Hospital Nurse Staffing and Surgical Outcomes of Cardiovascular Patients

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Hospital Nurse Staffing and Surgical Outcomes of Cardiovascular Patients

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ABSTRACT

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Background:

The association between mortality, along with complication rates, and nurse staffing has been previously reported in many countries and studies. However, nurse staffing has not yet been maintained at an optimal staffing level. To improve the nurse staffing level, many policies have been introduced, including "The Graded Fee of Nursing Management for Inpatient System," but most policies were focused on quantitative aspects. Few studies have considered the relationship between nurse staffing and the rates of mortality and complications in Korea using secondary data, which represent Korean hospitals. Therefore, this study aims to investigate the relationship between nurse staffing and cardiovascular surgery patients' mortality and complication rates.

Methods:

This study used the 2010 and 2011 'Patient Survey' dataset. The total population, which had undergone cardiovascular surgery, was 9,131 patients. Among the total population, 4,823 patients were in tertiary hospitals and 4,308 patients were in general hospitals. Among the 212 hospitals, 44 were tertiary hospitals and 168 were general hospitals. A linear mixed-effects model with a random intercept for multilevel data including patient and hospital was used to find the relationship between the level of nurse staffing and the mortality and complication rates. This study adjusted for independent variables at both the patient and hospital levels. At the patient level, age, sex, Charlson comorbidity index, type of admission, admission method, type of insurance, year, and length of stay were included. The type of hospital, ownership, region, teaching, number of beds, number of doctors per 100 beds, number of nurse aids per 100 beds were included at the hospital level.

Results:

In the linear mixed model, as the number of registered nurses per 100 beds increased, the mortality rate (%) at discharge decreased by 0.02% (P=0.04) in total and by 0.04% (P=0.02) in the general hospitals. However, there was no significant result in the tertiary hospitals. For the complication rate, as the number of registered nurses per 100 beds increased, the complication rate (%) decreased by 0.03% (P<0.0001) in total, by 0.02% (P=0.02) in the tertiary hospitals, and by 0.06% (P<0.0001) in the general hospitals.

Conclusions:

The proper level of nurse staffing should keep in mind the effects on the mortality and complication rates in the cardiovascular surgery population. Also, the different effects of the hospital type and the severity of patient disease should be considered at the same time when increasing nurse staffing.

Key words: nurse staffing, quality of care, mortality, complication

Ⅰ. INTRODUCTION

1. Background

A health care system is composed of many stakeholders such as health care providers, insurers, and insured individuals or groups. Each sector is in a different situation and has a different perspective on health policy. Recently, health policy has focused on the constraint of health-expenditure growth.[1-5] To allocate limited resources fairly, the constraint of health-expenditure growth is an important health policy. However, health policy that reduces medical costs is not always a perfect solution, like a double-edged sword. The hidden side of the constraint of health-expenditure growth is decreasing quality of care. To control a hospital's expense through health policy, the hospital may reduce the expense of hiring medical staff, resulting in a heavy workload for the medical staff and a high intensity of patient care.[1,6,7] The nurse is one of the most important professionals who care for individuals and help patients to attain optimal health and improved quality of life along with the other medical professionals in the hospital. Among the various medical staff, the nurse can be an easy target for saving on expenses.[1,8] A decrease in the number of staff nurses in intensive patient care may cause low quality of care.[7,9] In contrast, the mortality and complication rates could be decreased by an insufficient level of nurse staffing.

In many studies, the relationship between patient outcomes and nurse staffing levels has already been examined.[10] For mortality, Aiken reported that as the number of patients per nurse increased, the patients' mortality rate increased.[6] Also, Needleman mentioned that as the hours of nurse care increased, the complication rate and the length of stay decreased.[7] The longitudinal study by Mark showed that when the registered nurse staffing level increased, the mortality ratio decreased.[11] Also, other studies reported a positive relationship between decreasing the mortality rate and increasing the nurse

staffing level.[12-17] For complications, Kovner mentioned that the number of registered nurses per adjusted inpatient day and the rate of surgery adverse events, which are urinary tract infections and pneumonia after major surgery, had an inverse relationship.[2] Also, Blegen reported that adverse outcomes decreased by 87.5% as the registered nurse proportion increased.[18] In addition, Lichtig mentioned a result similar to that of other researchers, which is the adverse relationship between the proportion of registered nurses and the rate of complications.[19] In many studies, the influence of the nurse staffing level on the complication rate was demonstrated.[20-26]

Patients who are admitted to a hospital for surgery require intensive care with invasive procedures. Among the various surgeries, patients undergoing cardiovascular surgery were chosen as the target population for this study because of the high risk and the high volume of surgeries, and because the health care outcome-measurement and reporting system has long been well-executed.[15,27] After surgery, unexpected results, which are adverse outcomes such as mortality and complication, could occur. Under this situation, the nurse is a substantial part of the medical staff, because nurses represent about 46% of the workforce in health care.[28] Also, nurses provide 24-hour care directly beside the patients. Therefore, the appropriate nurse staffing level, optimized for a given workforce, improves the productivity of the organization and patient outcomes.

To improve the nurse staffing level, the Korean government put effort into making policy for secure and optimal nursing staff. Registered nurses are those who graduate from a nursing school and obtain a license by passing the national examination.[29] Usually, policy can be divided into two categories: regulation and incentive.[30] To increase the nurse level, the medical care law and the enforcement of its regulations in 1962 recommended that the ratio of hospital nurses to patients be one nurse per 2.5 annual average inpatients.[29-32] However, only 9.2% of hospitals followed the recommended nurse-to-patient ratios.[29]

After several years, another medical care law was established in 1999. “The Graded Fee of Nursing Management for Inpatient System” was introduced as an incentive system,

with hospitals rated from Grades 1–7.[28-32] A lower grade means the number of patients per nurse is low. Hospitals report their nursing grade to the government, and the hospitals are reimbursed with a nursing management fee by grade. However, the proportioning of the nurse-staffing grade is not reasonable. Only 4.9% of hospitals had obtained Grade 1 or 2, and the proportion with Grade 3 or higher was about 82% in 2010.[29] The nurse staffing has not been maintained at the proper level, yet, for several reasons, including policy limitations.

To provide information for making effective policies, studies that can provide evidence for making effective policy decisions should be conducted. However, there are few studies on the relationship between nurse staffing and patient outcomes in Korea. Therefore, this study investigated the relationship between nurse staffing and patient outcomes, which are the mortality and complication rates, in the cardiovascular surgery population.

2. Study Objectives

The purpose of this study was to investigate the relationship between nurse staffing and patient mortality and complications after cardiovascular surgery. The specific objectives are as follows.

First, this study investigated the relationship between nurse staffing and patient mortality rates. Second, this study investigated the relationship between nurse staffing and patient complication rates.

Ⅱ. LITERATURE REVIEW

1. Definition of Nurse Staffing

Nurse staffing is defined in many ways. In some research, nurse staffing is calculated as the nurse-to-patient ratio only[6] or with the nurses' last shift information.[1,33] In Korea, the nurse-to-patient ratio is categorized into seven groups to reimburse hospitals differently.[28,30] The number of nurses per 100 beds is also used to define nurse staffing.[34] Also, nurse staffing can be defined by counting the mean number of patients assigned to nurses at the last work shift.[35] In addition, the number of nursing staff could be calculated as the nursing hours per patient day (NHPPD). Each nursing unit was divided by the total hours worked by registered nurses.[15] Also, the levels of staffing by licensed practical nurses and nurse aides were estimated in hours, as well.[7] The educational level was measured by calculating the proportion of registered nurses with a Bachelor's degree or higher in each nursing unit.[6,15] In other research, nurse staffing was calculated as the difference between the target registered nurse hours for the shift and the actual hours worked on the unit in direct patient care.[36] The nurses' sex, years of experience in nursing, educational level such as baccalaureate degree or higher or diploma or associate degree, and nursing specialty could be considered when defining nurse staffing.[6]

2. Nurse Staffing and Patient Outcomes

In many studies, there are results showing the relationship between nurse staffing levels and patient outcomes such as mortality and complications (Table 1).

Hickey PA et al. [37,38] studied pediatric cardiac surgery. The result showed that neither registered nurse full-time equivalents nor registered nurse ratios were associated with mortality or complications, and that nursing care hours were associated with risk-adjusted mortality.

Van Den Heede et al. [8,39] mentioned that nurse staffing levels would avoid an estimated 45.9 patient deaths per year and generate 458.86 life-years gained annually. This corresponds to incremental cost-effectiveness ratios of EUR 26,372 per avoided death and EUR 2,639 per life-year gained in cardiac surgery. Also, increased nurse staffing in postoperative general nursing units was significantly associated with decreased mortality. However, nurse staffing in postoperative intensive care units was not significantly associated with in-hospital mortality, possibly due to a lack of variation in intensive care-unit staffing across hospitals.

Aiken [1,6,40] studied surgical patients. The results were that increasing the nurses' workload by one patient increased the likelihood of an inpatient dying within 30 days of admission by 7%. In addition, each additional patient per nurse was associated with a 7% (OR: 1.07, 95% CI: 1.02–1.11) increase in the odds of failure-to-rescue. In comparing magnet and non-magnet hospitals, the magnet hospitals had a 4.6% lower mortality rate compared with the non-magnet hospitals.

Kovner [2] said that a large and significant inverse relationship was found between full-time-equivalent registered nurses per adjusted inpatient day (RNAPD) and urinary tract infections after major surgery, as well as pneumonia after major surgery. A significant, but less robust, inverse relationship was found between RNAPD and thrombosis after major surgery as well as pulmonary compromise after major surgery.

Needleman [7] motioned that among medical patients, a higher proportion of hours of

care per day provided by registered nurses and a greater absolute number of hours of care per day provided by registered nurses were associated with lower rates of both urinary tract infections and upper gastrointestinal bleeding. A higher proportion of hours of care provided by registered nurses were also associated with lower rates of pneumonia, shock or cardiac arrest, and failure-to-rescue, which was defined as death from pneumonia, shock or cardiac arrest, upper gastrointestinal bleeding, sepsis, or deep venous thrombosis. Among surgical patients, a higher proportion of care provided by registered nurses was associated with lower rates of urinary tract infections; and a greater number of hours of care per day provided by registered nurses was associated with lower rates of failure-to-rescue. However, there were no associations between increased levels of staffing by registered nurses and the rate of in-hospital deaths.

Blegen et al. [41] showed that there were improvements in the rates of medication errors, patient falls, and cardiopulmonary arrests as registered nurse hours increased. Cho [42] said that an increase of 1 hour worked by registered nurses per patient day was associated with an 8.9% decrease in the odds of pneumonia. Similarly, a 10% increase in the registered nurse proportion was associated with a 9.5% decrease in the odds of pneumonia. Providing a greater number of nursing hours per patient day was associated with a higher probability of pressure ulcers in 20 surgical diagnosis-related groups.

Kovner et al. [43] reported that an inverse relationship was found between registered nurse hours per adjusted inpatient day and pneumonia ($p<0.05$) for routine and emergency patient admissions. Mark et al. [11] mentioned that increasing registered nurse staffing had a diminishing marginal effect on reducing the mortality ratio, but had no consistent effect on any of the complications. Person [44] studied acute myocardial infarction. The result was that patients treated in environments with higher registered nurse staffing levels were less likely to die in the hospital. However, after adjustment, patients treated in environments with higher Licensed Practical Nurse staffing were more likely to die in the hospital. Silber [45] studied general and orthopedic surgical admissions, and found reduced failure-to-rescue rates at higher staffing levels (registered nurses/bed).

Unruh [46] mentioned that a 10% increase in licensed nurses would lead to an estimated 1.5% decrease in atelectasis, a 2% reduction in pressure ulcers, a 3% reduction in falls, and a 1% reduction in urinary tract infections. Kuhn [13] said that mortality rates were decreased at higher staffing levels (registered nurses/all nurses). Blegen [18] showed that as the registered nurse proportion increased, the rates of adverse outcomes decreased by up to 87.5%. Also, as the registered nurse proportion increased, the adverse outcome rates also increased. Lichtig [19] reported that lower adverse outcome rates were more consistently related to a higher proportion of registered nurses. Robert [25] studied surgical intensive care-unit patients, and found that the nurse staffing composition, such as the pool-nurse-to-patient ratio, was related to the risk of primary bloodstream infections (BSI).

Kim et al. [32] reported that there was an inverse relationship between nurse staffing and the mortality rate among surgical patients. As the Nurse Grade increased, the number of patients per nurse increased. Compared with Nurse Grades 0–1, which are enough nurse staffing, Grades 6–7 (OR=2.99), Grades 4–5 (OR=1.78), and Grades 2–3 (OR=1.57) had higher mortality rates. Also, lower nurse staffing levels were associated with higher rates of complications such as pneumonia and sepsis.

Table 1. Literatures of Nurse Staffing Level and Quality of Care

Number	Author	Year	Country	Design	Subjects	Main results
1	Aiken et al. [1]	2014	Europe	Cross-sectional analyses	Surgical patients	An increase in a nurses' workload by one patient increased the likelihood of an inpatient dying within 30 days of admission by 7%.
2	Hickey et al. [37]	2011	U.S.	Cross-sectional analyses	Pediatric cardiac surgery	No association between registered nurse Full Time Equivalents, registered nurse ratios and mortality, complications.
3	Hickey et al. [38]	2010	U.S.	Cross-sectional analyses	Pediatric congenital heart surgery	Nursing worked hours was associated with risk-adjusted mortality.
4	Van Den Heede et al. [8]	2010	Belgium	Cost effectiveness analysis	Cardiac surgery	Nurse staffing levels would avoid 45.9 patient deaths per year, and generate 458.86 life-years gained annually.
5	Van Den Heede et al. [15]	2009	Belgium	Cross-sectional analyses	Cardiac surgery	Increased nurse staffing in postoperative general nursing units was associated with decreased mortality. No relationship on nurse staffing in postoperative intensive care units.
6	Mark et al. [11]	2004	U.S.	Longitudinal cohort	All patients	Increasing registered nurse staffing decrease marginal effect on reducing mortality ratio, but had no consistent effect on any of the complications.
7	Person et al. [44]	2004	U.S.	Cross-sectional analyses	Acute myocardial infarction	Higher registered nurse staffing reduces in-hospital mortality. But, higher Licensed Practice Nurses staffing increases in-hospital mortality.
8	Unruh [46]	2003	U.S.	Cross-sectional analyses	All patients	10% increase in Licensed Nurses lead to 1.5% decrease in atelectasis, 2% reduction in pressure ulcers, 3% reduction in falls, and 1% reduction in urinary tract infections.
9	Cho et al. [42]	2003	U.S.	Cross-sectional analyses	20 surgical diagnosis-related groups	An increase of 1 hour worked by registered nurses (RN) per patient day was associated with an 8.9% decrease in the odds of pneumonia. A 10% increase in RN Proportion was associated with a 9.5% decrease in the odds of pneumonia. Providing a greater number of nursing hours per patient day was associated with a higher probability of pressure ulcers.

Table 1. Literatures of Nurse Staffing Level and Quality of Care (continued)

Number	Author	Year	Country	Design	Subjects	Main results
10	Aiken et al. [6]	2002	U.S.	Cross-sectional analyses	Surgical patients (general, orthopedic, and vascular)	Each additional patient per nurse was associated with a 7% increase in the odds of failure-to-rescue.
11	Needleman et al. [7]	2002	U.S.	Cross-sectional analyses	Medical and Surgical patients	Medical patients: number of hours of care per day provided by registered nurses were associated with a lower rates of urinary tract infections, upper gastrointestinal bleeding, pneumonia, shock or cardiac arrest, and failure-to-rescue. Surgical patients: a higher proportion of care provided by registered nurses was associated with lower rates of urinary tract infections and failure-to-rescue. No associations between increased levels of staffing by registered nurses and the rate of in-hospital deaths.
12	Kovner et al. [43]	2002	U.S.	Cross-sectional analyses	All patients	An inverse relationship between registered nurse hours per adjusted inpatient day and pneumonia for routine and emergency admissions.
13	Kim et al. [32]	2002	Korea	Cross-sectional analyses	one of 12 types of surgery	Inverse relationship between nurse staffing and patient mortality. Increasing mortality with Grades 6–7 (OR=2.99), Grades 4–5 (OR=1.78), and Grades 2–3 (OR=1.57) compared with Grades 0–1. Lower nurse staffing level associated with higher pneumonia and sepsis rates.
14	Silber [45]	2000	U.S.	Cross-sectional analyses	General and Orthopedic surgical	Reduced failure-to-rescue rates at higher staffing levels (registered nurses/bed).
15	Robert et al. [25]	2000	U.S.	Cross-sectional analyses	Surgical intensive care unit	Nurse staffing composition such as pool-nurse-to-patient ratio was related to primary bloodstream infection risk.
16	Lichtig et al. [19]	1999	U.S.	Cross-sectional analyses	All patients	Lower adverse outcome rates were more consistently related to a higher proportion of registered nurses.

Table 1. Literatures of Nurse Staffing Level and Quality of Care (continued)

Number	Author	Year	Country	Design	Subjects	Main results
17	Blegen et al. [18]	1998	U.S.	Cross-sectional analyses	All patients	As the registered nurse proportion increased, rates of adverse outcomes decreased by up to 87.5%.
18	Blegen et al. [41]	1998	U.S.	Cross-sectional analyses	All patients	Improvements in rates of medication errors, patient falls, and cardiopulmonary arrests as registered nurse hours increased.
19	Kovner et al. [2]	1998	U.S.	Cross-sectional analyses	Surgical patients	Inverse relationship between full-time-equivalent registered nurses per adjusted inpatient day (RNAPD) and urinary tract infections, pneumonia, and thrombosis after major surgery.
20	Aiken et al. [40]	1994	U.S. and U.K.	Cross-sectional analyses	All patients	The magnet hospitals have a 4.6% lower mortality rate compared with non-magnet hospitals.
21	Kuhn et al. [13]	1991	U.S.	Cross-sectional analyses	All patients	Decreased mortality rates at higher staffing levels (registered nurses/all nurses).

Ⅲ. STUDY METHOD

1. Study Sample and Data

This study is a secondary data analysis. Patient and hospital data were obtained from the Patient Survey dataset assembled by the Ministry of Health and Welfare in 2010 and 2011. The total population with cardiovascular surgery and National Health Insurance and Medical Aid was 9,131 individuals. Among the total population, 4,823 patients were in tertiary hospitals and 4,308 patients were in general hospitals. Among the 212 hospitals, 44 were tertiary hospitals and 168 were general hospitals (Figure 1).

The Patient Survey dataset was built to investigate the status of medical care use, patient disease patterns, health care institutes, and medical staffs. The target institutions are all hospitals. Institutions under the hospital level conducted surveys with sampling, but all the institutions' data were collected at a level higher than the hospital level. All the hospitals submitted one month's worth of data per year.

The data on the patients were from the Patient Discharge dataset, which is collected from all hospitals and has medical information on patients. The target patients were those who experienced cardiovascular surgery. The International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) volume 3 categorized procedures (Appendix 1). Among the categories of procedures, codes 35–39 are for cardiovascular surgery. Appendix 2 shows the details of the ICD coding of procedures. The target insurance types were the National Health Insurance and Medical Aid.

The data on hospitals were from the Organization Survey dataset, which has hospital information. The target hospitals were tertiary and general hospitals. General hospitals have more than 100 beds, between 100 and 300 beds with more than seven specialized departments, or more than 300 beds with more than nine specialized departments. Tertiary hospitals were selected from among the general hospitals and met the requirements of the

Ministry of Health and Welfare, such as providing medical care for severe patients, having more than 20 specialized departments, being a teaching hospital, satisfying facility conditions and medical staffing levels, and having patients with mixed conditions.

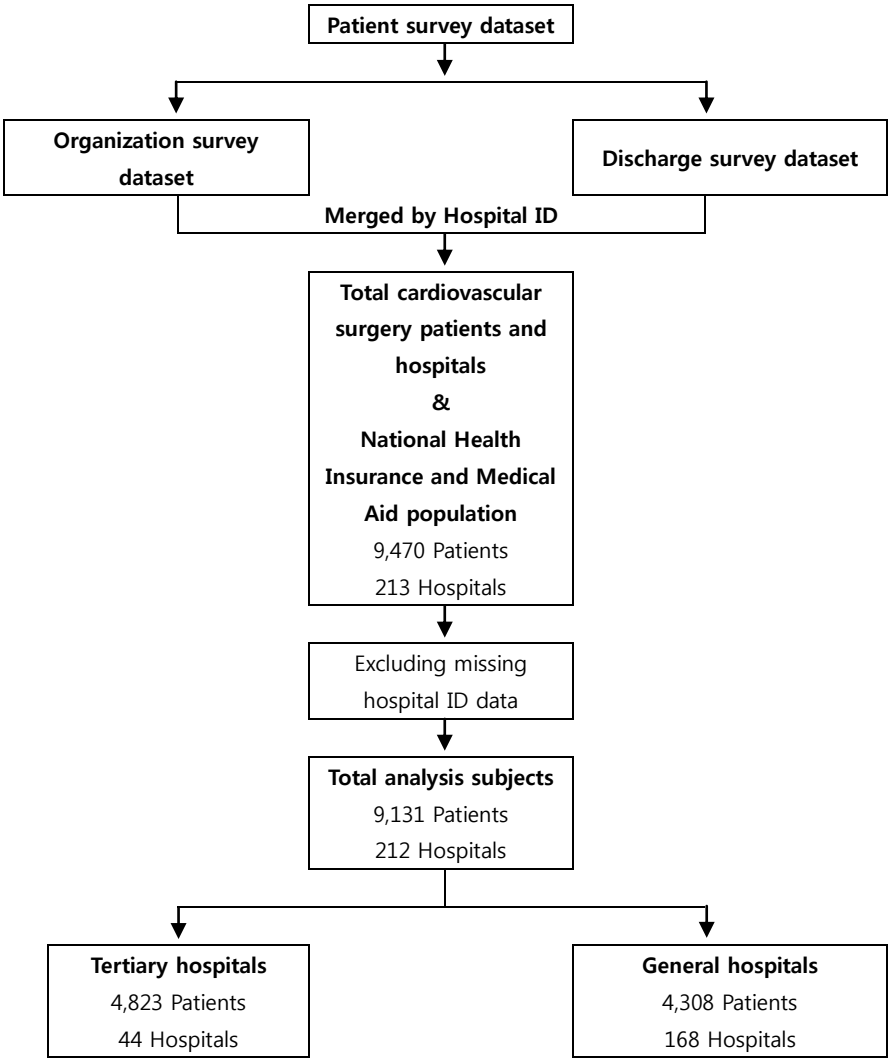

Figure 1. Flowchart of Subject Selection

2. Variables

1) Patient level (Table 2)

Age

In the patient level, the age variable was categorized into four groups: (1) <30, (2) 30–49, (3) 50–69, (4) 70≤.

Sex

The patients' sex was categorized into two groups: (1) Men and (2) Women.

Charlson Comorbidity Index

To adjust for the comorbidity of disease, the Charlson comorbidity index was used. The Charlson comorbidity score was calculated by taking the sum of the assigned weight score by diseases. The Charlson comorbidity index uses 17 comorbidities defined using clinical conditions by Charlson et al. in 1987.[47] The 10th Revision of the ICD (ICD-10) was made by the World Health Organization in 1992.[48] Halfon et al. [49] and Sundararajan et al. [50] developed ICD-10 coding algorithms to define the Charlson comorbidity index.

Type of Admission

The type of admission was categorized into two groups: (1) Outpatient and (2) Emergency.

Admission Method

The admission method was categorized into two responses: (1) Visit by oneself and (2) Transfer from other hospital.

Type of Insurance

The type of insurance was categorized into two types: (1) National Health Insurance and (2) Medical Aid.

Year

The included years were 2010 and 2011. Therefore, the variables were categorized into two responses: (1) 2010 and (2) 2011.

Length of Stay

The length of stay was the sum of the days from the date of admission to that of discharge. The length of stay was a continuous variable.

Table 2. Definitions of patient level variables

Variables		Definition
Patient Level	Age	(1) <30 (2) 30–49 (3) 50–69 (4) 70≤
	Sex	(1) Men (2) Women
	Charlson Comorbidity Index	(1) 0 (2) 1 (3) 2
	Type of Admission	(1) Outpatient (2) Emergency
	Admission Method	(1) Visit by oneself (2) Transfer from other hospital
	Type of Insurance	(1) National Health Insurance (2) Medical Aid
	Year	(1) 2010 (2) 2011
	Length of Stay	Total number of days from date of admission to that of discharge

2) Hospital level (Table 3)

Hospital Type

In the hospital level, the hospital type was divided into tertiary and general hospitals. The categories were: (1) Tertiary hospital and (2) General hospital.

Ownership of Hospital

The ownership of hospitals was divided into two groups: (1) Public and (2) Private.

Region of Hospital

The region of the hospitals was categorized into two groups: (1) Metropolitan area and (2) Non-metropolitan area.

Teaching Hospital

Teaching hospitals were categorized into two groups: (1) Yes and (2) No.

Number of Beds

The number of beds was the total number of beds on the general ward. The number of beds was a continuous variable.

Number of Doctors per 100 Beds

Doctor staffing is the number of doctors, including specialist and general doctors, per 100 beds by hospital.

Number of Nurse Aids per 100 Beds

The nurse aid staffing is the number of nurse aids per 100 beds.

Number of Registered Nurses per 100 Beds

Nurse staffing, which is a primary interest variable, is the number of registered nurses per 100 beds by hospital. In several studies [51-53], the number of nurses per 100 beds was used to represent the nurse staffing level.

Mortality rate (%)

The mortality rate, which is a dependent variable, is the rate of deaths in a hospital among the cardiovascular surgery population. This variable was asking about the "result of the treatment," and responses were categorized into five groups: (1) Recovery, (2) Not recovery, (3) Only diagnosis, (4) Discharge without hope, and (5) Death. The number of responses categorized as (5) Death was considered as a dependent variable.

Complication rate (%)

The complication rate, which is a dependent variable, is the rate of hospital patients among the cardiovascular surgery population that are diagnosed with complications by an ICD-10 code as a major or minor diagnosis. Complication codes were based on studies by Needleman et al. in 2001 and 2002, Van den Heede et al. in 2009 (Appendix 3), and Halfon et al. in 2002 (Appendix 4). This study combined two different complication codes to define complications.

Table 3. Definitions of hospital level variables

Variables		Definition
Hospital Level	Hospital Type	(1) Tertiary hospital (2) General hospital
	Ownership of Hospital	(1) Public (2) Private
	Region of Hospital	(1) Metropolitan area (2) Non-metropolitan area
	Teaching Hospital	(1) Yes (2) No
	Number of Beds	Total number of general ward's beds
	Number of Doctors per 100 Beds	Number of doctors including specialist and general doctors per 100 beds by hospital
	Number of Nurse Aids per 100 Beds	Number of nurse aids per 100 beds
	Number of Registered Nurses per 100 Beds (Primary interest)	Number of registered nurses per 100 beds by hospital
	Mortality Rate (Dependent)	Rate of in-hospital deaths among the cardiovascular surgery population
	Complication Rate (Dependent)	Rate of hospital complication among cardiovascular surgery population

3. Statistical Analysis

The data were structured hierarchically into two levels: hospital and patient. Data from 2010 and 2011 were matched by hospital. T-tests and chi-square tests were used to analyze whether general characteristics and nurse staffing had a relationship with mortality and complications at baseline time. Also, there were four models. In Model 1, we controlled nothing, which is the null model. In Model 2, we controlled patient-level variables such as age, sex, Charlson comorbidity index, type of admission, admission method, type of insurance, year, and length of stay. In Model 3, we controlled hospital-level variables such as type of hospital, ownership, region, teaching, number of beds, number of doctors per 100 beds, and number of nurse aids per 100 beds. In Model 4, we included patient-level and hospital-level variables. We accounted for the clustering of outcomes within hospitals using a linear mixed-effects model with a random intercept for multilevel data with patient and hospital levels. This approach is commonly used instead of basic regression approaches, because the outcomes for patients in the same hospital may be correlated. The threshold for significance was a p-value <0.05. All statistical analyses were conducted using SAS ver. 9.2 (SAS Institute, Cary, NC, US).

IV. RESULTS

1. Characteristics of Patients

Table 4 shows the characteristics of the patients with cardiovascular surgery. The total number of patients was 9,131. Among the total patients, 4,823 patients were in tertiary hospitals and 4,308 patients were in general hospitals.

At the patient level, in total as well as in the tertiary and general hospitals, about 51% of the patients were from 50 to 69 years of age, about 26% were 70 or more years of age, about 21% were from 30 to 49 years of age, and about 3% were 30 or fewer years of age. In terms of sex, about 56% of the patients were men, and there were similar proportions in the tertiary and general hospitals. For the Charlson comorbidity index score, about 51% of the patients were '0', 43% of the patients were '1', and 6% of the patients were '2'. In the general hospitals, about 57% of the patients were '0', 37% of the patients were '1', and 5% of the patients were '2'. However, in the tertiary hospitals, the proportions of Charlson comorbidity index scores were different from those in the general hospitals. About 46% of the patients were '0', 47% of the patients were '1', and 7% of the patients were '2'. Tertiary hospitals have more debilitated patients than general hospitals. In the type of admission, about 68% of the admissions were outpatient, and about 32% of the admissions were by emergency. There were similar proportions in the tertiary and general hospitals. About 91% of the patients had National Health Insurance, and the tertiary and general hospitals had similar patterns. The mortality rate, which is in-hospital deaths, was about 4% in the tertiary hospitals and 5% in the general hospitals. This difference indicates that patients in tertiary hospitals had less mortality than those in general hospitals.

The mortality rate, which is in-hospital deaths, was about 4% in the tertiary hospitals and 5% in the general hospitals.

The length of stay was 15 days in the tertiary hospitals and 13 days in the general hospitals. The tertiary hospitals' length of stay was longer than general hospitals' length of stay.

Table 4. Characteristics of patients Units: n (%) or Mean ± SD

Variable	Total	Tertiary	General	P-value
	n=9,131	*n=4,823*	*n=4,308*	
Age (years)				0.17
70≤	2,363 (25.9)	1,236 (25.6)	1,127 (26.2)	
50-69	4,631 (50.7)	2,487 (51.6)	2,144 (49.8)	
30-49	1,899 (20.8)	968 (20.1)	931 (21.6)	
<30	238 (2.6)	132 (2.7)	106 (2.5)	
Sex				0.02
Men	5,068 (55.5)	2,733 (56.7)	2,335 (54.2)	
Women	4,063 (44.5)	2,090 (43.3)	1,973 (45.8)	
Charlson Comorbidity Index				<0.0001
2	559 (6.1)	325 (6.7)	234 (5.4)	
1	3,886 (42.6)	2,274 (47.2)	1,612 (37.4)	
0	4,686 (51.3)	2,224 (46.1)	2,462 (57.2)	
Type of Admission				0.14
Outpatient	6,226 (68.2)	3,256 (67.5)	2,970 (68.9)	
Emergency	2,905 (31.8)	1,567 (32.5)	1,338 (31.1)	
Admission Method				<0.0001
Visit	7,230 (79.2)	3,404 (70.6)	3,826 (88.8)	
Transfer	1,901 (20.8)	1,419 (29.4)	482 (11.2)	
Type of Insurance				<0.0001
National Health Insurance	8,280 (90.7)	4,437 (92.0)	3,843 (89.2)	
Medical Aid	851 (9.3)	386 (8.0)	465 (10.8)	
Year				<0.0001
2010	4,938 (54.1)	2,464 (51.1)	2,474 (57.4)	
2011	4,193 (45.9)	2,359 (48.9)	1,834 (42.6)	
Mortality (%)	4.0 ± 6.2	3.9 ± 4.1	4.2 ± 7.9	<0.0001
Complications (%)	11.6 ± 13.7	14.1 ± 15.6	8.9 ± 10.4	<0.0001
Length of Stay (days)	13.9 ± 30.7	15.0 ± 36.8	12.7 ± 21.8	<0.0001

2. Characteristics of Hospitals

Table 5 shows the characteristics of the hospitals with cardiovascular surgery. At the hospital level, 22% public-type hospitals were tertiary hospitals and 13% were general hospitals. In terms of the region, 82% of the tertiary hospitals were in metropolitan areas, and 37% of the general hospitals were in metropolitan areas. The tertiary hospitals were more often located in big cities. The mean number of beds was 1,163 in the tertiary

hospitals and 489 in the general hospitals. The mean number of doctors, which includes specialists and generalists, per 100 beds was 27 doctors in the tertiary hospitals and 17 doctors in the general hospitals. The tertiary hospitals had more doctors than the general hospitals. The mean number of registered nurses per 100 beds was 96 nurses in the tertiary hospitals and 68 nurses in the general hospitals. The tertiary hospitals had more registered nurses than the general hospitals. The number mean of nurse aids per 100 beds was seven both in the tertiary and the general hospitals.

The total number of hospitals was 212. The number of tertiary hospitals was 44, and the number of general hospitals was 168. In ownership, about 23% of the tertiary hospitals were public, and 16% of the general hospitals were public. Sixty-eight per cent of the tertiary hospitals were located in metropolitan areas, and 48% of the general hospitals were located in metropolitan areas. All the tertiary hospitals were teaching hospitals. Approximately 63% of the general hospitals were teaching hospitals.

Table 5. Characteristics of hospitals Units: n (%) or Mean ± SD

Variable	Total	Tertiary	General	P-value
Number of Patients	*n=9,131*	*n=4,823*	*n=4,308*	
Ownership				<0.0001
Public	1,620 (17.7)	1,044 (21.7)	576 (13.4)	
Private	7,511 (82.3)	3,779 (78.4)	3,732 (86.6)	
Region				<0.0001
Metropolitan Area	5,545 (60.7)	3,972 (82.4)	1,573 (36.5)	
Non-metropolitan Area	3,586 (39.3)	851 (17.6)	2,735 (63.5)	
Teaching				<0.0001
No	564 (6.2)	-	564 (13.1)	
Yes	8,567 (93.8)	4,823 (100)	3,744 (86.9)	
Number of Beds	844.6 ± 574.2	1162.5 ± 620.2	488.7 ± 168.8	<0.0001
Number of Doctors per 100 Beds	22.5 ± 8.3	27.3 ± 7.3	17.1 ± 5.6	<0.0001
Number of Registered Nurses per 100 Beds	82.9 ± 25.5	96.2 ± 21.8	67.9 ± 20.5	<0.0001
Number of Nurse Aids per 100 Beds	7.0 ± 6.6	6.9 ± 7.7	7.2 ± 5.0	0.02
Number of Hospitals	*n=212*	*n=44*	*n=168*	
Ownership				
Public	37 (17.5)	10 (22.7)	27 (16.1)	
Private	175 (82.6)	34 (77.3)	141 (83.9)	
Region				
Metropolitan-area	110 (51.9)	30 (68.2)	80 (47.6)	
Non-metropolitan area	102 (48.1)	14 (31.8)	88 (52.4)	
Teaching				
No	63 (29.7)	-	63 (37.5)	
Yes	149 (70.3)	44 (100)	105 (62.5)	

3. Characteristics of Nurse Staffing

Table 6 shows the characteristics of the nurses staffing in the hospitals. The mean number of registered nurses was 83 among the total hospitals. The mean number of registered nurses was 83 in the public hospitals and 68 in the private hospitals. About 88 registered nurses were working in metropolitan-area hospitals, and 74 nurses were working in non-metropolitan-area hospitals. The mean number of registered nurses was 85 in the teaching hospitals and 48 in the non-teaching hospitals.

The mean number of nurse aids was 7.0 in the total hospitals. About 10 nurse aids were working in the public hospitals, and 7 were working in the private hospitals. The mean number of nurse aids was eight in metropolitan hospitals and six in non-metropolitan hospitals. Approximately seven nurse aids were working in both the teaching and the non-teaching hospitals.

The mean number of registered nurses and nurse aids as a total nursing staff was 90 in the total hospitals. In the public hospitals the average size of the nursing staff was 93, and in the private hospitals, it was 75. The size of the nursing staff was about 96 in the metropolitan hospitals and 80 in the non-metropolitan hospitals. The size of the nursing staff was 55 in the teaching hospitals and 92 in the non-teaching hospitals.

Table 6. Characteristics of Nurse Staffing Units: Mean ± SD

Nurse Type	Variable	2010	2011	Mean
Number of Registered Nurses per 100 Beds	**Type of Hospital**			
	Total	82.2 ± 25.7	83.4 ± 25.4	82.9 ± 25.5
	Tertiary	95.3 ± 21.5	97.1 ± 22.1	96.2 ± 21.8
	General	65.3 ± 20.2	69.8 ± 20.6	67.9 ± 20.5
	Ownership			
	Public	82.0 ± 20.1	83.6 ± 25.0	82.8 ± 22.7
	Private	82.2 ± 26.8	83.4 ± 25.4	82.9 ± 26.1
	Region			
	Metropolitan Area	88.3 ± 25.8	88.4 ± 25.6	88.4 ± 25.7
	Non-metropolitan Area	72.4 ± 22.3	75.9 ± 23.0	74.3 ± 22.7
	Teaching			
	No	49.3 ± 17.4	47.2 ± 16.1	48.1 ± 16.7
	Yes	84.2 ± 24.7	86.0 ± 23.9	85.1 ± 24.3
Number of Nurse Aids per 100 Beds	**Type of Hospital**			
	Total	7.1 ± 6.5	7.0 ± 6.7	7.0 ± 6.6
	Tertiary	6.9 ± 7.6	6.9 ± 7.9	6.9 ± 7.7
	General	7.3 ± 4.8	7.2 ± 5.2	7.2 ± 5.0
	Ownership			
	Public	9.6 ± 7.3	10.1 ± 8.2	9.9 ± 7.8
	Private	6.5 ± 6.1	6.4 ± 6.2	6.4 ± 6.2
	Region			
	Metropolitan Area	7.9 ± 7.4	7.7 ± 7.8	7.7 ± 7.6
	Non-metropolitan Area	5.8 ± 4.3	6.1 ± 4.4	5.9 ± 4.4
	Teaching			
	No	7.5 ± 4.6	7.4 ± 4.5	7.4 ± 4.5
	Yes	7.0 ± 6.6	7.0 ± 6.8	7.0 ± 6.7
Number of Total Nursing Staff per 100 Beds	**Type of Hospital**			
	Total	89.2 ± 25.7	90.5 ± 24.3	89.9 ± 24.2
	Tertiary	102.2 ± 19.3	104.0 ± 7.9	103.1 ± 20.0
	General	72.5 ± 18.6	77.0 ± 19.8	75.1 ± 19.4
	Ownership			
	Public	91.6 ± 22.0	93.7 ± 28.0	92.6 ± 25.2
	Private	88.7 ± 24.4	89.8 ± 23.4	89.3 ± 23.9
	Region			
	Metropolitan-area	96.1 ± 23.6	96.1 ± 24.3	96.1 ± 24.0
	Non-metropolitan area	78.2 ± 20.2	82.0 ± 21.7	80.3 ± 21.1
	Teaching			
	No	56.8 ± 17.2	54.6 ± 15.3	55.5 ± 16.2
	Yes	91.2 ± 22.9	93.0 ± 22.8	92.2 ± 22.8

4. Characteristics of Dependent Variables

Table 7 shows the characteristics of the dependent variables at the patient level in the total hospitals. In the mortality rate (%), the older age group had a higher mortality rate compared with the younger age group. The men had a higher mortality rate, which was 4.06%, compared with the women, who had a 3.96% mortality rate. As the Charlson comorbidity index score increased from 0 to 2, the mortality rate increased from 3.89% to

4.58%. The mortality rate of the patients admitted through emergency, 4.70%, was higher than that of the patients admitted through outpatient, 3.69%. The mortality rate of the patients, who were admitted through visiting, was 4.15%, which was higher than that of the patients who were transferred, 3.51%. The mortality rate among the patients insured through Medical Aid was 4.67%, which was higher than that of the patients insured through the National Health Insurance. The length of stay was categorized by quartile. As the length of stay increased, the mortality rate increased.

In terms of the mean complication rate (%), the complication rate increased as the age increased. Women had a higher complication rate, which was 11.94%, compared with the men, who had a complication rate of 11.34%. As the Charlson comorbidity index score increased from 0 to 2, the complication rate increased from 9.50% to 13.98%. The complication rate of those admitted through outpatient, 11.81%, was higher than that of those admitted through emergency, 11.16%. The complication rate of the patients who were admitted by transfer was 15.99%, which was higher than that of the patients admitted through visiting, which was 10.45%. The Medical Aid patients' complication rate was 14.73%, which was higher than that of the National Health Insurance patients. As the length of stay increased, the mortality rate increased.

Table 7. Characteristics of dependent variables at the patient level in Total

Units: Mean ± SD

Variable	Total	
	Mortality Rate (%)	Complication Rate (%)
Age (years)		
70≤	4.72 ± 7.79	12.25 ± 14.31
50–69	3.89 ± 5.70	11.45 ± 13.47
30–49	3.48 ± 5.14	11.27 ± 13.26
<30	3.56 ± 5.20	11.01 ± 14.34
Sex		
Men	4.06 ± 6.23	11.34 ± 13.56
Women	3.96 ± 6.19	11.94 ± 13.82
Charlson Comorbidity Index		
2	4.58 ± 5.95	13.98 ± 13.71
1	4.09 ± 6.15	13.80 ± 15.67
0	3.89 ± 6.29	9.50 ± 11.38
Type of Admission		
Outpatient	3.69 ± 5.34	11.81 ± 14.23
Emergency	4.70 ± 7.71	11.16 ± 12.40
Admission Method		
Visit	4.15 ± 6.41	10.45 ± 11.45
Transfer	3.51 ± 5.37	15.99 ± 19.38
Type of Insurance		
National Health Insurance	3.95 ± 6.00	11.29 ± 13.39
Medical Aid	4.67 ± 7.91	14.73 ± 15.92
Year		
2010	4.20 ± 6.58	11.28 ± 13.89
2011	3.81 ± 5.77	11.97 ± 13.43
Length of Stay (days)		
17≤	4.94 ± 7.77	12.28 ± 13.16
7–16	4.25 ± 5.93	11.21 ± 12.62
2–6	3.47 ± 5.17	11.54 ± 14.07
<2	3.20 ± 5.63	11.31 ± 15.40

Table 8 shows the characteristics of the dependent variables at the hospital level in the total hospitals. In the mean mortality rate (%), the public hospitals had a higher mortality rate, 5.62%, compared with the private hospitals, which had 3.67%. The hospitals located in non-metropolitan areas had a higher mortality rate of 4.69% compared with those located in metropolitan areas of 3.58%. The mortality rate of the non-teaching hospitals was 5.04%, which was higher than that of the teaching hospitals. The mortality rate of the hospitals with more than 1000 beds was the lowest at 2.05%. When the number of doctors per 100 beds was higher than 26, the mortality rate was lowest at 2.94%. When the number of registered nurses per 100 beds was higher than 94, the mortality rate was lowest at 2.71%. The mortality rate was lowest when the nurse-to-patient ratio was between 3.5 and 3.9.

In the complication rate (%), the private hospitals had a higher complication rate, 12.18%, compared with the public hospitals, which had 8.97%. The hospitals located in

non-metropolitan areas had a lower complication rate, which was 9.51%, compared with the hospitals located in metropolitan areas, which had 12.96%. The complication rate of the non-teaching hospitals was 7.86%, which was lower than that of the teaching hospitals. The complication rate of the hospitals with between 600 and 699 beds was the highest at 22.14%. The number of doctors per 100 beds was categorized by quartile. When the number of doctors per 100 beds was higher than 26, the complication rate was lowest at 8.68%. The number of registered nurses per 100 beds was categorized by quartile. When the number of registered nurses per 100 beds was higher than 94, the complication rate was lowest at 6.56%. The complication rate was lowest when the nurse-to-patient ratio was between 3.5 and 3.9.

Table 8. Characteristics of dependent variables at the hospital level in Total

Units: Mean ± SD

Variable	Total	
	Mortality Rate (%)	Complication Rate (%)
Ownership		
Public	5.62 ± 9.83	8.97 ± 7.86
Private	3.67 ± 5.04	12.18 ± 14.57
Region		
Metropolitan Area	3.58 ± 5.25	12.96 ± 15.23
Non-metropolitan Area	4.69 ± 7.40	9.51 ± 10.52
Teaching		
No	5.04 ± 12.76	7.86 ± 17.99
Yes	3.95 ± 5.51	11.85 ± 13.31
Number of Beds		
1000≤	2.05 ± 2.36	9.12 ± 7.07
900–999	4.24 ± 3.82	14.83 ± 7.75
800–899	4.15 ± 2.08	11.88 ± 8.79
700–799	5.37 ± 7.10	13.47 ± 13.89
600–699	4.11 ± 3.78	22.14 ± 25.36
500–599	3.24 ± 5.78	8.37 ± 6.99
400–499	3.88 ± 4.66	9.42 ± 8.69
300–399	4.58 ± 7.82	6.59 ± 9.07
<300	6.32 ± 13.50	7.28 ± 15.85
Number of Doctors per 100 Beds		
26≤	2.94 ± 3.29	8.68 ± 9.87
21–25	4.25 ± 4.82	12.18 ± 14.56
17–20	4.73 ± 4.71	17.51 ± 15.48
<17	4.26 ± 10.04	8.91 ± 12.67
Number of Registered Nurses per 100 Beds		
94≤	2.71 ± 2.68	6.56 ± 4.67
80-93	4.28 ± 4.38	13.29 ± 11.50
67-79	3.94 ± 5.07	17.90 ± 19.18
<67	5.20 ± 10.12	8.71 ± 12.38
Nurse-to-Patient Ratio		
4≤	0.58 ± 4.42	12.30 ± 27.82
3.5–3.9	0 ± 0	3.23 ± 5.13
3–3.4	8.98 ± 14.60	6.65 ± 16.24
2.5–2.9	12.19 ± 22.44	9.30 ± 13.95
2–2.4	2.90 ± 6.17	4.67 ± 10.35
<2	3.92 ± 5.37	12.04 ± 13.54
Number of Nurse Aids per 100 Beds		
6≤	4.52 ± 7.54	12.85 ± 16.41
<6	3.43 ± 4.08	10.16 ± 9.35

Table 9 shows the characteristics of the dependent variables at the patient level in tertiary hospitals. In the mean mortality rate (%), the older age group had a higher mortality rate compared with the younger age group. Women had a higher mortality rate, which was 3.95%, compared with men, who had a mortality rate of 3.80%. As the Charlson comorbidity index score increased from 0 to 2, the mortality rate increased from 3.75% to 4.62%. The mortality rate of the admissions through emergency departments, 4.14%, was higher than that of the outpatient admissions, 3.74%. The mortality rate of the patients who were admitted by visiting was 4.20%, which was higher than that of the patients admitted by transfer, 3.07%. The Medical Aid patients' mortality rate was 3.96%,

which was higher than the National Health Insurance patients' mortality rate. The length of stay was categorized by quartile. As the length of stay increased, the mortality rate increased.

In terms of the mean complication rate (%), the complication rate increased as the age increased. Women had a higher complication rate, which was 14.77%, compared with men, who had 13.51%. When the Charlson comorbidity index score was '1', the complication rate was highest at 16.58%. The complication rate among the admissions through outpatient, 14.92%, was higher than that among the emergency admissions, 12.24%. The complication rate among the patients who were admitted by transfer was 18.04% higher than that among the patients who were admitted by visiting, which was 12.39%. The Medical Aid patients' complication rate was 18.49%, which was higher than the National Health Insurance patients' complication rate.

Table 9. Characteristics of dependent variables at the patient level in Tertiary hospitals

Units: Mean ± SD

Variable	Tertiary	
	Mortality Rate (%)	Complication Rate (%)
Age (years)		
70≤	5.38 ± 10.27	10.76 ± 12.76
50–69	3.87 ± 7.07	8.26 ± 9.28
30–49	3.46 ± 6.41	8.09 ± 9.17
<30	3.76 ± 6.59	7.99 ± 12.57
Sex		
Men	3.80 ± 4.07	13.51 ± 15.60
Women	3.95 ± 4.13	14.77 ± 15.66
Charlson Comorbidity Index		
2	4.62 ± 4.27	16.01 ± 13.86
1	3.88 ± 3.95	16.58 ± 18.19
0	3.75 ± 4.20	11.18 ± 12.20
Type of Admission		
Outpatient	3.74 ± 3.98	14.92 ± 16.87
Emergency	4.14 ± 4.31	12.24 ± 12.51
Admission Method		
Visit	4.20 ± 4.31	12.39 ± 12.50
Transfer	3.07 ± 3.41	18.04 ± 20.84
Type of Insurance		
National Health Insurance	3.86 ± 4.09	13.67 ± 15.22
Medical Aid	3.96 ± 4.19	18.49 ± 19.24
Year		
2010	4.16 ± 4.47	13.79 ± 16.29
2011	3.58 ± 3.66	14.32 ± 14.95
Length of Stay (days)		
18≤	4.27 ± 4.26	13.92 ± 13.92
9–17	4.26 ± 4.01	11.74 ± 12.46
3–8	3.32 ± 3.70	15.33 ± 17.50
<3	3.67 ± 4.43	15.32 ± 17.96

Table 10 shows the characteristics of the dependent variables at the hospital level in the tertiary hospitals. In the mean mortality rate (%), the private hospitals had a higher mortality rate, 3.98%, compared with the public hospitals, which had 3.44%. The hospitals located in non-metropolitan areas had a higher mortality rate, which was 5.08%, compared with those located in metropolitan areas, which had 3.61%. The mortality rate in hospitals with over 1000 beds was lowest at 2.05%. When the number of doctors per 100 beds was higher than 31, the mortality rate was lowest at 2.98%. When the number of registered nurses per 100 beds was higher than 118, the mortality rate was lowest at 2.68%.

In the complication rate (%), the private hospitals had a higher complication rate, 15.59%, compared with the public hospitals, which had 8.48%. The hospitals located in non-metropolitan areas had a lower complication rate, which was 12.77%, compared with the hospitals located in metropolitan areas, which had 14.3%. The complication rate in the hospitals with between 600 and 699 beds was the highest at 30.40%. The number of doctors per 100 beds was categorized by quartile. When the number of doctors per 100 beds was higher than 31, the complication rate was lowest at 6.30%. The number of registered nurses per 100 beds was categorized by quartile. When the number of registered nurses per 100 beds was higher than 118, the complication rate was lowest at 7.02%.

Table 10. Characteristics of dependent Variables at the hospital level in Tertiary hospitals

Units: Mean ± SD

Variable	Tertiary	
	Mortality Rate (%)	Complication Rate (%)
Ownership		
Public	3.44 ± 4.86	8.48 ± 6.00
Private	3.98 ± 3.85	15.59 ± 17.06
Region		
Metropolitan Area	3.61 ± 3.77	14.33 ± 16.27
Non-metropolitan Area	5.08 ± 5.20	12.77 ± 12.18
Teaching		
No	3.87 ± 4.10	14.05 ± 15.64
Yes	-	-
Number of Beds		
1000≤	2.05 ± 2.36	9.12 ± 7.07
900–999	4.18 ± 3.86	15.27 ± 7.42
800–899	4.13 ± 2.08	12.03 ± 8.74
700–799	6.44 ± 5.99	15.68 ± 17.10
600–699	3.29 ± 3.98	30.40 ± 31.76
500–599	14.36 ± 7.44	18.54 ± 2.66
400–499	6.78 ± 0.79	6.40 ± 7.62
300–399		
<300		
Number of Doctors per 100 Beds		
31≤	2.98 ± 3.03	6.30 ± 4.33
24–30	4.00 ± 4.35	12.25 ± 12.16
21–23	5.18 ± 5.63	20.37 ± 21.79
<21	3.80 ± 2.97	22.09 ± 17.68
Number of Registered Nurses per 100 Beds		
118≤	2.68 ± 2.95	7.02 ± 4.87
86–117	4.25 ± 3.94	13.23 ± 13.95
78–85	3.97 ± 3.67	23.65 ± 22.08
<78	5.09 ± 5.49	12.46 ± 9.94
Nurse-to-Patient Ratio		
4≤	-	-
3.5–3.9	-	-
3–3.4	-	-
2.5–2.9	-	-
2–2.4	-	-
<2	3.87 ± 4.10	14.05 ± 15.64
Number of Nurse Aids per 100 Beds		
5≤	4.42 ± 4.88	16.68 ± 19.02
<5	3.28 ± 2.94	11.24 ± 10.19

Table 11 shows the characteristics of the dependent variables at the patient level in the general hospitals. In the mean mortality rate (%), as the age went up, the mortality rate increased. Men had a higher mortality rate, which was 4.36%, compared with women, who had 3.96%. As the Charlson comorbidity index score increased from 0 to 2, the mortality rate increased from 4.01% to 4.52%. The mortality rate among the admissions through emergency, 5.36%, was higher than that among the outpatient admissions, 3.64%. The mortality rate of the patients who were admitted by transfer was 4.81%, which was higher than that of the patients who were admitted by visiting, 4.10%. The Medical Aid patients' mortality rate was 5.27%, which was higher than the National Health Insurance

patients' mortality rate. The length of stay was categorized by quartile. As the length of stay increased, the mortality rate increased.

In terms of the mean of complication rate (%), the complication rate was high when the age was between 30 and 69 years. Women had a higher complication rate, which was 8.94%, compared with men, who had 8.80%. As the Charlson comorbidity index score increased from '0' to '2', the complication rate increased from 7.98% to 11.17%. The complication rate of the admissions through emergency, 9.89%, was higher than that of the outpatient admissions, 8.41%. The complication rate of the patients who were admitted by transfer was 9.98%, which was higher than that of the patients who were admitted by visiting, which was 8.73%. The Medical Aid patients' complication rate was 11.61%, which was higher than the National Health Insurance patients' complication rate. As the length of stay increased, the complication rate increased.

Table 11. Characteristics of dependent variables at the patient level in General hospitals

Units: Mean ± SD

Variable	General	
	Mortality Rate (%)	Complication Rate (%)
Age (years)		
70≤	4.12 ± 4.39	13.61 ± 15.48
50–69	3.91 ± 4.16	14.20 ± 15.73
30–49	3.49 ± 3.51	14.33 ± 15.66
<30	3.41 ± 3.76	13.43 ± 15.23
Sex		
Men	4.36 ± 8.04	8.80 ± 10.12
Women	3.96 ± 7.80	8.94 ± 10.79
Charlson Comorbidity Index		
2	4.52 ± 7.71	11.17 ± 13.01
1	4.38 ± 8.30	9.88 ± 9.96
0	4.01 ± 7.70	7.98 ± 10.36
Type of Admission		
Outpatient	3.64 ± 6.51	8.41 ± 9.51
Emergency	5.36 ± 10.32	9.89 ± 12.16
Admission Method		
Visit	4.10 ± 7.82	8.73 ± 10.13
Transfer	4.81 ± 8.79	9.98 ± 12.47
Type of Insurance		
National Health Insurance	4.04 ± 7.64	8.54 ± 10.22
Medical Aid	5.27 ± 9.97	11.61 ± 11.65
Year		
2010	4.24 ± 8.20	8.71 ± 10.28
2011	4.10 ± 7.59	9.07 ± 10.60
Length of Stay (days)		
15≤	5.60 ± 10.38	10.39 ± 12.45
5–14	4.46 ± 7.94	9.27 ± 9.54
2–4	3.32 ± 5.97	7.59 ± 9.38
<2	3.18 ± 6.23	8.19 ± 9.77

Table 12 shows the characteristics of the dependent variables at the hospital level in the general hospitals. In the mean mortality rate (%), the public hospitals had a higher mortality rate, 9.55%, compared with the private hospitals, which had 3.35%. The hospitals located in non-metropolitan areas had a higher mortality rate, which was 4.57%, compared with the hospitals located in metropolitan areas, which had 3.50%. The mortality rate of the non-teaching hospitals was 5.04%, which was higher than that of the teaching hospitals. When the number of beds was between 500 and 599, the mortality rate was lowest at 1.94%. When the number of doctors was more than 21, the mortality rate was lowest at 0%. When the number of registered nurses per 100 beds was higher than 81, the mortality rate was lowest at 3.19%. The mortality rate was lowest when the nurse-to-patient ratio was between 3.5 and 3.9.

In the complication rate (%), the public hospitals had a higher complication rate, 9.86%, compared with the private hospitals, which had 8.72%. The hospitals located in non-metropolitan areas had a lower complication rate, which was 8.50%, compared with those located in metropolitan areas, which had 9.51%. The complication rate of the non-teaching hospitals was 7.86%, which was lower than that of the teaching hospitals. The number of doctors per 100 beds was categorized by quartile. When the number of doctors per 100 beds was higher than 21, the complication rate was lowest at 3.45%. The number of registered nurses per 100 beds was categorized by quartile. When the number of registered nurses per 100 beds was higher than 81, the complication rate was lowest at 7.00%. The complication rate was lowest when the nurse-to-patient ratio was between 3.5 and 3.9.

Table 12. Characteristics of dependent variables at the hospital level in General Hospitals

Units: Mean ± SD

Variable	General	
	Mortality Rate (%)	Complication Rate (%)
Ownership		
Public	9.55 ± 14.33	9.86 ± 10.37
Private	3.35 ± 5.99	8.72 ± 10.43
Region		
Metropolitan Area	3.50 ± 7.83	9.51 ± 11.51
Non-metropolitan Area	4.57 ± 7.96	8.50 ± 9.73
Teaching		
No	5.04 ± 12.76	7.86 ± 17.99
Yes	4.05 ± 6.91	9.02 ± 8.73
Number of Beds		
1000≤	-	-
900–999	6.25 ± 0.00	0 ± 0
800–899	5.83 ± 1.61	0 ± 0
700–799	4.26 ± 7.94	11.19 ± 9.00
600–699	5.03 ± 3.31	12.88 ± 8.49
500–599	1.94 ± 3.85	7.18 ± 6.34
400–499	3.59 ± 4.79	9.72 ± 8.74
300–399	4.58 ± 7.82	6.59 ± 9.07
<300	6.32 ± 13.50	7.28 ± 15.85
Number of Doctors per 100 Beds		
21≤	0 ± 0	3.45 ± 2.17
16–21	2.97 ± 3.34	8.28 ± 4.06
13–16	2.98 ± 3.96	5.80 ± 3.07
<13	4.71 ± 9.08	9.84 ± 12.07
Number of Registered Nurses per 100 Beds		
81≤	3.19 ± 3.93	7.00 ± 3.79
67–80	3.23 ± 5.14	11.65 ± 10.38
54–66	4.69 ± 6.69	9.33 ± 9.31
<54	5.66 ± 12.92	7.88 ± 15.13
Nurse-to-Patient Ratio		
4≤	0.58 ± 4.42	12.30 ± 27.82
3.5–3.9	0 ± 0	3.23 ± 5.13
3–3.4	8.98 ± 14.60	6.65 ± 16.24
2.5–2.9	12.19 ± 22.44	9.30 ± 13.95
2-2.4	2.90 ± 6.17	4.67 ± 10.35
<2	3.99 ± 6.69	9.35 ± 9.44
Number of Nurse Aids per 100 Beds		
6≤	4.50 ± 9.17	9.20 ± 11.78
<6	3.67 ± 5.40	8.35 ± 7.81

5. Results of the Linear Mixed Model

1) Mortality

Tables 13, 14, and 15 show the results of the linear mixed-effects model of mortality rate (%) with cardiovascular surgery. The interclass correlation was close to 1, so a multilevel analysis was fitted. Also, the interclass correlation of Model 4 was decreased or similar compared to that of Model 1 as the model was adjusted with patient and hospital.

In Table 13, Model 4 shows the results of the adjustment with the patient-level and hospital-level variables in total. At the hospital level, the coefficient of ownership was 5.53520 (P<0.0001) for public hospitals compared with private hospitals. In terms of teaching, the coefficient of non-teaching hospitals was -1.15330 (P<0.0001). The coefficient of the number of registered nurses per 100 beds was -0.01561 (P=0.04). In addition, the hospital variation decreased from Model 1 (93.35260) to Model 4 (88.38170).

In the tertiary hospitals (Table 14), Model 4 shows that the coefficient of the number of nurse aids per 100 beds was -0.01850 (P=0.02). There was no significant result for the number of registered nurses per 100 beds, and hospital variation did not decrease from Model 1 to Model 4.

Table 15 shows the results for general hospitals. In Model 4, the coefficient of ownership was 7.89060 (P<0.0001) for public hospitals compared with private hospitals. In terms of teaching, the coefficient of non-teaching hospitals was -1.09590 (P<0.0001). The coefficient of the number of registered nurses per 100 beds was -0.03667 (P=0.02). The hospital variation decreased from Model 1 (112.16000) to Model 4 (102.72000). The number of registered nurses per 100 beds in the total and general hospitals significantly affected the mortality rate.

Table 13. Results of the linear mixed model on mortality (total) Unit : %

Variable	Model 1 (Null)		Model 2 (Patient)		Model 3 (Hospital)		Model 4 (Patient & Hospital)	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Intercept	4.47190	<0.0001	4.41240	<0.0001	5.44300	<0.0001	6.08090	<0.0001
Patient Characteristic								
Age (years)								
70≤			0.06805	0.56			0.06830	0.56
50–69			0.07483	0.51			0.07620	0.50
30–49			0.06597	0.57			0.06940	0.55
<30			ref.				ref.	
Sex								
Men			-0.03630	0.31			-0.03628	0.31
Women			ref.				ref.	
Charlson Comorbidity Index								
2			-0.02289	0.77			-0.02336	0.77
1			0.01580	0.69			0.01641	0.68
0			ref.				ref.	
Type of Admission								
Outpatient			-0.04909	0.24			-0.05089	0.22
Emergency			ref.				ref.	
Admission Method								
Visit			0.00440	0.93			0.01646	0.76
Transfer			ref.				ref.	
Type of Insurance								
National Health Insurance			-0.02432	0.70			-0.01488	0.81
Medical Aid			ref.				ref.	
Year								
2010			0.09947	0.01			0.12410	<0.0001
2011			ref.				ref.	
LOS			0.00024	0.69			0.00030	0.62
Hospital Characteristic								
Type of Hospital								
Tertiary					-0.11570	0.95	0.70300	0.69
General					ref.		ref.	
Ownership								
Public					5.53920	<0.0001	5.53520	<0.0001
Private					ref.		ref.	
Region								
Metropolitan Area					-1.86970	0.16	-1.76460	0.18
Non-metropolitan Area					ref.		ref.	
Teaching								
No					-1.17760	<0.0001	-1.15330	<0.0001
Yes					ref.		ref.	
Number of Beds					-0.00031	0.75	-0.00153	0.15
Number of Doctors per 100 Beds					0.02061	0.23	0.01959	0.26
Number of Registered Nurses per 100 Beds					-0.00975	0.18	**-0.01561**	**0.04**
Number of Nurse Aids per 100 Beds					-0.02309	0.21	-0.02283	0.21
Variation								
Hospital	93.35260	<0.0001	93.24100	<0.0001	88.87580	<0.0001	88.38170	<0.0001
Patient	2.77550	<0.0001	2.77560	<0.0001	2.76880	<0.0001	2.76870	<0.0001
Statistics (AIC)	36594.5		36637.9		36581.2		36622.7	
Interclass Correlation (ICC)	0.97113		0.97109		0.96979		0.96962	

Table 14. Results of the linear mixed model on mortality (tertiary hospitals) Unit : %

Variable	Model 1 (Null)		Model 2 (Patient)		Model 3 (Hospital)		Model 4 (Patient & Hospital)	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Intercept	4.54290	<0.0001	4.57530	<0.0001	4.84420	<0.0001	5.15220	<0.0001
Patient Characteristic								
Age (years)								
70≤			0.02888	0.58			0.02540	0.63
50–69			0.00974	0.85			0.00716	0.89
30–49			-0.01931	0.72			-0.01993	0.71
<30			ref.				ref.	
Sex								
Men			-0.00293	0.86			-0.00367	0.83
Women			ref.				ref.	
Charlson Comorbidity Index								
2			-0.00213	0.95			-0.00004	1.00
1			-0.00342	0.85			-0.00397	0.83
0			ref.				ref.	
Type of Admission								
Outpatient			-0.02431	0.20			-0.02510	0.18
Emergency			ref.				ref.	
Admission Method								
Visit			-0.01097	0.61			-0.00560	0.80
Transfer			ref.				ref.	
Type of Insurance								
National Health Insurance			-0.02705	0.38			-0.02484	0.42
Medical Aid			ref.				ref.	
Year								
2010			0.02321	0.19			0.02503	0.23
2011			ref.				ref.	
LOS			-0.00006	0.80			-0.00003	0.88
Hospital Characteristic								
Type of Hospital								
Tertiary								
General								
Ownership								
Public					-0.96060	0.59	-0.95330	0.59
Private					ref.		ref.	
Region								
Metropolitan-area					-0.57300	0.72	-0.51730	0.74
Non-metropolitan area					ref.		ref.	
Number of Beds					0.00008	0.86	-0.00015	0.76
Number of Doctors per 100 Beds					-0.00277	0.70	-0.00278	0.70
Number of Registered Nurses per 100 Beds					0.00506	0.20	0.00366	0.38
Number of Nurse Aids per 100 Beds					-0.01972	0.01	-0.01850	0.02
Variation								
Hospital	22.03300	<0.0001	22.02420	<0.0001	23.08060	<0.0001	22.87640	<0.0001
Patient	0.32490	<0.0001	0.32510	<0.0001	0.32460	<0.0001	0.32480	<0.0001
Statistics (AIC)	8645.7		8708.9		8670.9		8734.6	
Interclass Correlation (ICC)	0.98547		0.98545		0.98613		0.98600	

Table 15. Results of the linear mixed model on mortality (general hospitals) Unit : %

Variable	Model 1 (Null)		Model 2 (Patient)		Model 3 (Hospital)		Model 4 (Patient & Hospital)	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Intercept	4.46030	<0.0001	4.27290	<0.0001	5.15790	<0.0001	6.02460	<0.0001
Patient Characteristic								
Age (years)								
70≤			0.11150	0.66			0.09934	0.70
50–69			0.15000	0.54			0.13770	0.58
30–49			0.17210	0.50			0.16070	0.52
<30			ref.				ref.	
Sex								
Men			-0.07787	0.30			-0.07526	0.32
Women			ref.				ref.	
Charlson Comorbidity Index								
2			-0.06965	0.69			-0.06312	0.71
1			0.03567	0.68			0.04618	0.59
0			ref.				ref.	
Type of Admission								
Outpatient			-0.07762	0.40			-0.08482	0.36
Emergency			ref.				ref.	
Admission Method								
Visit			0.03888	0.77			0.05936	0.66
Transfer			ref.				ref.	
Type of Insurance								
National Health Insurance			-0.03090	0.81			-0.01059	0.93
Medical Aid			ref.				ref.	
Year								
2010			0.19570	0.02			0.21960	0.01
2011			ref.				ref.	
LOS			0.00151	0.41			0.00134	0.46
Hospital Characteristic								
Type of Hospital								
Tertiary								
General								
Ownership								
Public					7.90790	<0.0001	7.89060	<0.0001
Private					ref.		ref.	
Region								
Metropolitan-area					-2.42400	0.13	-2.34870	0.14
Non-metropolitan area					ref.		ref.	
Teaching								
No					-1.13290	<0.0001	-1.09590	<0.0001
Yes					ref.		ref.	
Number of Beds					-0.00012	0.96	-0.00196	0.42
Number of Doctors per 100 Beds					0.09899	0.10	0.09816	0.11
Number of Registered Nurses per 100 Beds					-0.02893	0.06	**-0.03667**	**0.02**
Number of Nurse Aids per 100 Beds					-0.01813	0.68	-0.01972	0.66
Variation								
Hospital	112.16000	<0.0001	111.99000	<0.0001	103.42000	<0.0001	102.72000	<0.0001
Patient	5.60390	<0.0001	5.60570	<0.0001	5.58880	<0.0001	5.59080	<0.0001
Statistics (AIC)	20575.7		20602.4		20564.5		20590.4	
Interclass Correlation (ICC)	0.95241		0.95233		0.94873		0.94838	

2) Complications

Tables 16, 17, and 18 show the results of the linear mixed-effects model of complication rate (%) with cardiovascular surgery. All the tables show that the interclass correlation was close to 1. The interclass correlation of Model 4 was decreased or similar compared with Model 1 as the model was adjusted with patient and hospital.

Table 16 and Model 4 show the result of the adjustment with patient-level and hospital-level variables in total. The outpatient coefficient was -0.09233 (P=0.03) compared with emergency in the type of admission. The tertiary hospitals' coefficient was 6.76810 (P=0.04) compared with the general hospitals. The non-teaching hospitals' coefficient was -1.24440 (P<0.0001) compared with the teaching hospitals. The coefficient of the number of registered nurses per 100 beds was -0.03296 (P<0.0001). The hospital variation decreased from Model 1 (346.56000) to Model 4 (343.74000).

In Table 17, the tertiary hospitals and Model 4 show that the National Health Insurance population's coefficient was 0.26980 (P<0.0001). The coefficient of the number of registered nurses per 100 beds was -0.01995 (P=0.02). The hospital variation decreased from Model 1 (242.08000) to Model 4 (241.05000).

Table 18 shows the results for the general hospitals. In Model 4, the coefficient of the number of registered nurses per 100 beds was -0.05536 (P<0.0001). The hospital variation decreased from Model 1 (368.07000) to Model 4 (363.63000). Therefore, in every type of hospital, the complication rate decreased as the number of registered nurses per 100 beds increased.

Table 16. Results of the linear mixed model on complications (total) Unit : %

Variable	Model 1 (Null)		Model 2 (Patient)		Model 3 (Hospital)		Model 4 (Patient & Hospital)	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Intercept	10.33810	<0.0001	10.53070	<0.0001	12.32670	<0.0001	11.84130	<0.0001
Patient Characteristic								
Age (years)								
70≤			-0.02098	0.86			-0.01736	0.89
50–69			-0.08189	0.49			-0.07576	0.52
30–49			-0.15160	0.21			-0.14220	0.24
<30			ref.				ref.	
Sex								
Men			-0.02630	0.48			-0.02621	0.48
Women			ref.				ref.	
Charlson Comorbidity Index								
2			-0.00887	0.91			-0.01364	0.87
1			0.06019	0.14			0.05877	0.15
0			ref.				ref.	
Type of Admission								
Outpatient			-0.08720	0.04			-0.09233	0.03
Emergency			ref.				ref.	
Admission Method								
Visit			-0.04893	0.37			-0.02333	0.67
Transfer			ref.				ref.	
Type of Insurance								
National Health Insurance			0.08086	0.22			0.09181	0.16
Medical Aid			ref.				ref.	
Year								
2010			-0.15420	<0.0001			-0.09618	0.03
2011			ref.				ref.	
LOS			0.00008	0.89			0.00021	0.74
Hospital Characteristic								
Type of Hospital								
Tertiary					7.48600	0.02	6.76810	0.04
General					ref.		ref.	
Ownership								
Public					2.30440	0.49	2.31440	0.49
Private					ref.		ref.	
Region								
Metropolitan Area					1.06290	0.68	0.97870	0.71
Non-metropolitan Area					ref.		ref.	
Teaching								
No					-1.21180	<0.0001	-1.24440	<0.0001
Yes					ref.		ref.	
Number of Beds					-0.00467	<0.0001	-0.00365	<0.0001
Number of Doctors per 100 Beds					0.04750	0.01	0.04879	0.01
Number of Registered Nurses per 100 Beds					**-0.03781**	**<0.0001**	**-0.03296**	**<0.0001**
Number of Nurse Aids per 100 Beds					-0.04365	0.02	-0.04315	0.02
Variation								
Hospital	346.56000	<0.0001	346.30000	<0.0001	342.67000	<0.0001	343.74000	<0.0001
Patient	2.97610	<0.0001	2.96850	<0.0001	2.95870	<0.0001	2.95460	<0.0001
Statistics (AIC)	37493.1		37512.6		37452.4		37482.8	
Interclass Correlation (ICC)	0.99149		0.99150		0.99144		0.99148	

Table 17. Results of the linear mixed model on complications (tertiary hospitals) Unit : %

Variable	Model 1 (Null)		Model 2 (Patient)		Model 3 (Hospital)		Model 4 (Patient & Hospital)	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Intercept	14.50350	<0.0001	14.38240	<0.0001	18.83220	<0.0001	18.35660	<0.0001
Patient Characteristic								
Age (years)								
70≤			-0.02206	0.84			-0.01727	0.87
50–69			-0.02038	0.85			-0.00877	0.93
30–49			0.01505	0.89			0.03630	0.74
<30			ref.				ref.	
Sex								
Men			-0.01443	0.67			-0.01829	0.59
Women			ref.				ref.	
Charlson Comorbidity Index								
2			0.06226	0.39			0.05745	0.43
1			0.05647	0.12			0.04877	0.18
0			ref.				ref.	
Type of Admission								
Outpatient			-0.04283	0.26			-0.04931	0.20
Emergency			ref.				ref.	
Admission Method								
Visit			-0.05358	0.23			-0.01908	0.67
Transfer			ref.				ref.	
Type of Insurance								
National Health Insurance			0.25910	<0.0001			0.26980	<0.0001
Medical Aid			ref.				ref.	
Year								
2010			-0.10040	0.01			-0.01851	0.67
2011			ref.				ref.	
LOS			-0.00008	0.87			0.00015	0.75
Hospital Characteristic								
Type of Hospital								
Tertiary								
General								
Ownership								
Public					-5.97280	0.30	-5.97300	0.30
Private					ref.		ref.	
Region								
Metropolitan Area					3.35740	0.51	3.29930	0.52
Non-metropolitan Area					ref.		ref.	
Number of Beds					-0.00402	<0.0001	-0.00378	<0.0001
Number of Doctors per 100 Beds					0.02648	0.07	0.02464	0.09
Number of Registered Nurses per 100 Beds					**-0.02173**	**0.01**	**-0.01995**	**0.02**
Number of Nurse Aids per 100 Beds					-0.06645	<0.0001	-0.06852	<0.0001
Variation								
Hospital	242.08000	<0.0001	241.91000	<0.0001	240.71000	<0.0001	241.05000	<0.0001
Patient	1.35860	<0.0001	1.35260	<0.0001	1.34760	<0.0001	1.34380	<0.0001
Statistics (AIC)	15586.2		15610.0		15564.9		15596.1	
Interclass Correlation (ICC)	0.99442		0.99444		0.99443		0.99446	

Table 18. Results of the linear mixed model on complications (general hospitals) Unit : %

Variable	Model 1 (Null)		Model 2 (Patient)		Model 3 (Hospital)		Model 4 (Patient & Hospital)	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Intercept	9.23940	<0.0001	9.72310	<0.0001	11.94360	<0.0001	11.06640	<0.0001
Patient Characteristic								
Age (years)								
70≤			-0.02079	0.93			-0.03133	0.89
50–69			-0.15050	0.51			-0.16320	0.48
30–49			-0.34090	0.15			-0.35150	0.13
<30			ref.				ref.	
Sex								
Men			-0.03614	0.60			-0.03256	0.64
Women			ref.				ref.	
Charlson Comorbidity Index								
2			-0.13380	0.40			-0.13100	0.41
1			0.04191	0.60			0.05544	0.48
0			ref.				ref.	
Type of Admission								
Outpatient			-0.15170	0.08			-0.16240	0.06
Emergency			ref.				ref.	
Admission Method								
Visit			-0.00819	0.95			0.02397	0.85
Transfer			ref.				ref.	
Type of Insurance								
National Health Insurance			-0.08834	0.45			-0.07048	0.55
Medical Aid			ref.				ref.	
Year								
2010			-0.22600	<0.0001			-0.18950	0.02
2011			ref.				ref.	
LOS			0.00066	0.69			0.00045	0.79
Hospital Characteristic								
Type of Hospital								
Tertiary								
General								
Ownership								
Public					5.39470	0.18	5.38400	0.18
Private					ref.		ref.	
Region								
Metropolitan Area					0.27650	0.93	0.20620	0.94
Non-metropolitan Area					ref.		ref.	
Teaching								
No					-1.12290	<0.0001	-1.15880	<0.0001
Yes					ref.		ref.	
Number of Beds					-0.00498	0.05	-0.00281	0.30
Number of Doctors per 100 Beds					0.13100	0.02	0.14170	0.01
Number of Registered Nurses per 100 Beds					**-0.06222**	**<0.0001**	**-0.05536**	**<0.0001**
Number of Nurse Aids per 100 Beds					0.01704	0.69	0.02014	0.64
Variation								
Hospital	368.07000	<0.0001	367.17000	<0.0001	362.10000	<0.0001	363.63000	<0.0001
Patient	4.84390	<0.0001	4.82640	<0.0001	4.81690	<0.0001	4.80170	<0.0001
Statistics (AIC)	20169.6		20181.5		20155.0		20169.8	
Interclass Correlation (ICC)	0.98701		0.98703		0.98687		0.98697	

Ⅴ. DISCUSSION

Nurse staffing is one of the main factors influencing mortality and complication rates. In previous studies, there was a relationship between the staffing level and the mortality and complication rates.[1,2,8,37-39] Health care service is workforce intensive, so appropriate staffing levels influence health care quality and outcomes.[54,55] Among health care staffs, the nurses are one of the most important staffs for providing 24-hour direct patient care. Also, most studies included both patient and hospital levels in the analyses. Between the nurse staffing level and patient outcomes, there were variables that were related.

This study investigated the relationship between nurse staffing and mortality and complications in the cardiovascular surgery population. The independent variable was the number of registered nurses per 100 beds. The hospital mortality rate and the complication rate were used as dependent variables. These outcomes were the most common in measuring patient outcomes. In many studies, mortality was applied as an outcome variable.[56,57] Also, complications were used for measuring patient outcomes, because nurses play a significant role in detecting complication signs in advance and in preventing complications. In many studies, complications were used as a dependent variable in assessing the quality of nursing care. [2,37]

To assess the relationship between nurse staffing and mortality and complication rates, Donabedian's models; which are about "structure," "process," and "outcome"; can be applied.[58,59]

Structure means "the attributes of the settings in which care occurs." Structure includes material and human resources and organizational structure. For example, material resources include facilities, equipment, and money. Human resources include the number of professions; and organizational structures include the medical staff organization, methods of peer review, and methods of reimbursement. In this study, the organizational factors included were the type of hospital, ownership, teaching status, region of the

hospital, number of beds, number of doctors per 100 beds, and number of nurse aids per 100 beds. The patient factors included were the age, sex, Charlson comorbidity index, type of admission, admission method, type of insurance, and length of stay. Process indicates "what is actually done in giving and receiving care." Process covers the patients' activities in seeking care and carrying it out as well as the practitioners' activities in making a diagnosis and recommending or implementing treatment. However, this study did not include process variables. Outcome means "the effects of care on the health status of patients and populations." It includes improvements in the patients' knowledge; salutary changes in the patients' behavior are included under a broad definition of health status, as is the degree of the patients' satisfaction with the care. This study included mortality and complications as outcome variables.[58,60-62]

Although this study included only two factors, structure and outcome, in assessing the relationship between the nurse staffing level and patient outcomes, it is still meaningful.

In this study's results, the cardiovascular surgery population reported that as the number of registered nurses per 100 beds increased, the mortality rate decreased, but only in the total and general hospitals. However, there was no significant result in the tertiary hospitals. From this result, it is possible to determine that the mortality rate in hospitals is affected by the level of nurse staffing. In other words, if the level of nurse staffing is properly maintained, the mortality rate could be decreased.[32] In contrast, when the level of nurse staffing is insufficient, the mortality rate could increase. This result is similar to previously published reports. This study confirms the relationship between nurse staffing levels and in-hospital mortality among cardiovascular surgery patients. Kane et al. concluded that higher levels of registered nurse staffing were associated with less hospital-related mortality in acute-care hospitals.[56] Aiken et al. reported that the magnet hospitals, which have enough nurse staffing, had a 4.6% lower mortality rate compared with non-magnet hospitals [40], and increasing the nurses' workload by one patient increased the inpatient mortality rate within 30 days of admission by 7%.[1] Also, Mark et al. mentioned that increasing registered nurse staffing decreased the marginal effect on

reducing the mortality rate.[11] Among general patients and orthopedic surgical patients, Siber et al. showed that failure-to-rescue rates were decreased at higher staffing levels.[45] In addition, our result supported the previous study, which was about the association between nurse staffing levels and mortality in cardiac surgery.[63] Increasing nurse staffing levels could prevent 45.9 patient deaths per year in the pediatric cardiac surgery population.[8] Therefore, the results from this study supported the previous results.

In the complication rate, the cardiovascular surgery population reported that as the number of registered nurses per 100 beds increased, the complication rate decreased in all hospital types. This result is similar to those of previous studies. Kane et al. mentioned that higher registered nurse staffing levels were associated with lower rates of cardiac arrest, hospital acquired pneumonia, and other adverse events.[56] Kovner et al. stated that there was an inverse relationship between the number of registered nurses and the rates of urinary tract infections, pneumonia, and thrombosis after major surgery.[2] Needleman et al. also showed that a higher proportion of care provided by registered nurses was associated with lower rates of urinary tract infections and failure-to-rescue in medical and surgical patients.[7] According to Blegen et al., there were improvements in the rates of cardiopulmonary arrests as the registered-nurse hours increased.[41] Therefore, the results of this study added to the evidence showing a relationship between nurse staffing levels and complication rates.

In total, there were positive results among the patients undergoing cardiovascular surgery, in terms of mortality and complication rates. The reason the cardiovascular surgery results were significant is that patients undergoing vascular surgery have a higher risk of mortality than other general surgery patients.[64] Therefore, the cardiovascular surgery patients were influenced by an increase in the number of registered nurses per 100 beds.

Also, the mortality or compilation rates in all the hospital types were affected by the level of medical staffing. In other words, if the level of medical staffing were properly maintained, the mortality or compilation rate could be decreased.[32] In contrast, when the

level of nurse staffing is not enough, the mortality or compilation rate could increase. The result of the hospital type is different from that of the hospital characteristic. In general, to be a tertiary hospital, there are conditions about the level of medical staffing that should be satisfied. Therefore, tertiary hospitals have enough nursing staff; so additional nurses might not significantly influence outcomes. However, general hospitals have different circumstances. There is no adjustment tool for the nurse staffing level. Therefore, the possibility of an inappropriate nurse staffing level, in a general hospital, is higher than that in a tertiary hospital. Also, general hospitals might not perfectly follow the pre-surgery and post-surgery guidelines or may have inferior facilities and human resources for disinfection systems compared with tertiary hospitals.[65] In addition, the level of hospital quality-improvement activity could affect the mortality and complication rates.

There are several limitations in this study. The hospital data were collected during 1 month of 1 year. The data do not have a time variable that can recognize admission, discharge, and surgery dates. Therefore, other dependent variables related to time, such as the readmission rate, could not be included in this study. Also, socioeconomic status-related variables, such as patient and nurse incomes and educational levels, were not included in the data. The definition of the level of nurse staffing that could be applied in this study was limited. Nurses' or other medical staff's information such as working hours, years of experience, and job satisfaction were limited. In addition, the data provided major and minor diagnosed diseases, so Charlson's comorbidity index score was calculated based on two diseases. Process outcomes including waiting time, treatment process, and nursing delivery system were not available.

There were some strengths in this study. Most of the previous studies were based on cross-sectional designs, but the number of target hospitals was small. However, this study used the dataset with all hospital discharge data collected in Korea from 2010 to 2011. Therefore, the data are representative of all hospitals. Also, this study applied a multilevel linear mixed regression, which considers the hospital and patient levels at the same time. In this study, to adjust for comorbidity of diseases, Charlson's comorbidity index scoring

method was used by the sum of the assigned scores of two diagnosed diseases. Not only was Charlson's comorbidity index used for adjusting comorbidity, but also the length of stay was also included for adjustment. Recently, there were some results about the relationship between the length of stay and the complication rate.[66] Although this study has some limitations, comorbidity and other variables that should be included to adjust for exact results were considered. Also, the multilevel design helped to converge two different characteristics.

Although there are many policies and research studies on nurse staffing, the level of nurse staffing is not yet properly and consistently maintained. To obtain the proper level of nurse staffing, it is necessary to consider both quantitative and qualitative aspects at the same time, such as nurse staffing levels and patient outcomes. Therefore, the result of this study could provide evidence for nurse staffing policies in the future.

Ⅵ. CONCLUSION

There were several significant results concerning the relationship between nurse staffing and mortality and complication rates in previous studies. This study investigated the relationship between nurse staffing and surgical outcomes, such as mortality and complication rates, within the cardiovascular surgery population. The results showed that as the number of registered nurses per 100 beds increased, the mortality rate decreased in the cardiovascular surgery populations of the total and general hospitals. In terms of the complication rate, this study reported that as the number of registered nurses per 100 beds increased, the complication rate decreased in the total, tertiary, and general hospitals. These results confirmed the results of other studies. Other studies also showed that when nurse staffing levels were improved, the mortality and complication rates decreased significantly.

There have been numerous efforts made to improve nurse staffing by researchers and many other policy makers. However, nurse staffing levels are not properly and consistently maintained. To obtain the proper level of nurse staffing, improving only the quantity of nurse staffing is not enough. To have an effective policy, the quality of care brought about by improving nurse staffing should also be considered at the same time. Therefore, when government or hospital administrators define proper levels of nurse staffing, mortality and complication rates should be considered. Also, the government needs to implement national-level standards through policy, and hospitals need to improve organizational efforts through human-resource management. Also, the different effects of increasing nurse staffing should be considered by hospital type and severity of the target disease at the same time.

Although this study included only the cardiovascular surgery population, the results of this study could provide important evidence for nurse staffing policies. To improve this study, we need to target other diseases and investigate the relationship between nurse

staffing and quality of care with many other dependent variables, such as the readmission rate within 30 days, in addition to mortality and complications. Also, to further support these conclusions, the definition of nurse staffing should be varied to gain additional insight into the diverse effects of improving nurse staffing.

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APPENDIX

Appendix 1. ICD-9-CM Procedures [67]

Number	Code	Procedure
1	00	Procedures and interventions, not elsewhere classified
2	01-05	Operations on the nervous system
3	06-07	Operations on the endocrine system
4	08-16	Operations on the eye
5	18-20	Operations on the ear
6	21-29	Operations on the nose, mouth and pharynx
7	30-34	Operations on the respiratory system
8	35-39	**Operations on the cardiovascular system**
9	40-41	Operations on the hemic and lymphatic system
10	42-54	Operations on the digestive system
11	55-59	Operations on the urinary system
12	60-64	Operations on the male genital organs
13	65-71	Operations on the female genital organs
14	72-75	Obstetrical procedures
15	76-84	Operations on the musculoskeletal system
16	85-86	Operations on the integumentary system
17	87-99	Miscellaneous diagnostic and therapeutic procedures

* From CMS centers for Medicare and Medicaid services: http://www.cms.gov/Medicare/Coding/ICD9ProviderDiagnosticCodes/addendum.html

Appendix 2. Cardiovascular system procedures from ICD-9-CM volume 3 [67]

Code & Procedure
Heart
(35) Operations on valves and septa of heart
(35.0) Closed heart valvotomy
(35.1) Open heart valvuloplasty without replacement
(35.2) Replacement of heart valve
(35.3) Operations on structures adjacent to heart valves
(35.4) Production of septal defect in heart
(35.5) Repair of atrial and ventricular septa with prosthesis
(35.6) Repair of atrial and ventricular septa with tissue graft
(35.7) Other and unspecified repair of atrial and ventricular septa
(35.8) Total repair of certain congenital cardiac anomalies
(35.9) Other operations on valves and septa of heart
(36) Operations on vessels of heart
(36.0) Removal of coronary artery obstruction and insertion of stent(s)
(36.1) Bypass anastomosis for heart revascularization
(36.2) Heart revascularization by arterial implant
(36.3) Other heart revascularization
(36.9) Other operations on vessels of heart
(37) Other operations on heart and pericardium
(37.0) Pericardiocentesis
(37.1) Cardiotomy and pericardiotomy
(37.2) Diagnostic procedures on heart and pericardium
(37.3) Pericardiectomy and excision of lesion of heart
(37.4) Repair of heart and pericardium
(37.5) Heart replacement procedures
(37.6) Implantation of heart and circulatory assist system
(37.7) Insertion, revision, replacement, and removal of pacemaker leads; insertion of temporary pacemaker system; or revision of cardiac device pocket
(37.8) Insertion, replacement, removal, and revision of pacemaker device
(37.9) Other operations on heart and pericardium
Vessels
(38) Incision, excision, and occlusion of vessels
(38.0) Incision of vessel Thrombectomy
(38.1) Endarterectomy
(38.2) Diagnostic procedures on blood vessels
(38.3) Resection of vessel with anastomosis
(38.4) Resection of vessel with replacement
(38.5) Ligation and stripping of varicose veins
(38.6) Other excision of vessel
(38.7) Interruption of the vena cava
(38.8) Other surgical occlusion of vessels
(38.9) Puncture of vessel
(39) Other operations on vessels
(39.0) Systemic to pulmonary artery shunt
(39.1) Intra-abdominal venous shunt transjugular intrahepatic portosystemic shunt
(39.2) Other shunt or vascular bypass
(39.3) Suture of vessel
(39.4) Revision of vascular procedure
(39.5) Other repair of vessels
(39.6) Extracorporeal circulation and procedures auxiliary to heart surgery
(39.7) Endovascular repair of vessel
(39.8) Operations on carotid body and other vascular bodies
(39.9) Other operations on vessels

Appendix 3.Coding rules for complication with ICD-9-CM (1) [7,39,68]

Outcome	Included codes
Urinary tract infection	ICD-9-CM: 599.0, 996.64
Pressure ulcers	ICD-9-CM: 682, 707.0
Hospital-acquired pneumonia	ICD-9-CM: 507.0, 997.3, 514, 482.0-482.2, 482.4-482.9, 485, 486
Shock or cardiac arrest	ICD-9-CM: diagnosis-427.5, 785.5, 785.50, 785.51, 785.59, 799.1; procedures-93.93, 99.6, 99.63
Upper-gastrointestinal bleeding	ICD-9-CM: 531.00-531.31, 531.9, 532.00-532.31, 532.9, 533.00-533.31, 533.9, 534.00-534.31, 534.9, 535.01, 535.4, 578.9, 530.82
Hospital-acquired sepsis	ICD-9-CM: 038, 790.7
Deep venous thrombosis	ICD-9-CM: 415.1, 415.11, 451.11, 451.19, 451.2, 451.81, 453.8
Central nervous system complications	ICD-9-CM: 780.0, 293.0, 298.2, 309.1-309.9
Failure-to-rescue	Discharge status-death, with sepsis, pneumonia, upper gastrointestinal bleeding, shock or cardiac arrest, or deep venous thrombosis
Wound infection	ICD-9-CM: 958.3, 998.5
Pulmonary failure	ICD-9-CM: 514, 518.4, 518.5, 518.81, 518.82
Metabolic derangement	ICD-9-CM: 250.10, 250.11 (excluding diabetes as primary diagnosis), 998.0 (excluding those without operation or procedure during hospital stay), 788.5 (excluding acute myocardial infarction3, cardiac arrhythmia3, cardiac arrest3, or gastrointestinal haemorrhage3 as primary diagnosis), 276 (excluding MDC 5, MDC 7, MDC 10, and MDC 11), 251.0

Appendix 4.Coding rules for complication with ICD-10-CM (2) [49]

Outcome	Included
1. Related to surgical care	E89.0–E89.9, H59.0–H59.9, G97.0–G97.2, 97.8–G97.9, H95.0–H95.1, H95.8–H95.9, I97.0–I97.2, I97.8–I97.9, J95.0–J95.9, K43.0–K43.9, K91.0–K91.5, K91.8–K91.9, M02.0, M80.3, M81.3, M84.0, M84.1, M96.0–M96.1, M96.3–M96.4, M96.6, M96.8–M96.9, N99.0–N99.5, N99.8–N99.9, O35.7, T81.0–T81.9, T82.0–T82.9, T83.0–T83.9, T84.0–T84.9, T85.0–T85.9, T86.0–T86.4, T86.8–T86.9, T87.0–T87.6.
2. Related to a delivery or an abortion	O04.0–O04.8, O05.0–O05.8, O06.0–O06.8, O07.0–O07.3, O08.0–O08.9, O85, O86.0–O86.4, O86.8, O87.0–O87.3, O87.8–O87.9, O88.0–O88.3, O88.8, O90.0–O90.9, O91.0–O91.2, O92.0–O92.7, O96, O97.
3. Some infections of a surgical site classified elsewhere	J85.0–J85.3, J86.0, J86.9, M00.0–M00.9, M46.2, M46.3, M86.2–M86.4, M86.6–M86.9, T79.3.
4. Drug- or radiation-induced disorders	D61.1, D69.5, D70, E06.4, E13.–E13.9, E16.0, E23.1, E24.2, E27.3, E66.1, G21.0, G21.1,G25.1, G24.0, G25.4; G25.6, G44.4, G62.0, H26.3, H40.6, I95.2, K52.0, K62.7, K71.0–K71.9, L23.3, L24.4, L27.0–L27.1, L51.2, L53.0, L56.0–L56.1, L58.0–L58.1, L58.9, L59.0, L59.8, L59.9, M02.2, M10.2, M32.0, M80.4, M81.4, M83.5, M87.1, M96.5, N14.0–N14.2, N30.4, N98.0–N98.3, N98.8, N98.9, O29.0–O29.6, O29.8–O29.9, O35.5–O35.6, O89.0–O89.6, O89.8–O89.9, T80.0, T80.1–T80.6, T80.8–T80.9, T88.0–T88.9.
5. Conditions generally resulting from preexisting disease with multiple accompanying diseases	B20.0–B20.9, B21.0–B21.3, B21.7–B21.9, B22.0–B22.2, B22.7, B25.0–B25.2, B25.8–B25.9, C77.0–C77.9, C78.0–C78.8, C79.0–C79.8, C80., I46.0–I46.9, I85.0, J81, R40.0–R40.2, R55, R57.0–R57.1, R57.8–R57.9
6. Deep vein thrombosis, pulmonary embolism, and decubitus ulcer	I26.0, I26.9, I80.0–I80.3, I80.8–I80.9, I81, I82.0–I82.3, I82.8–I82.9, L89

Appendix 5. Translation of Charlson comorbidity index components into ICD–10 codes [49]

Diagnostic category	ICD-10 codes	Assigned weights
Cerebrovascular disease	I69.0–I69.4, I69.8	1
Congestive heart failure	I11.0, I13.0, I13.2, I42.0–I42.9, I43.0–I43.2, I43.8, I50.0, I50.1, I50.9, I51.7	1
Chronic pulmonary disease	I27.8, I27.9, J41.0, J41.1, J41.8 J42., J43.0, J43.1, J43.2, J43.8, J43.9 J44.0, J44.1, J44.8, J44.9, J45.0, J45.1 J45.8, J45.9, J46., J47., J60., J61., J62.0, J62.8, J63.0–J63.5, J63.8, J64., J65., J66.0, J66.1, J66.2, J66.8, J68.4, J70.1, J70.3	1
Dementia	F00.0–F00.2, F00.9, F01.0–F01.3, F01.8, F01.9, F02.0–F02.4, F02.8, F03., G30.0, G30.1, G30.8, G30.9, G31.0, G31.1	1
Diabetes without organ damage	E10.0–E10.1, E10.8–E10.9, E11.0–E10.1, E11.8–E11.9, E12.0–E12.1, E12.8–E12.9, E13.0–E13.1, E13.8–E13.9, E14.0–E14.1, E14.8–E14.9,	1
Mild liver disease	K70.3, K71.3–K71.5, K71.7–K71.8, K73.0–K73.2 K73.8, K73.9, K74.3–K74.6, K76.1, B18.0–B18.2, B18.8, B18.9	1
Former myocardial infarction	I25.2	1
Peripheral vascular disease	I70.0, I70.2, I70.8–I70.9, I71.0–I71.9, I73.1, I73.9, I77.1, Z95.1, Z95.5, Z95.8–Z95.9	1
Peptic ulcer disease	K25.4–K25.7, K26.4–K26.7, K27.4–K27.7, K28.4–K28.7	1
Rheumatic disease	M05.0–M05.3, M05.8–M05.9, M06.0, M31.5, M32.0–M32.1, M32.8–M32.9, M33.2, M34.0–M34.2, M34.8–M34.9, M35.3	1
Diabetes with organ damagec	E10.2–E10.7, E11.2–E11.7, E12.2–E12.7, E13.2–E13.7, E14.2–E14.7	2
Hemiplegia or paraplegia	G81.0–G81.1, G81.9, G82.0–G82.5	2
Any malignancy including lymphoma or leukemia	C00.0–C41.9,C45–C76.8,C80,C81.0–C97, Z85.0–Z85.9	2
Renal disease	N18.0, N18.8–N18.9, Z49.0–Z49.2, Z99.2	2
Moderate or severe liver disease	I85.0, I85.9, K70.4, K71.1, K72.1, K72.9, K76.5–K76.7	3
AIDS	B20.0–B20.9, B21.0–B21.3, B21.7–B21.9, B22.0–B22.2, B22.7	6
Metastatic solid tumor	C77.0–C79.8	6

Appendix 6. Result of linear mixed model by independent variable

Unit : %

Variable	Total*				Tertiary§				General§			
	Mortality		Complication		Mortality		Complication		Mortality		Complication	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Number of Doctors per 100 beds	-0.00771	0.54	-0.00703	0.59	-0.00139	0.79	-0.00889	0.40	-0.00531	0.90	0.01063	0.81
Number of RNs per 100 beds	**-0.01111**	**0.05**	**-0.02073**	**<0.0001**	0.00143	0.64	**-0.01418**	**0.02**	-0.02014	0.07	**-0.03075**	**0.01**
Number of RNs+NAs per 100 beds	**-0.01124**	**0.03**	**-0.02083**	**<0.0001**	-0.00117	0.66	**-0.01965**	**<0.0001**	-0.01923	0.06	**-0.02573**	**0.02**
Number of Doctors per 100 beds	0.01691	0.32	0.04407	0.01	-0.00566	0.42	0.01409	0.33	0.09799	0.11	0.14220	0.01
Number of RNs+NAs per 100 beds	**-0.01619**	**0.03**	**-0.03439**	**<0.0001**	0.00370	0.37	**-0.01990**	**<0.0001**	**-0.03758**	**0.02**	**-0.05414**	**<0.0001**
Number of RNs+NAs per 100 beds	-0.00989	0.08	**-0.01824**	**<0.0001**	0.00257	0.40	-0.01023	0.11	-0.01922	0.09	**-0.03217**	**0.01**
Number of NAs per 100 beds	-0.02023	0.27	-0.03707	0.05	**-0.01901**	**0.01**	**-0.06408**	**<0.0001**	-0.01929	0.66	0.02201	0.61
Number of Doctors per 100 beds	-0.00792	0.53	-0.00519	0.69	-0.00260	0.62	-0.01197	0.26	-0.00152	0.97	0.04114	0.36
RN rate (RNs/(RNs+NAs))	0.66240	0.71	**-7.64170**	**<0.0001**	**2.55960**	**0.01**	**6.50660**	**<0.0001**	-1.75130	0.59	**-20.12870**	**<0.0001**
Number of Doctors per 100 beds	-0.00338	0.79	0.00066	0.96	0.00145	0.79	0.00159	0.88	0.00518	0.91	0.00842	0.85
RN grade(Beds/nurse)												
5(4.0 ≤)	-2.76940	0.52	10.53650	0.23	-	-	-	-	-2.65330	0.58	10.51510	0.24
4(3.5-3.9)	-3.44040	0.47	-5.41530	0.57	-	-	-	-	-3.29410	0.53	-5.19750	0.60
3(3.0-3.4)	6.83890	0.11	6.46570	0.46	-	-	-	-	6.59650	0.16	6.10920	0.50
2(2.5-2.9)	**5.56620**	**0.03**	-3.24290	0.53	-	-	-	-	5.20970	0.07	-3.79550	0.48
1(2.0-2.4)	-2.36400	0.26	-5.02460	0.24	-	-	-	-	-2.45230	0.29	-5.15990	0.24
0(≤1.9)	ref.		ref.		-	-	-	-	ref.		ref.	
Number of NAs per 100 beds	-0.02543	0.16	**-0.04930**	**0.01**	**-0.01853**	**0.02**	**-0.06847**	**<0.0001**	-0.03434	0.43	-0.00639	0.88

* Adjusting for Age, Sex, Charlson comorbidity index, Type of admission, Admission method, Type of insurance, Year, Length of stay, Type of Hospital, Ownership, Region, Teaching, Number of beds

§ Adjusting for Age, Sex, Charlson comorbidity index, Type of admission, Admission method, Type of insurance, Year, Length of stay, Ownership, Region, Teaching, Number of beds

Appendix 7. Result of incision, excision, and occlusion of vessels- ICD-9-CM – 38 (Appendix 2) Unit : %

Variable	Total				Tertiary				General			
	Mortality		Complication		Mortality		Complication		Mortality		Complication	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Patient Characteristic												
Age (years)												
70≤	0.32050	0.15	0.17100	0.45	0.11520	0.40	0.06627	0.61	0.47200	0.22	0.23190	0.55
50-69	0.26970	0.20	0.00328	0.99	0.12010	0.36	0.00219	0.99	0.37180	0.30	-0.00888	0.98
30-49	0.16210	0.45	-0.14970	0.50	0.01705	0.90	0.02591	0.84	0.25160	0.49	-0.27600	0.46
<30	ref.		ref.		ref.		ref.		ref.		ref.	
Sex												
Men	-0.05829	0.44	-0.05827	0.45	-0.00752	0.87	0.03082	0.48	-0.08257	0.53	-0.12060	0.36
Women	ref.		ref.		ref.		ref.		ref.		ref.	
Charlson comorbidity index												
2	-0.20120	0.30	0.15380	0.44	-0.01461	0.89	-0.03016	0.76	-0.41380	0.30	0.48620	0.23
1	-0.12090	0.20	0.06009	0.53	-0.04900	0.35	-0.03514	0.49	-0.17440	0.32	0.16880	0.34
0	ref.		ref.		ref.		ref.		ref.		ref.	
Type of Admission												
Outpatient	-0.16060	0.13	-0.22960	0.03	-0.11050	0.06	-0.07324	0.19	-0.21980	0.27	-0.41110	0.04
Emergency	ref.		ref.		ref.		ref.		ref.		ref.	
Admission Method												
Visit	-0.01228	0.93	-0.14390	0.28	-0.00629	0.92	-0.03180	0.62	-0.04807	0.87	-0.28630	0.34
Transfer	ref.		ref.		ref.		ref.		ref.		ref.	
Type of insurance												
National Health Insurance	0.14110	0.32	0.20990	0.14	-0.07726	0.37	0.14590	0.08	0.30680	0.21	0.27320	0.27
Medical Aid	ref.		ref.		ref.		ref.		ref.		ref.	
Year												
2010	0.11160	0.21	-0.29250	<0.0001	0.14750	0.02	-0.01386	0.82	0.09207	0.53	-0.44470	<0.0001
2011	ref.		ref.		ref.		ref.		ref.		ref.	
LOS	0.00322	0.15	-0.00028	0.90	0.00041	0.77	0.00029	0.83	0.00485	0.19	-0.00171	0.65
Hospital Characteristic												
Type of Hospital												
Tertiary	1.33390	0.49	5.04360	0.13								
General	ref.		ref.									
Ownership												
Public	5.72440	<0.0001	-0.28680	0.93	-1.00120	0.57	-6.42810	0.26	8.16990	<0.0001	2.00340	0.61
Private	ref.		ref.		ref.		ref.		ref.		ref.	
Region												
Metropolitan-area	-2.01660	0.13	1.00040	0.69	-0.28840	0.86	2.23040	0.67	-2.85790	0.08	0.60530	0.83
Non-metropolitan area	ref.		ref.		ref.		ref.		ref.		ref.	
Teaching												
No	-2.11880	<0.0001	-0.44930	0.26					-2.15920	<0.0001	-0.38000	0.46
Yes	ref.		ref.						ref.		ref.	
Number of beds	-0.00324	0.07	-0.00033	0.88	-0.00202	0.06	-0.00132	0.29	-0.00498	0.12	-0.00033	0.94
Number of Doctors per 100 beds	0.04837	0.17	0.04196	0.25	0.00659	0.71	0.00559	0.75	0.09735	0.33	0.16810	0.12
Number of RNs per 100 beds	**-0.02972**	**0.04**	-0.00217	0.89	-0.01207	0.33	-0.00521	0.69	-0.04103	0.11	-0.02928	0.30
Number of NAs per 100 beds	-0.08176	0.03	0.00071	0.99	-0.00616	0.76	0.00910	0.64	-0.17380	0.02	-0.00063	0.99

Appendix 8. Result of other operations on vessels - ICD-9-CM – 39 (Appendix 2) Unit : %

Variable	Total				Tertiary				General			
	Mortality		Complication		Mortality		Complication		Mortality		Complication	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Patient Characteristic												
Age (years)												
70≤	-0.17950	0.40	0.17100	0.45	-0.01655	0.81	-0.13350	0.62	-0.60740	0.34	-0.60660	0.15
50-69	-0.16380	0.43	0.00328	0.99	-0.03408	0.62	-0.04632	0.86	-0.55860	0.37	-0.60550	0.15
30-49	-0.02473	0.91	-0.14970	0.50	-0.04090	0.56	0.05457	0.84	-0.12070	0.85	-0.86230	0.04
<30	ref.		ref.		ref.		ref.		ref.		ref.	
Sex												
Men	-0.06189	0.31	-0.05827	0.45	0.01001	0.65	-0.05800	0.50	-0.17750	0.23	0.08282	0.40
Women	ref.		ref.		ref.		ref.		ref.		ref.	
Charlson comorbidity index												
2	-0.09873	0.41	0.15380	0.44	0.06503	0.15	0.32210	0.07	-0.30430	0.27	-0.12560	0.49
1	0.01655	0.83	0.06009	0.53	0.08713	<0.0001	0.28880	0.01	-0.04738	0.79	-0.06234	0.60
0	ref.		ref.		ref.		ref.		ref.		ref.	
Type of Admission												
Outpatient	0.01608	0.81	-0.22960	0.03	-0.00014	1.00	-0.11090	0.24	0.07730	0.65	-0.05498	0.63
Emergency	ref.		ref.		ref.		ref.		ref.		ref.	
Admission Method												
Visit	0.03235	0.71	-0.14390	0.28	-0.00884	0.76	-0.04193	0.71	0.11510	0.63	0.04313	0.78
Transfer	ref.		ref.		ref.		ref.		ref.		ref.	
Type of insurance												
National Health Insurance	0.07001	0.46	0.20990	0.14	0.00055	0.99	0.45890	<0.0001	0.11440	0.59	-0.28180	0.05
Medical Aid	ref.		ref.		ref.		ref.		ref.		ref.	
Year												
2010	0.14630	0.05	-0.29250	<0.0001	-0.01827	0.54	0.07361	0.52	0.35790	0.03	0.22960	0.05
2011	ref.		ref.		ref.		ref.		ref.		ref.	
LOS	0.00020	0.77	-0.00028	0.90	0.00004	0.84	0.00066	0.42	0.00173	0.54	0.00014	0.94
Hospital Characteristic												
Type of Hospital												
Tertiary	0.53360	0.75	5.04360	0.13								
General	ref.		ref.									
Ownership												
Public	-0.25670	0.89	-0.28680	0.93	-0.89800	0.62	-5.47150	0.34	-0.06510	0.98	8.63800	0.03
Private	ref.		ref.		ref.		ref.		ref.		ref.	
Region												
Metropolitan-area	0.06134	0.96	1.00040	0.69	-0.70680	0.67	4.85750	0.35	0.28950	0.87	2.37290	0.36
Non-metropolitan area	ref.		ref.		ref.		ref.		ref.		ref.	
Teaching												
No	-0.18400	0.76	-0.44930	0.26					0.08083	0.93	0.26300	0.69
Yes	ref.		ref.						ref.		ref.	
Number of beds	-0.00027	0.86	-0.00033	0.88	0.00101	0.09	-0.00754	<0.0001	0.00252	0.49	-0.00145	0.69
Number of Doctors per 100 beds	0.00214	0.94	0.04196	0.25	-0.00646	0.50	0.03961	0.28	0.22160	0.06	0.18070	0.03
Number of RNs per 100 beds	-0.00438	0.71	-0.00217	0.89	**0.01220**	**0.03**	**-0.06406**	**<0.0001**	-0.04286	0.15	**-0.05074**	**0.02**
Number of NAs per 100 beds	-0.00724	0.78	0.00071	0.99	-0.03375	<0.0001	-0.14530	<0.0001	0.16670	0.05	0.20100	<0.0001

Appendix 9. Result of operations on valves and septa of heart - ICD-9-CM – 35 (Appendix 2) Unit : %

Variable	Total				Tertiary			
	Mortality		Complication		Mortality		Complication	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Patient Characteristic								
Age (years)								
70≤	-0.01229	0.89	-0.00640	0.86	-0.02058	0.85	-0.01076	0.82
50-69	-0.04182	0.60	-0.01785	0.59	-0.05936	0.56	-0.02592	0.54
30-49	0.00999	0.91	0.00325	0.93	0.00309	0.98	-0.00039	0.99
<30	ref.		ref.		ref.		ref.	
Sex								
Men	-0.03638	0.31	-0.01544	0.30	-0.04542	0.30	-0.01940	0.29
Women	ref.		ref.		ref.		ref.	
Charlson comorbidity index								
2	-0.02896	0.87	-0.00938	0.90	-0.03219	0.87	-0.01143	0.89
1	0.02425	0.63	0.01176	0.57	0.02853	0.64	0.01288	0.61
0	ref.		ref.		ref.		ref.	
Type of Admission								
Outpatient	-0.01507	0.74	-0.00576	0.76	-0.01448	0.80	-0.00677	0.77
Emergency	ref.		ref.		ref.		ref.	
Admission Method								
Visit	-0.00666	0.89	-0.00329	0.87	-0.00374	0.95	-0.00277	0.91
Transfer	ref.		ref.		ref.		ref.	
Type of insurance								
National Health Insurance	0.00189	0.98	-0.00128	0.97	-0.00675	0.95	-0.00390	0.92
Medical Aid	ref.		ref.		ref.		ref.	
Year								
2010	-0.00565	0.90	-0.00818	0.67	-0.02547	0.65	-0.01357	0.58
2011	ref.		ref.		ref.		ref.	
LOS	0.00043	0.68	0.00018	0.67	0.00055	0.66	0.00023	0.65
Hospital Characteristic								
Type of Hospital								
Tertiary	1.80320	0.15	6.35970	0.05				
General	ref.		ref.					
Ownership								
Public	-0.97900	0.47	-4.05310	0.28	-0.91280	0.63	-7.46690	0.24
Private	ref.		ref.		ref.		ref.	
Region								
Metropolitan-area	-0.83490	0.49	2.36390	0.48	-0.89020	0.63	2.41130	0.69
Non-metropolitan area	ref.		ref.		ref.		ref.	
Teaching								
No	-0.03502	0.92	-0.01942	0.89				
Yes	ref.		ref.					
Number of beds	-0.00159	0.12	-0.00032	0.55	-0.00164	0.18	-0.00043	0.51
Number of Doctors per 100 beds	0.00850	0.53	0.00195	0.74	0.00660	0.72	0.00120	0.88
Number of RNs per 100 beds	-0.00700	0.36	-0.00108	0.76	-0.00153	0.91	0.00065	0.92
Number of NAs per 100 beds	0.00369	0.87	0.00134	0.89	0.00188	0.95	0.00173	0.90

Appendix 10. Result of other operations on heart and pericardium - ICD-9-CM – 37 (Appendix 2) Unit : %

Variable	Total				Tertiary				General			
	Mortality		Complication		Mortality		Complication		Mortality		Complication	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Patient Characteristic												
Age (years)												
70≤	0.08012	0.55	0.00391	0.94	0.14170	0.49	-0.00777	0.92	0.02232	0.53	0.00290	0.94
50-69	0.00561	0.97	-0.00014	1.00	0.03365	0.87	-0.00063	0.99	0.03296	0.32	-0.02946	0.40
30-49	0.01399	0.92	0.00074	0.99	0.05055	0.80	-0.01222	0.87	0.01575	0.67	-0.01689	0.66
<30	ref.		ref.		ref.		ref.		ref.		ref.	
Sex												
Men	0.00478	0.93	0.01067	0.59	0.00609	0.93	0.02322	0.38	0.01630	0.35	-0.03643	0.05
Women	ref.		ref.		ref.		ref.		ref.		ref.	
Charlson comorbidity index												
2	0.28530	0.12	-0.12390	0.07	0.34090	0.14	-0.13190	0.12	-0.00807	0.93	0.02043	0.83
1	-0.01225	0.86	-0.00908	0.73	-0.02822	0.76	0.00234	0.95	-0.00720	0.78	-0.03559	0.19
0	ref.		ref.		ref.		ref.		ref.		ref.	
Type of Admission												
Outpatient	0.02313	0.71	0.00517	0.82	0.03595	0.67	0.01040	0.73	0.00635	0.78	-0.02616	0.27
Emergency	ref.		ref.		ref.		ref.		ref.		ref.	
Admission Method												
Visit	0.00254	0.98	-0.00275	0.93	-0.00877	0.94	0.00041	0.99	0.00337	0.92	0.01378	0.69
Transfer	ref.		ref.		ref.		ref.		ref.		ref.	
Type of insurance												
National Health Insurance	0.02509	0.85	0.00709	0.89	0.04003	0.83	-0.00584	0.93	0.00551	0.91	-0.00455	0.93
Medical Aid	ref.		ref.		ref.		ref.		ref.		ref.	
Year												
2010	-0.01744	0.78	0.03178	0.19	-0.04932	0.58	0.06207	0.07	0.00438	0.92	0.00227	0.96
2011	ref.		ref.		ref.		ref.		ref.		ref.	
LOS	0.00175	0.32	-0.00079	0.24	0.00358	0.15	-0.00141	0.14	-0.00009	0.88	-0.00043	0.49
Hospital Characteristic												
Type of Hospital												
Tertiary	2.03080	0.10	6.05120	0.02								
General	ref.		ref.									
Ownership												
Public	-1.89900	0.22	-6.04530	0.09	-2.54820	0.16	-7.84260	0.11	-0.76660	0.80	-1.18110	0.84
Private	ref.		ref.		ref.		ref.		ref.		ref.	
Region												
Metropolitan-area	0.58670	0.60	-1.90940	0.46	-0.53140	0.77	-2.85200	0.54	1.52450	0.30	-0.93890	0.74
Non-metropolitan area	ref.		ref.		ref.		ref.		ref.		ref.	
Teaching												
No	-3.76540	0.12	-8.38180	0.13					-3.29260	0.18	-8.14920	0.09
Yes	ref.		ref.						ref.		ref.	
Number of beds	-0.00170	0.20	-0.00057	0.57	-0.00183	0.22	-0.00029	0.84	0.00026	0.81	0.00029	0.80
Number of Doctors per 100 beds	0.02754	0.52	0.00202	0.91	0.05494	0.38	-0.02266	0.43	0.00076	0.98	-0.00623	0.85
Number of RNs per 100 beds	-0.00960	0.51	-0.00125	0.85	-0.02031	0.35	0.00787	0.48	0.00112	0.89	-0.01206	0.19
Number of NAs per 100 beds	-0.00459	<0.0001	-0.00337	0.81	0.00301	0.95	0.00392	0.83	-0.00045	0.98	0.01408	0.45

Appendix 11. Results of linear mixed model on mortality (death at discharge + hopeless discharge)

Unit : %

Variable	Total		Tertiary		Genreal	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Patient Characteristic						
Age (years)						
70≤	0.05933	0.61	0.02853	0.60	0.07429	0.77
50-69	0.07216	0.53	0.01131	0.83	0.12250	0.62
30-49	0.06562	0.58	-0.01671	0.76	0.14620	0.56
<30	ref.		ref.		ref.	
Sex						
Men	-0.03658	0.31	-0.00013	0.99	-0.08031	0.29
Women	ref.		ref.		ref.	
Charlson comorbidity index						
2	-0.02500	0.75	-0.00325	0.93	-0.06034	0.73
1	0.01074	0.79	-0.00651	0.73	0.03738	0.66
0	ref.		ref.		ref.	
Type of Admission						
Outpatient	-0.05663	0.18	-0.02889	0.14	-0.09429	0.31
Emergency	ref.		ref.		ref.	
Admission Method						
Visit	0.01698	0.75	-0.00708	0.75	0.06569	0.63
Transfer	ref.		ref.		ref.	
Type of insurance						
National Health Insurance	-0.01179	0.85	-0.02909	0.36	-0.00054	1.00
Medical Aid	ref.		ref.		ref.	
Year						
2010	0.12210	0.01	0.03075	0.15	0.20750	0.02
2011	ref.		ref.		ref.	
LOS	0.00030	0.61	-0.00003	0.89	0.00136	0.46
Hospital Characteristic						
Type of Hospital						
Tertiary	0.59660	0.73	-	-	-	-
General	ref.		-	-	-	-
Ownership						
Public	5.45260	<0.0001	-0.97260	0.58	7.78000	<0.0001
Private	ref.		ref.		ref.	
Region						
Metropolitan-area	-1.62710	0.22	-0.51490	0.75	-2.17310	0.17
Non-metropolitan area	ref.		ref.		ref.	
Teaching						
No	-1.15800	<0.0001	-	-	-1.10710	<0.0001
Yes	ref.		-	-	ref.	
Number of beds	-0.00149	0.17	-0.00016	0.75	-0.00186	0.44
Number of Doctors per 100 beds	0.01833	0.29	-0.00457	0.54	0.09478	0.12
Number of RNs per 100 beds	**-0.01566**	**0.04**	0.00434	0.31	**-0.03664**	**0.02**
Number of NAs per 100 beds	-0.02214	0.23	-0.01795	0.02	-0.01766	0.69

국문 요약

병원의 간호인력과 심혈관 수술환자의 의료결과

권정아

서론: 간호인력과 환자결과인 사망률과 합병증률의 관계는 이미 많은 연구에서 입증되어왔다. 그러나 여전히 간호인력은 적정한 수준으로 유지되지 않고 있다. 간호인력수준을 향상시키기 위하여 정부차원의 정책들이 있어왔지만 양적 향상 부분에 초점을 맞추어온 경향이 있다. 한국에서는 국가차원의 데이터로 간호인력과 사망률, 합병증률을 연구한 논문이 극히 드물었다. 그리하여 이 연구에서는 한국병원을 대표하는 데이터로 간호인력과 환자결과인 사망률과 합병증률의 관계를 연구하였다.

방법: 이 연구에서는 보건복지부에서 시행하는 '환자조사' 2010년과 2011년 데이터를 사용하였다. 전체 심혈관 수술을 받은 환자 9,131명 중 상급종합병원과 종합병원에 각각 4,823명, 4308명이 포함되었다. 전체 212개 병원 중 상급종합병원과 종합병원이 각각 44개, 168개이었다. 통계분석을 위하여 Linear Mixed effects 모델을 사용하여 병원과 환자수준의 다수준 분석을 시행하였다. 보정을 위해 포함된 변수는 환자수준에서 연령, 성별, Charlson comorbidity index, 입원경로, 내원경위, 진료비지불방법, 재원일수, 년도가 포함되었고, 병원수준에서는 의료기관종류, 설립구분, 지역, 수련병원여부, 일반병상수, 100병상당 의사수, 100병상당 조무사무가 포함되었다.

결과: 심혈관수술을 받은 환자를 대상으로 분석한 결과 100병상당 간호사수가 많아질수록 병원의 사망률(%)은 전체병원에서 0.02% (P=0.04), 종합병원에서 0.04% (P=0.02) 감소하였다. 합병증률(%)은 100병상당 간호사수가 많아질수록 전체병원에서 0.03 % (P<0.0001), 상급종합병원에서 0.02% (P=0.02), 종합병원에서 0.06 % (P<0.0001) 감소하였다.

결론: 이 연구를 통해서 간호인력수준이 환자의 사망률과 합병증률에 영향을 미친다는 것을 확인하였고, 의료기관의 종류와 대상질병에 따라서 환자결과에 다른 영향을 줄을 수 있기 때문에 간호인력수준을 향상시킬 때 이러한 부분들도 고려할 필요성이 있다. 그리하여 이 연구의 결과는 앞으로 간호인력수준 향상을 위한 정책수립과 관련하여 근거가 될 수 있을 것이다.

핵심어 : 간호인력, 의료의 질, 사망, 합병증