Association of nurse staffing grade and 30-day mortality in intensive care units among cardiovascular disease patients

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Abstract

After the implementation of a policy differentiating inpatient nursing fees, no study is found in the nursing literature for intensive care unit (ICU) patients admitted with cardiovascular (CV) disease exclusively in Korea. This study investigates the relationship between ICU nurse staffing and 30-day mortality using large representative claim database.

National Health Insurance Service-Senior (NHIS-Senior) claim database from 2002 to 2013, which was released by the Korean National Health Insurance Service (KNHIS), was used in this study. We included CV disease inpatients as a primary diagnostic code (I20-I25) who had their ICU utilization records from differentiating inpatient nursing fees code, resulting in 17,081 subjects.

After adjusting for confounders, the hazard ratio (HR) for 30-day mortality after discharge (HR: 1.177; P: .018) and in-hospital 30-day mortality (HR: 1.145; P: .058) were higher in general hospital (GH) than in tertiary hospital (TH). In GH setting, HR for 30-day mortality after discharge (HR: 1.499; P: .010) and in-hospital 30-day mortality (HR: 1.377; P: .042) were higher in grade 7 to 9 than grade 1 to 2, but not in TH setting.

This study shows that ICU nurse staffing related to improved mortality risk in GHs. Therefore, adequate nurse staffing to provide safe and high-quality care can be ensured by continuous monitoring and evaluation of nurse staffing.

Abbreviations: CCI = charlson comorbidity index, CV = cardiovascular, GH = general hospital, HR = hazard ratio, ICU = intensive care unit, KNHIS = Korean National Health Insurance Service, TH = tertiary hospital.

Keywords: aging, care, mortality, nurse staffing

Key Points

• Significant relationship between nurse staffing grade and mortality in general hospital.
• General hospitals have a relatively lower need to improve nurse staffing than tertiary hospitals.
• Nurse staffing grade in tertiary hospital was not significantly associated with possibilities of dying.

1. Introduction

Admission to the intensive care unit (ICU) has been known as a risk factor for increased morbidity and mortality outcomes, especially in those with cardiovascular (CV) disease. Although ICU for the severely ill patients is associated with specialized clinical team with access to the most technologically sophisticated equipment to provide close nursing surveillance and life-sustaining interventions, advances in technology are just tools to support health care staff in closely monitoring and properly treating patients who are critically ill. Nurses of skilled health care staffs in hospitals are crucial to providing good-quality care services, providing patients with holistic care 24-hour a day.

A recent systematic review suggests that better nurse staffing is associated with improved patient outcomes. Although some researchers express skepticism about its sensitivity to nursing care quality, mortality of those patients is often used as an important indicator for hospital quality. Although research evidence has increased concerning the relationship between bed-to-nurse ratio and patient outcomes in Korea, hospital administrators tend to reduce nurse staffing to decrease hospital costs and maximize efficiency of operation.

Several countries regulate minimum requirements of nurse staffing or offer financial incentives for guaranteed nursing care quality. In 1999, the Korean government implemented a new incentive policy for nurse staffing, namely differentiating inpatient nursing fees by nurse staffing levels to financially incentivize hospitals to improve nurse staffing and the quality of nursing care services. At first, there were 6 grades of nurse staffing levels based on the nurse-to-bed ratio only for general care units of all types of hospital, which extended to 7 grades of

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nurse staffing levels in general hospitals (GHs) in 2007 and 9 grades in 2008 (see Supplemental Digital Content which demonstrates the differentiating nursing fees and code according to staffing level, http://links.lww.com/MD/C564).\(^{[11,14]}\)

After the implementation of the policy, differentiating inpatient nursing fees, a few studies have been published on the effects of the policy on nurse staffing in Korea.\(^{[12,15-18]}\) However, no study is found in the nursing literature for ICU patients admitted with CV disease exclusively and thus, we examine the relationship is found in the nursing literature for ICU patients admitted with CV disease exclusively and thus, we examine the relationship between ICU nurse staffing and patient mortality using large representative claim database.

2. Methods

2.1. Study design and data source

Study data were obtained from National Health Insurance Service-Senior (NHIS-Senior) claim database from 2002 to 2013 which was released by the Korean National Health Insurance Service (KNHIS).\(^{[19]}\) The initial NHIS-Senior cohort data was comprised of 558,147 participants. Approximately 10% of the 60 years and above elderly population in 2002 was analyzed, using a stratified random sampling method, excluding non-citizens and special purpose employees with an unidentified income level. The baseline cohort members were followed for 11 years until 2013 unless the beneficiaries were disqualified due to death or emigration. Detailed methods for establishing and ensuring the representativeness of NHIS-Senior cohort were published on the KNHIS website (https://nhiss.nhis.or.kr/bd/asy/bdaya001v.do).\(^{[19]}\) For the analysis we included CV disease inpatients as a primary diagnostic code (I20-I25) in the International Classification of Diseases, 10th revision (ICD-10) who had their ICU utilization records from differentiating inpatient nursing fees code, resulting in 17,081 subjects. This study does not need ethical approval because it is not a study using human derivatives, and all subjects are encrypted and cannot be identified.

2.2. Independent variable

The highest nurse staffing grade was grade 1 (beds/nurse ratio < 0.5), with the lowest nurse staffing grade being grade 9 (beds/nurse ratio ≥ 2.0). Level of nurse staffing was categorized into 4 groups in each year: grade 1 to 2, grade 3 to 4, grade 5 to 6, and grade 7 to 9.

3. Dependent variable

3.1. All-cause mortality

Thirty-day mortality after discharge was determined by death certificates and discharge diagnosis was determined at the time of discharge by calculating the admission date and length of stay. In-hospital 30-day mortality was determined by mortality date after admission date.

3.2. Control variables

The present analyses included age, sex, income, type of insurance, region, primary diagnosis, route of admission, Charlson Comorbidity Index (CCI), organization type, number of doctors, and hospital technology as control factors; all of the covariates were categorical except for age, and number of doctors. Sex was grouped into male and female. Based on the premiums of the National Health Insurance, which reflects household income in our database, all the people were divided into 10 quintiles and we were further categorized into 3 groups: low (≤ 3), middle (4–7), or high (8–10). Region was categorized into metropolitan (Seoul), urban (Daejeon, Daegu, Busan, Incheon, Kwangju, or Ulsan), and rural (otherwise). Primary diagnosis of CV disease was categorized into 5 groups: angina pectoris (I20), acute myocardial infarction (I21), subsequent myocardial infarction (I22), certain current complications following acute myocardial infarction (I23), other acute ischemic heart diseases (I24), and chronic ischemic heart disease (I25). Route of admission was categorized into emergency and outpatient, and CCI was grouped as scores of 0, 1, 2, and over 3. Organization type of hospital was categorized into 3 groups: public, corporate, and private. Based on our previous research\(^{[20]}\) as a proxy to sophisticated equipment, hospital technology was investigated. Using SAS Rank function, hospital technology was categorized into 3 groups.

3.3. Statistical analysis

Chi-square test, log-rank test, analysis of variance (ANOVA), and Cox proportional hazards models were used to investigate the association between nurse staffing and mortality. For all analyses, the criterion for statistical significance was \(P < .05\), 2-tailed. All analyses were conducted using the SAS statistical software package, version 9.4 (SAS Institute Inc., Cary, NC).

4. Results

4.1. General characteristics of CV disease ICU patients

Table 1 shows the general characteristics for 30-day mortality after discharge and in-hospital 30-day mortality, respectively. Of 17,081 patients with CV disease, 8428 patients (49.3%) used ICU in tertiary hospital (TH) and 8653 patients (50.7%) used in GH. Of the patients admitted to low hospital technology, 14.2% died within 30 days after discharge and 12.9% died within 30 days, respectively (Table 1, Fig. 1). In addition, the prevalence of 30-day mortality after discharge and in-hospital 30-day mortality was 10.3% and 9.3%, respectively (Table 1). Of those admitted to TH, the prevalence of 30-day mortality after discharge and in-hospital 30-day mortality was 8.5% and 7.7%, respectively. Of those admitted to GH, the prevalence of 30-day mortality after discharge and in-hospital 30-day mortality was 12.1% and 10.9%, respectively (Table 2).

4.2. Adjusted effect of nurse staffing level on mortality by hospital type

After adjusting for all of these confounders, the hazard ratio (HR) for 30-day mortality after discharge (HR: 1.177; \(P: .018\)) and in-hospital 30-day mortality (HR: 1.145; \(P: .058\)) in GH were higher than TH (Table 3).

Table 4 showed adjusted effect between nurse staffing level and 30-day mortality according to hospital type (e.g., TH and GH). After adjusting for all confounders in TH, HR in both 30-day mortality after discharge and in-hospital 30-day mortality were not statistically significant, but in GH setting, HR for 30-day mortality after discharge (HR: 1.499; \(P: .010\)) and in-hospital 30-day mortality (HR: 1.377; \(P: .042\)) were higher in grade 7 to 9 than grade 1 to 2. In addition, hospital technology, which is considered to be an important indicator of mortality of hospital
in ICU, was associated with 1.33 times higher mortality (HR in in-hospital 30-day mortality: 1.328; \( P \) = .002) in hospital with low technology than high technology.

### 5. Discussion

This study shows the differences that exist in grade of ICU nurse staffing with 30-day mortality among CV disease inpatients in Korea. An important finding of this study was that there was a more significant relationship between nurse staffing grade and mortality at GH rather than TH. In Korea, GHs are institutions that have a minimum of 100 inpatient beds and provide physician specialist services in major areas (e.g., internal medicine, surgery, and pediatrics) and THs indicate GHs that are approved to provide most types of advanced medical care and treat severely ill patients. So, GHs have a relatively lower need to improve nurse staffing than THs because they may be delivering care to patients with less critical conditions than those in THs. In contrast, nurse staffing grade in TH was not significantly associated with possibilities of dying. THs play a role as specialized care providers in Korea. Patients who require more intensive care tend to be admitted to THs following an easily obtainable referral from a primary care physician, where they can receive specialized high-quality care.\(^{[21]}\) Therefore, it is possible that there are higher

### Table 1

| Characteristics                      | Total | No | Yes | \( P \) value |
|---------------------------------------|-------|----|-----|---------------|
|                                       | N     | %  | Mean | SD | Mean | SD | P value | Mean | SD | Mean | SD | P value |
| Age                                   | 17,081| 100.0 | 73.5 | 6.5 | 77.9 | 7.3 | <.0001 | 73.5 | 6.5 | 78.0 | 7.4 | <.0001 |
| Number of doctors                     | 17,081| 100.0 | 359.5 | 305.0 | 266.5 | 247.8 | <.0001 | 338.8 | 304.8 | 264.6 | 244.3 | <.0001 |
| Hospital type                         |       |     | No | N | % | N | % | No | N | % | N | % | <.0001 | <.0001 |
| Tertiary hospital (TH)                | 8428  | 49.3 | 7713 | 91.5 | 715 | 8.5 | .064 | .067 |
| General hospital (GH)                 | 8653  | 50.7 | 7603 | 87.9 | 1050 | 12.1 | .001 | .001 |
| CCI                                    | 6752  | 39.5 | 6012 | 89.0 | 740 | 11.0 | .001 | .001 |
| 0                                      | 3904  | 23.0 | 3250 | 89.5 | 414 | 10.5 | .001 | .001 |
| 1                                      | 2593  | 15.2 | 2342 | 90.3 | 251 | 9.7 | .001 | .001 |
| ≥3                                     | 3802  | 22.3 | 3442 | 90.5 | 360 | 9.5 | .001 | .001 |
| Sex                                    |       |     | Male | 8697 | 50.9 | 7868 | 90.5 | 829 | 9.5 | 7964 | 91.5 | 743 | 8.5 |
|                                       | Female | 8384 | 49.1 | 7448 | 88.8 | 936 | 11.2 | 7538 | 89.9 | 846 | 10.1 | .056 | .098 |
| Income                                 | 4450  | 26.1 | 3960 | 89.0 | 490 | 11.0 | .001 | .001 |
| Low                                    | 4378  | 25.6 | 3909 | 89.3 | 469 | 10.7 | .001 | .001 |
| Middle                                 | 8253  | 48.3 | 7447 | 90.2 | 806 | 9.8 | .001 | .001 |
| High                                   |       |     |      |     |     |     |     |     |     |     |     |     | .011 | .071 |
| Type of insurance                      |       |     | Community insurance | 5606 | 32.8 | 5045 | 90.0 | 561 | 10.0 | 5107 | 91.1 | 499 | 8.9 |
|                                       | Workplace insurance | 10,033 | 56.7 | 8983 | 89.5 | 1050 | 10.5 | 9075 | 90.5 | 958 | 9.6 | .001 | .001 |
| Medical Aid                           | 1442  | 8.4 | 1268 | 89.3 | 154 | 10.7 | .001 | .001 |
| Region                                 |       |     | Metropolitan | 3582 | 21.0 | 3232 | 90.2 | 350 | 9.8 | 3274 | 91.4 | 308 | 8.6 |
|                                       | Urban | 3725 | 21.8 | 3312 | 88.9 | 413 | 11.1 | 3347 | 89.9 | 378 | 10.2 | .001 | .001 |
|                                       | Rural | 9774 | 57.2 | 8772 | 89.8 | 1002 | 10.3 | 8871 | 90.8 | 903 | 9.2 | .001 | .001 |
| Primary diagnosis                      |       |     | Angina pectoris | 6604 | 38.7 | 6400 | 96.9 | 204 | 3.1 | 6427 | 97.3 | 177 | 2.7 |
|                                       | Acute myocardial infarction | 7778 | 45.5 | 6428 | 82.6 | 1530 | 17.4 | 6548 | 84.2 | 1230 | 15.8 | .001 | .001 |
|                                       | Subsequent myocardial infarction | 48 | 0.3 | 38 | 84.4 | 7 | 15.6 | .001 | .001 |
|                                       | Certain current complications following acute myocardial infarction | 24 | 0.1 | 16 | 66.7 | 8 | 33.3 | .001 | .001 |
|                                      | Other acute ischemic heart diseases | 90 | 0.5 | 76 | 84.4 | 14 | 15.6 | .001 | .001 |
|                                      | Chronic ischemic heart disease | 2540 | 14.9 | 2358 | 92.8 | 728 | 7.2 | 2385 | 93.0 | 155 | 6.1 | .001 | .001 |
| Route of admission                    |       |     | Emergency | 9253 | 54.2 | 8058 | 87.1 | 1195 | 12.9 | 8163 | 88.2 | 1090 | 11.8 |
|                                       | Outpatient | 7628 | 45.8 | 7258 | 92.7 | 570 | 7.3 | 7329 | 93.6 | 409 | 6.6 | .001 | .001 |
| Organization type                     |       |     | Public | 263 | 1.5 | 202 | 76.8 | 61 | 32.3 | 206 | 78.3 | 57 | 21.7 | .001 | .001 |
|                                       | Corporate | 16,290 | 95.4 | 14,672 | 90.1 | 1618 | 9.9 | 14,836 | 91.1 | 1454 | 8.9 | .001 | .001 |
|                                       | Private | 528 | 3.1 | 442 | 83.7 | 86 | 13.6 | 450 | 85.2 | 78 | 14.8 | .001 | .001 |
| Hospital technology                   |       |     | Low | 6036 | 35.3 | 5180 | 85.8 | 856 | 14.2 | 5260 | 87.1 | 776 | 12.9 |
|                                       | Middle | 6118 | 35.8 | 5598 | 91.5 | 520 | 8.5 | 5657 | 92.5 | 461 | 7.5 | .001 | .001 |
|                                       | High | 4927 | 28.8 | 4538 | 92.1 | 389 | 7.9 | 4575 | 92.9 | 352 | 7.1 | .001 | .001 |
| Total                                 | 17,081 | 100.0 | 15,316 | 89.7 | 1,765 | 10.3 | .001 | .001 |

CCI = Charlson Comorbidity Index, SD = standard deviation.
proportion of patients with greater severity of illnesses such as CV disease for the delivery of intensive and sophisticated care for patients in THs. Thus, this result suggests that mortality risk of THs that had highly intensive and complex medical technology in ICU may be more affected by advanced medical technology rather than nursing personnel.

The UK Department of Health and Intensive Care Society has proposed a minimum standard of a nurse-to-patient ratio of 1:1 for ICU patients.\textsuperscript{[22,23]} The state of Victoria, Australia, has implemented a minimum ratio of 1 nurse to 1 unconscious patient or 2 to 4 highly dependent patients.\textsuperscript{[24]} However, in Korea, this policy did not include adequate levels of nurse staffing, such as the mandated minimum nurse-to-patient ratios. Although there is a regulation regarding nurse staffing in hospital, approximately 50% of hospitals do not comply with the regulation, largely because there are no penalties for noncompliance.\textsuperscript{[25]} Moreover, it does not consider the occupancy rate and does not reflect the number of direct nursing hours. Therefore, policymakers should

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Thirty-day mortality after discharge (left) and in-hospital 30-day mortality (right) for tertiary (upper) and general (lower).}
\end{figure}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
\hline
 & \multicolumn{2}{c|}{Total} & \multicolumn{2}{c|}{30-day mortality after discharge} & \multicolumn{2}{c|}{In-hospital 30-day mortality} \\
 & \multicolumn{2}{c|}{No} & \multicolumn{2}{c|}{Yes} & \multicolumn{2}{c|}{No} & \multicolumn{2}{c|}{Yes} \\
\hline
 & N & \% & N & \% & N & \% & N & \% \\
\hline
Level of nurse staffing in TH & & & & & & & & \\
Grade 1–2 & 1762 & 20.9 & 1603 & 91.0 & 159 & 9.0 & 1624 & 92.2 \\
Grade 3–4 & 1729 & 20.5 & 1535 & 88.8 & 194 & 11.2 & 1546 & 89.4 \\
Grade 5–6 & 54 & 0.6 & 43 & 79.6 & 11 & 20.4 & 45 & 83.3 \\
Grade 7–9 & 4883 & 57.9 & 4532 & 92.8 & 351 & 7.2 & 4565 & 93.5 \\
Total & 8428 & 100.0 & 7713 & 91.5 & 715 & 8.5 & 7780 & 92.3 \\
\hline
Level of nurse staffing in GH & & & & & & & & \\
Grade 1–2 & 584 & 6.8 & 530 & 90.8 & 54 & 9.3 & 534 & 91.4 \\
Grade 3–4 & 2047 & 23.7 & 1797 & 87.6 & 250 & 12.2 & 1824 & 89.1 \\
Grade 5–6 & 927 & 10.7 & 801 & 86.4 & 126 & 13.6 & 814 & 87.8 \\
Grade 7–9 & 5095 & 58.9 & 4475 & 87.8 & 620 & 12.2 & 4540 & 89.1 \\
Total & 8653 & 100.0 & 7603 & 87.9 & 1050 & 12.1 & 7712 & 92.3 \\
\hline
\end{tabular}
\end{table}
consider several approaches to recommend improving nurse staffing. Ideally, every hospital, to see how differences in policies and financial performance affect the cost-effectiveness of staffing and its effect on quality of health care, should be monitored.\[26,27\]

In a variety of healthcare and clinical settings, further research on the workforce is urgently required to guide decisions about safe staffing levels to ensure patient safety, because nurses and doctors may substitute 1 another, so that units that are short of doctors may compensate by hiring more nurses.\[28\]

A large number of units and patients analyzed in this study, as well as the use of appropriate methods for the structure of the data, are additional strengths of this study. These results will hopefully be developed in future qualitative and quantitative research. Despite access to a large national sample, this study has limitations in terms of interpreting and comparing results with other studies. Major limitation relates to risk adjustment in patient mortality. Although age, gender, income, type of insurance, residential region, primary diagnosis, and comorbidity for risk adjustment were used, we were not able to adjust treatment of ICU variable that may affect risk of mortality because of lack of information. Inaccuracy of risk adjustment may lead to skewed results. Furthermore, because our claim database analyzed do not contain any clinical findings or information about the disease’s severity, we were unable to consider all possible covariates associated with risk of mortality. Therefore, our analytic approach was to apply regression models separately to tertiary and GHs because they had groups of patients and disease severity. Inclusion of hospital characteristics (i.e., ownership, hospital technology) should contribute indirectly to reducing variations in disease severity. Additional measures

### Table 3

|                                | 30-day mortality after discharge | In-hospital 30-day mortality |
|--------------------------------|----------------------------------|-----------------------------|
|                                | HR  | SE  | P value | HR  | SE  | P value |
| **Age**                        | 1.067 | 0.003 | <.0001 | 1.069 | 0.004 | <.0001 |
| **Number of doctors**          | 1.000 | 0.000 | .107 | 1.000 | 0.000 | .046 |
| **Hospital type**              |      |      |        |      |      |        |
| Tertiary hospital (TH)         | 1.000 | 1.000 |        |      |      |        |
| General hospital (GH)          | 1.177 | 0.069 | .018 | 1.145 | 0.071 | .058 |
| **CCI**                        |      |      |        |      |      |        |
| 0                              | 0.954 | 0.066 | .475 | 0.991 | 0.069 | .894 |
| 1                              | 0.976 | 0.073 | .764 | 0.982 | 0.077 | .810 |
| 2                              | 0.957 | 0.083 | .597 | 1.006 | 0.086 | .944 |
| ≥3                             | 1.000 | 1.000 |        |      |      |        |
| **Sex**                        |      |      |        |      |      |        |
| Male                           | 1.038 | 0.050 | .460 | 1.026 | 0.052 | .626 |
| Female                         | 1.000 | 1.000 |        |      |      |        |
| **Income**                     |      |      |        |      |      |        |
| Low                            | 1.043 | 0.069 | .538 | 1.073 | 0.072 | .326 |
| Middle                         | 1.078 | 0.060 | .210 | 1.107 | 0.062 | .103 |
| High                           | 1.000 | 1.000 |        |      |      |        |
| **Type of insurance**          |      |      |        |      |      |        |
| Community insurance            | 1.208 | 0.104 | .069 | 1.282 | 0.110 | .023 |
| Workplace insurance            | 1.278 | 0.106 | .020 | 1.412 | 0.111 | .002 |
| Medical Aid                    | 1.000 | 1.000 |        |      |      |        |
| **Region**                     |      |      |        |      |      |        |
| Metropolitan                   | 1.168 | 0.065 | .017 | 1.162 | 0.068 | .029 |
| Urban                          | 1.090 | 0.060 | .151 | 1.126 | 0.062 | .056 |
| Rural                          | 1.000 | 1.000 |        |      |      |        |
| **Primary diagnosis**          |      |      |        |      |      |        |
| Angina pectoris                | 0.421 | 0.104 | <.0001 | 0.441 | 0.111 | <.0001 |
| Acute myocardial infarction    | 2.044 | 0.082 | <.0001 | 2.243 | 0.088 | <.0001 |
| Subsequent myocardial infarction | 1.513 | 0.388 | .286 | 1.778 | 0.389 | .139 |
| Certain current complications following acute myocardial infarction | 6.342 | 0.363 | <.0001 | 6.859 | 0.388 <.0001 |
| Other acute ischemic heart diseases | 1.375 | 0.280 | .255 | 1.476 | 0.291 | .181 |
| Chronic ischemic heart disease | 1.000 | 1.000 |        |      |      |        |
| **Route of admission**         |      |      |        |      |      |        |
| Emergency                      | 1.105 | 0.055 | .068 | 1.133 | 0.057 | .030 |
| Outpatient                     | 1.000 | 1.000 |        |      |      |      |
| **Organization type**          |      |      |        |      |      |        |
| Public                         | 1.506 | 0.170 | .016 | 1.608 | 0.176 | .007 |
| Corporate                      | 0.948 | 0.117 | .652 | 0.932 | 0.122 | .567 |
| Private                        | 1.000 | 1.000 |        |      |      |      |
| **Hospital technology**        |      |      |        |      |      |        |
| Low                            | 1.427 | 0.066 | <.0001 | 1.426 | 0.068 | <.0001 |
| Middle                         | 1.073 | 0.069 | .308 | 1.066 | 0.072 | .370 |
| High                           | 1.000 | 1.000 |        |      |      |      |

CCI = Charlson Comorbidity Index.
that take account of severity of illness are needed for more complete risk adjustment. Second, the rates of nurse turnover at different types of hospitals were not considered in this study. A higher turnover rate will increase the cost of employing nurses, and so further studies considering nurse turnover will be helpful to understand the nurse staffing levels at specific hospitals. Finally, we used an anonymized and auto-generated claim database with ICD-10 codes, limiting validation of the individual ICD codes. In particular, there is frequent under-reporting of certain medical conditions resulting in incomplete coding.\cite{29,30}

### 6. Conclusions

The findings of this study show that increased nurse staffing levels related to improved mortality risk in ICU of GHs in Korea. Therefore, adequate nurse staffing to provide safe and high-quality care can be ensured by continuous monitoring and evaluation of nurse staffing. These findings recommend that a strategy need to be developed towards better compliance to conduct future research.

### Author contributions

KJH contributed to designing the study and editing the manuscript. JHK collected, analyzed and interpreted the data and writes the manuscript. Data curation: Jae Hyun Kim. Formal analysis: Jae Hyun Kim. Funding acquisition: Jae Hyun Kim. Investigation: Jae Hyun Kim. Methodology: Jae Hyun Kim. Project administration: Jae Hyun Kim. Resources: Jae Hyun Kim. Software: Jae Hyun Kim.
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