart surgeries performed and the treatment outcomes

Differences in the mortality rate within the hospital or within 30 days of the surgery for each volume group of heart surgery patients (accounting for patient characteristics) is depicted in Fig. 1. It is clear that the mortality rate within the hospital or within 30 days of surgery decreases as the volume of heart surgeries performed increases. In cases of congenital heart disease surgery, heart valve surgery, coronary artery surgery, and aorta surgery the mortality rate decreases as the volume of the heart surgery hospital increases.

Discussion

This study analyzed the relationship between the number of heart surgeries performed by a hospital and the mortality rate from the surgery for heart surgery hospitals nationwide in the last five years (2010–2014). The mortality rate in the hospital or within 30 days of surgery in Korea was 5.4%, and factors such as age, whether a PCI was performed within a year prior to the surgery, and whether the surgery was an emergency surgery, all significantly affected the mortality rate.

Compared to large hospitals, which perform many heart surgeries annually, smaller hospitals received patients who had national Medicare and were relatively older, with many of the patients being 65 years old and older, while also performing relatively more emergency surgeries. This indicates that the conditions of patients admitted to smaller hospitals are much worse compared to those admitted to larger hospitals with more experience in heart surgery. The adjusted mortality rate showed that the mortality rate decreases as the volume of surgeries performed by the hospital increases, and the adjusted mortality rate in hospitals that performed more than 200 surgeries annually was less than half that in hospitals that performed 49 or less surgeries annually. This demonstrates that there is an intimate relationship between the number of heart surgeries performed and the mortality rate of the heart surgery, while also emphasizing that in order to maintain or improve the quality of heart surgeries, a certain number of heart surgeries should be performed annually.

Although there is limited research conducted domestically regarding the relationship between the volume of heart surgeries performed and the treatment outcomes, such research has been conducted quite thoroughly in foreign countries and results have been used to manage the quality of heart surgeries. As an example, the Leapfrog Group in the United States requires hospitals to perform at least 500 coronary artery bypass surgeries annually [4,5]. However, research regarding the relationship between the volume of heart surgeries performed and the treatment outcomes have caused controversy. In the case of the United States, there has been criticism that many of the factors that could affect heart sur-

gery cannot be properly reflected in the research due to the nature of heart surgery, and that such results could reduce the number of surgeries requested of small hospitals, hence exacerbating the situation. Other concerns have been identified, such as patients with high degree of comorbidity avoiding surgery and safety concerns regarding patients who have no choice but to seek treatment from hospitals with little surgical experience regardless of any increase in accessibility of larger, more experienced hospitals [10]. However, despite the controversy, problems are slowly being resolved.

Although the situation in Korea is much different, in the state of New York, it was found that one hospital had a low number of heart surgeries and unsatisfactory results, and it was traced to a certain doctor who had an unusually high mortality rate [11]. The doctor, who was a pediatric heart surgeon, had to perform emergency heart surgery on adults as well as children due to hospital management [11]. In another hospital, the high mortality rate of heart surgery was because surgery was carried out when the patient had not been sufficiently stabilized [11].

To help reduce the mortality rate, some hospitals in the state of New York hired a thoracic surgeon to be on duty in order to lower the mortality rate of heart surgery, placed the intensive care unit for heart surgery and heart-surgery equipment on one floor, and hired numerous dedicated anesthetists, nurses, and physician assistants with ongoing education and evaluation [11].

The role of the head surgeon is important in the result of heart surgery. However, in surgeries that require high levels of cooperation, such as heart surgery, we acknowledge the fact that the role of the professional staff (e.g., physician assistants, dedicated surgical nurses, cardiopulmonary experts, cardiologists, heart anesthetists, and the intensive care unit team) involved in managing pre and post-surgery conditions is much more significant than other surgeries. In order to obtain good treatment outcomes, the professional staff must be experienced and be able to cooperate smoothly.

Each hospital in Korea has their own unique situation, and we note that this research does not encompass individual circumstances in our calculations. In order to improve the mortality rates of hospitals that have a low number of heart surgeries, consid-

eration is needed for the diverse situations of each hospitals and analysis regarding the particular high mortality rates. For heart surgeries, the clinical conditions of the patients, such as comorbidity and emergency surgeries, have a significant impact in the treatment outcomes [12,13].

Results of this research indicate there is a higher percentage of severe patients in hospitals that perform fewer surgeries annually. However, there is a possibility that our research has neglected some other clinical factors that could affect the heart surgery mortality rates. Because we cannot specifically identify the clinical characteristics of the heart surgery patients, this study used administrative data and the widely used Charlson Comorbidity Index in its calculations. There is a limitation that these analyses cannot directly correct for the clinical characteristics of cyclical conditions. Further analysis that sufficiently considers the clinical conditions of the heart surgery patients through a combination of administrative and clinical data is needed.

Despite these limitations, this study is significant in that it is the first to reveal a relationship between the number of heart surgeries performed and mortality rate for every hospital in the last five years throughout Korea. This research is of utmost importance when considering the imbalance of medical services caused by the concentration of heart surgery in certain hospitals. It is also important as a research study that reveals the relationship between the volume of surgery performed and the surgery mortality rate domestically. Results of this research can be used effectively to help improve the health and safety of the citizens of Korea.

In conclusion, all heart surgery hospitals in Korea displayed a tendency to have a decreased mortality rate as the volume of the heart surgeries performed increased. This trend emphasizes the need to perform at least a certain number of heart surgeries in order to maintain or improve the quality of heart surgeries in hospitals. In order to improve the treatment outcomes of smaller hospitals with fewer heart surgeries, a support policy that shares the experience of professionals and allows for smooth cooperation is desperately required.

Conflict of interest

No potential conflicts of interest relevant to this article are reported.

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