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Impact of Intensivist and Nursing Staff on Critically Ill Patient Mortality: A Retrospective Analysis of the Korean NHIS Cohort Data, 2011–2015

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Purpose: Critical care medicine continues to evolve. However, critical care cases require increasing amount of medical resources. Intensive care unit (ICU) mortality significantly impacts the overall efficiency of healthcare resources within a system of limited medical resources. This study investigated the factors related to ICU mortality using long-term nationwide cohort data in South Korea.
Materials and Methods: This retrospective cohort study used data of 14905721 patients who submitted reimbursement claims to the Korean Health Insurance Service between January 1, 2011 and December 31, 2015. A total of 1498102 patients who were admitted to all ICU types, except neonatal and long-term acute care hospitals, were enrolled.
Results: Of the total 1498102 participants, 861397 (57.5%) were male and 636705 (42.5%) were female. The mean age at admission was 63.4±18.2 years; most of the subjects were aged over 60 years. During the 5-year period, in-hospital mortality rate was 12.9%. In Cox analysis, both in-hospital and 28-day mortality rates were significantly higher in male patients and those of lower socioeconomic status. As age increased and the number of nursing staff decreased, the mortality risk increased significantly by two or three times. The mortality risk was lower in patients admitted to an ICU of a tertiary university hospital and an ICU where intensivists worked.
Conclusion: The number of nursing staff and the presence of an intensivist in ICU were associated with the ICU mortality rate. Also, increasing the number of nursing staff and the presence of intensivist might reduce the mortality rate among ICU patients.

Key Words: Critical care, intensive care unit, mortality, nursing staff, intensivist

INTRODUCTION

According to recent data, the number of people aged ≥65 years is expected to increase to approximately 1.5 billion by the year 2050, surpassing the number of those aged <5 years by 2050.[1] Older patients have a high incidence of chronic degenerative diseases, such as physiological aging processes, cerebrovascular diseases, and cancer, and frequently experience unplanned hospitalization.[2,3] Older patients with various comorbidities are more often admitted to the intensive care unit (ICU) compared

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to younger patients. Also, due to the aging society, critical care medicine continued to grow compared to general hospital care between 2000 and 2005.[2,4-6] However, an increasing number of critical care cases calls for an increase in medical resources as well.[7] Among the total hospital cost, daily ICU hospitalization cost was relatively higher than that of general ward hospitalization, and increased treatment intensity required higher costs.[8] In addition, patients who die in the ICU incur higher costs than those who survive.[9] Therefore, the length of stay and mortality rates at ICU significantly impact the overall healthcare resource efficiency within systems with limited medical resources.

ICU mortality is related to the patient's conditions, such as the need for mechanical ventilation, vasopressors, and renal replacement treatment.[10-12] However, recent studies have reported that non-patient factors, including the presence of intensivists and nurse-to-patient ratio, were related to ICU mortality.[13,14] The presence of intensivist could reduce the in-hospital mortality risk to 0.83, and the nurse-to-patient ratio exceeding 1:1.5 was associated with a lower in-hospital mortality rate than that with a 1:2 ratio.[13,15] In South Korea, there have been recent studies on the effects of intensivists and the nurse-to-patient ratio at ICU;[16,17] unfortunately, these studies included relatively small sample sizes or did not analyze mortality-related factors. Therefore, the current study aimed to investigate the clinical characteristics of ICU patients and estimate their mortality-related factors, including the presence of intensivists and nurse-to-patient ratio in South Korea, using long-term nationwide cohort data.

MATERIALS AND METHODS

Study population and data

This study analyzed data from the Korean National Health Insurance Service (KNHIS-2019-1-164) from January 1, 2011 to December 31, 2015. All citizens of South Korea are obligated to enroll in the NHIS, a single insurer system for medical care; and their data, including insurance eligibility, medical treatment, and medical care institutions, are stored in the NHIS database.[18]

A total of 14905721 patients submitted reimbursement requests to the KNHIS during the study period. Subjects who submitted duplicate reimbursement claims at the same institute, who were admitted to the ICU before January 1, 2011, or for whom hospital records were recorded after their death were excluded. Among them, 9714083 patients did not have an ICU admission until January 1, 2011. All 1498102 patients were admitted to all ICU types except neonatal subjects, and those of long-term acute care hospitals were enrolled. ICU admission was defined as the submission of more than one reimbursement request with the NHIS claim code AJ100-AJ390 (Fig. 1, Supplementary Table 1, only online).

Definition and analysis variables

To investigate patient-related demographic factors, age, sex, income level, and chronic medical condition were examined at the time of admission. To assess chronic medical conditions, the Charlson Comorbidity Index (CCI) was calculated using the claim code for healthcare utilization at baseline.[19] Income level was categorized into five quintiles except Medicaid, with quintile 1 being the lowest income group. To investigate severity, the application of mechanical ventilation, renal replacement therapy, as well as vasopressor and inotropic drugs during hospitalization were examined. The application of mechanical ventilation was identified using the claim code indicating that the ventilator was used for more than 8 hours. The use of vasopressor and inotropic drugs (norepinephrine, epinephrine, dopamine, dobutamine, phenylephrine, isoproterenol, and milrinone) was identified using the anatomical therapeutic chemical classification system.[20] Hospitals (excluding long-term acute care hospitals) were classified as tertiary, general, or other, as defined by the healthcare law in South Korea. Total ICU bed-to-total number of nursing staff ratios and the presence of intensivists were identified by claim codes. Nursing grade was categorized into grades 1–9 based on the total ICU bed-to-total nursing staff ratios. Grade 1 indicated that total ICU beds/total number of nursing staff was <0.5, approximately 1:2.5 when converted to the actual acting nurse-to-patient ratio. Grade 9 indicated a total ICU bed/total nursing staff ratio >2 (Supplementary Table 2, only online). The presence of intensivists regulation in South Korea was at least one daytime worker per 30 ICU beds. In-hospital mortality and 28-day mortality rates were examined as final outcomes, and related variables were analyzed.

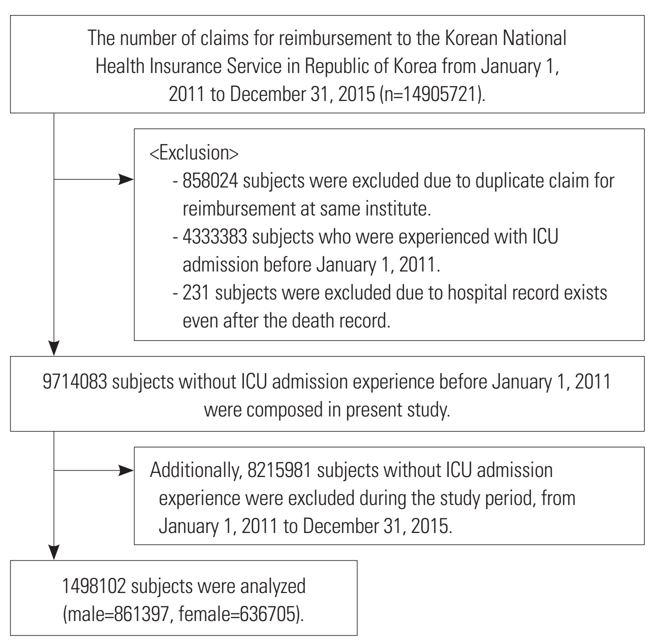

Fig. 1. Flow of study. ICU, intensive care unit.

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Ethical approval and consent to participate

This study was approved by the Institutional Review Board of the National Health Insurance Service of the Ilsan Hospital (approval number: NHIMC2017PR026), and it adhered to the tenets of the Declaration of Helsinki. Informed consent was waived by the institutional review board due to the study's retrospective nature, and the data were de-identified in the used database.

Statistical analysis

All continuous data except hospital length of stay are described as mean±standard deviation, and categorical data are described as frequency and proportion. Length of hospital stay is shown as median and interquartile range. Continuous data were analyzed using the Student's t test, and categorical data were analysed using the chi-square test. The risk factors for in-hospital and 28-day mortality are presented as hazard ratios using a Cox proportional hazards model. A trend test was performed on the effect of age and nursing grade on in-hospital mortality. All statistical analyses were conducted using the SAS ver. 9.4 software (SAS Institute, Cary, NC, USA). Two-sided p values <0.05 were considered statistically significant.

RESULTS

Baseline characteristics

Among a total of 1498102 subjects who were admitted to the ICU during the study period, 861397 were male (57.5%) and 636705 were female (42.5%). The mean age at admission was 63.4±18.2 years (male, 61.3; female, 66.3), and most patients were aged above 60 years (male, 58.4%; female, 70.8%). Approximately 22.1% of the patients received mechanical ventilation and 4.1% required renal replacement therapy. Vasopressor and inotropic drugs were used in 15.0% of the patients. Forty percent of patients were admitted to the ICU of a tertiary hospital; only 48.9% of patients were treated in the ICU by an intensivist who dedicated much of their clinical practice to ICU work. Nursing grades were variable; nursing services grade 2 or higher were provided in 86.4% of hospitals, indicating that one nurse cared for more than 2.5 patients in 86.4% of the facilities. Other baseline characteristics of the study subjects are described in Table 1 and Supplementary Table 3 (only online).

Change in characteristics of patients admitted to the ICU, 2011–2015

From 2011 to 2015, the number of patients admitted to the ICU and the rate of admission among patients aged over 70 years gradually increased (Fig. 2, p for trend <0.001). During the 5-year period, the median length of hospital stay was 12 days, and the in-hospital mortality rate was 12.9% (Table 1 and Supplementary Table 3, only online). From 2011 to 2015, the mortality rate slightly decreased from 13.2% to 12.4% (Fig. 2, p for trend <0.001). The proportion of patients who were managed by intensivists also slightly decreased over these 5 years (Fig. 2, p for trend <0.001). However, the proportion of ICU wards offering grade 1 nursing services showed an increase from 13.1% to 13.8% (Supplementary Table 3, only online).

Risk factors for in-hospital and 28-day mortality of ICU patients

Table 2 shows the statistically significant risk factors for in-hospital and 28-day mortality rates of ICU patients using a Cox proportional hazards model that includes sex, age, CCI, income, mechanical ventilator, vasopressor, nursing grade hospitalization type, and the presence of intensivist. Both in-hospital and 28-day mortality rates were significantly higher in male patients and those of lower socioeconomic status. With increasing age and lower number of nursing staff, the mortality risk increased significantly by two or three times. Patients who received mechanical ventilator care, renal replacement therapy, or vasopressor and inotropic drugs showed higher mortality rates compared to those who did not. The mortality risk was lower in patients admitted to an ICU of a tertiary university hospital and an ICU where an intensivist worked.

In-hospital mortality according to age, nurse-to-patient ratio, presence of intensivist, and hospital type

We investigated the in-hospital mortality rate among all patients, as well as those using mechanical ventilation, those using vasopressor and inotropic drugs, and those receiving renal replacement therapy. Fig. 3 shows the results of our analysis. As age increased, in-hospital mortality increased in all groups including mechanical ventilation, vasopressor and inotropic drugs, and renal replacement (Fig. 3A, p for trend <0.001). In terms of nursing grade, all patients, those using mechanical ventilators, as well as those using vasopressor and inotropic drugs showed an increasing trend of in-hospital mortality according to increasing nursing grade (p for trend <0.001). Patients receiving renal replacement therapy showed high in-hospital mortality rates regardless of nursing grade (Fig. 3B). All groups managed by intensivists showed lower in-hospital mortality rates compared to those without intensivists (without vs. with, 18.3% vs. 15.0%, p<0.001). Moreover, in-hospital mortality rates were significantly lower with intensivists compared to without intensivists in the analysis of all patients, patients using mechanical ventilation, and patients using vasopressor and inotropic drugs (Fig. 3C, p<0.001). Furthermore, analysis by hospital type showed that a tertiary hospital had significantly lower in-hospital mortality rates in all patients, patients using vasopressor and inotropic drugs, patients using mechanical ventilators, and patients using renal replacement (Fig. 3D).

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Table 1. Characteristics of ICU Hospitalizations in South Korea, 2011–2015

Variable	Total	Male	Female	*p* value
Number of hospitalizations	1498102	861397	636705	
Number of patients	1150452	656409	494043	
Age (yr)	63.4±18.2	61.3±17.4	66.3±18.8	<0.001
Age group (yr)				<0.001
0–9	29770 (1.99)	16599 (1.93)	13171 (2.07)	
10–19	17780 (1.19)	10956 (1.27)	6824 (1.07)	
20–29	28268 (1.89)	16599 (1.93)	11669 (1.83)	
30–39	59472 (3.97)	35253 (4.09)	24219 (3.8)	
40–49	144893 (9.67)	97177 (11.28)	47716 (7.49	
50–59	264167(17.63)	181836 (21.11)	82331 (12.93)	
60–69	296215 (19.77)	190583 (22.12)	105632 (16.59)	
70–79	394902 (26.36)	210365 (24.42)	184537 (28.98)	
80–89	227610 (15.19)	91649 (10.64)	135961 (21.35)	
≥90	35025 (2.34)	10380 (1.21)	24645 (3.87)	
<18	42389 (2.83)	24251 (2.82)	18138 (2.85)	0.223
≥18	1455713 (97.17)	837146 (97.18)	618567 (97.15)	
Comorbidity				
Myocardial infarction	253652 (16.93)	159388 (18.5)	94264 (14.8)	<0.001
Congestive heart failure	536474 (35.81)	287776 (33.41)	248698 (39.06)	<0.001
Peripheral vascular disease	520002 (34.71)	283563 (32.92)	236439 (37.13)	<0.001
Cerebrovascular disease	754821 (50.39)	407627 (47.32)	347194 (54.53)	<0.001
Dementia	404308 (26.99)	187530 (21.77)	216778 (34.05)	<0.001
Chronic pulmonary disease	1077478 (71.92)	602356 (69.93)	475122 (74.62)	<0.001
Connective tissue disease	198078 (13.22)	89561 (10.4)	108517 (17.04)	<0.001
Peptic ulcer disease	929906 (62.07)	525346 (60.99)	404560 (63.54)	<0.001
Liver disease	955098 (63.75)	564587 (65.54)	390511 (61.33)	<0.001
Diabetes mellitus	986796 (65.87)	568550 (66)	418246 (65.69)	<0.001
Renal disease	389749 (26.02)	222923 (25.88)	166826 (26.2)	<0.001
Hemiplegia	258928 (17.28)	146448 (17)	112480 (17.67)	<0.001
Tumor	204757 (13.67)	120497(13.99)	84260 (13.23)	<0.001
Leukaemia	491896 (32.83)	314903 (36.56)	176993 (27.8)	<0.001
Lymphoma	96019 (6.41)	68227 (7.92)	27792 (4.36)	<0.001
Metastatic solid tumor	139497 (9.31)	87247 (10.13)	52250 (8.21)	<0.001
AIDS	2967 (0.2)	2003 (0.23)	964 (0.15)	<0.001
CCI	6.98±3.84	7±3.96	6.95±3.68	<0.001
Income				<0.001
Medicaid	202559 (13.52)	107239 (12.45)	95320 (14.97)	
Quintile 1 (lowest)	210809 (14.07)	115876 (13.45)	94933 (14.91)	
Quintile 2	189078 (12.62)	116467 (13.52)	72611 (11.4)	
Quintile 3	222309 (14.84)	133552 (15.5)	88757 (13.94)	
Quintile 4	268035 (17.89)	159092 (18.47)	108943 (17.11)	
Quintile 5 (highest)	405312 (27.06)	229171 (26.6)	176141 (27.66)	
Mechanical ventilation	331328 (22.12)	200815 (23.31)	130513 (20.5)	<0.001
Renal replacement	61471 (4.1)	37584 (4.36)	23887 (3.75)	<0.001
Vasopressor and inotropic drugs	225208 (15.03)	130157 (15.11)	95051 (14.93)	0.002

Table 1. Characteristics of ICU Hospitalizations in South Korea, 2011–2015 (continued)

Variable	Total	Male	Female	*p* value
Nursing grade				<0.001
Grade 1*	203635 (13.59)	119217 (13.84)	84418 (13.26)	
Grade 2	338125 (22.57)	197944 (22.98)	140181 (22.02)	
Grade 3	411535 (27.47)	239300 (27.78)	172235 (27.05)	
Grade 4	137967 (9.21)	80307 (9.32)	57660 (9.06)	
Grade 5	75653 (5.05)	42448 (4.93)	33205 (5.22)	
Grade 6	145941 (9.74)	79447 (9.22)	66494 (10.44)	
Grade 7	90598 (6.05)	49145 (5.71)	41453 (6.51)	
Grade 8	47449 (3.17)	28071 (3.26)	19378 (3.04)	
Grade 9†	47120 (3.15)	25470 (2.96)	21650 (3.4)	
Hospitalization type				<0.001
Tertiary	599858 (40.04)	354119 (41.11)	245739 (38.6)	
General	856443 (57.17)	484880 (56.29)	371563 (58.36)	
Other	41722 (2.79)	22350 (2.59)	19372 (3.04)	
Intensivists	732931 (48.92)	428729 (49.77)	304202 (47.78)	<0.001
Length of hospital stay, days, median (IQR)	12 (6–21)	12 (6–21)	12 (6–22)	<0.001
In-hospital mortality	193118 (12.89)	113104 (13.13)	80014 (12.57)	<0.001
28-day mortality	209216 (13.97)	121989 (14.16)	87227 (13.7)	<0.001

ICU, intensive care unit; AIDS, acquired immunodeficiency syndrome; CCI, Charlson Comorbidity Index; IQR, interquartile range.
Data are presented as mean±standard deviation or n (%).
*Nursing grade 1=total nursing staff-to-total ICU beds >2, †Nursing grade 9=total nursing staff-to-total ICU beds ≤0.5.

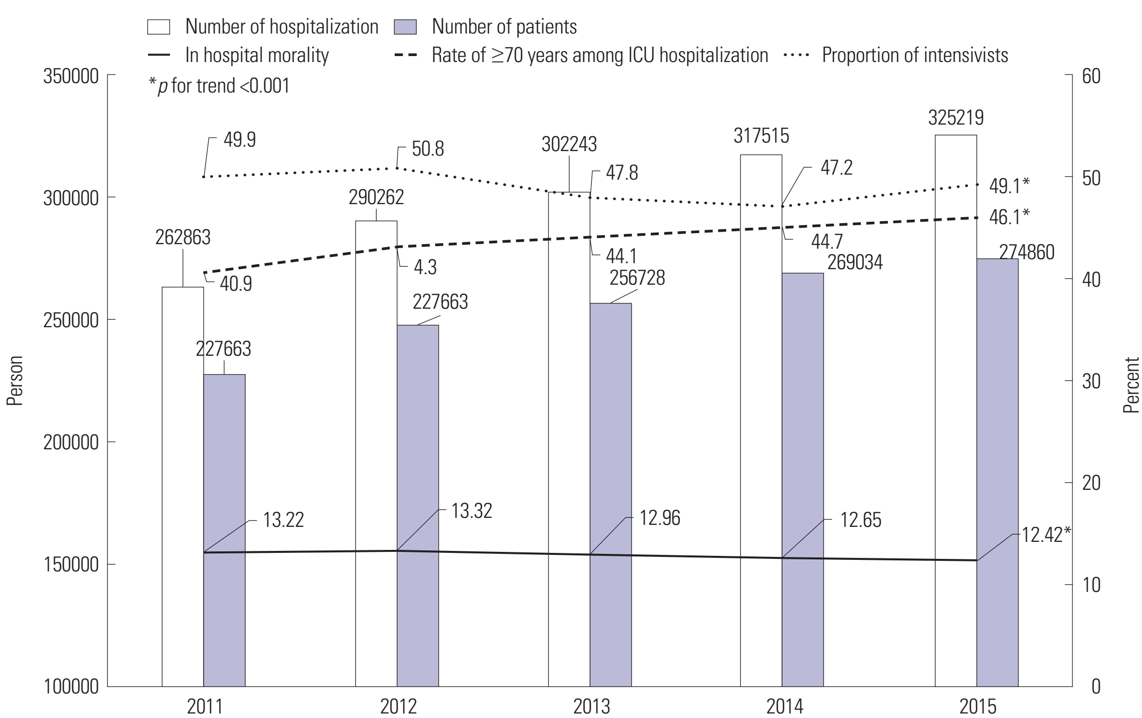

Fig. 2. Change in number and mortality rate of patients admitted to the ICU, 2011–2015. ICU, intensive care unit.

DISCUSSION

In this study, we investigated the changes of in-hospital mortality rates and risk factors related to mortality in ICUs of South Korea. The in-hospital mortality rates of patients admitted to all ICU types over the 5-year study period was 12.9%, while the mortality rate slightly decreased from 13.2% to 12.4% from 2011 to 2015. Male sex, older age, lower socioeconomic status, need

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for mechanical ventilation, need for vasopressor and inotropic drugs, need for renal replacement therapy, ICU treatment without an intensivist, and ICU treatment with lower nursing staff numbers were identified as risk factors associated with in-hospital mortality.

Table 2. Risk Factors for in-Hospital and 28-Day Mortality

	In-hospital mortality HR (95% CI)	28-day mortality HR (95% CI)
Sex		
Male	1	1
Female	0.89 (0.884–0.9)	0.88 (0.867–0.883)
Age group (yr)		
0–9	1.00	1.00
10–19	1.20 (1.111–1.303)	1.49 (1.369–1.615)
20–29	1.14 (1.067–1.227)	1.49 (1.388–1.601)
30–39	1.36 (1.281–1.442)	1.86 (1.75–1.979)
40–49	1.69 (1.602–1.784)	2.45 (2.311–2.587)
50–59	1.95 (1.846–2.05)	2.78 (2.635–2.943)
60–69	2.26 (2.144–2.38)	3.25 (3.08–3.439)
70–79	3.02 (2.868–3.183)	4.69 (4.436–4.951)
80–89	4.21 (3.992–4.432)	6.86 (6.492–7.248)
≥90	5.70 (5.394–6.024)	9.79 (9.245–10.37)
CCI	0.98 (0.979–0.981)	0.98 (0.974–0.976)
Income		
Medicaid	1.00	1.00
Quintile 1 (lowest)	0.88 (0.866–0.895)	0.90 (0.887–0.916)
Quintile 2	0.90 (0.882–0.913)	0.91 (0.891–0.921)
Quintile 3	0.89 (0.877–0.907)	0.90 (0.882–0.911)
Quintile 4	0.89 (0.879–0.908)	0.89 (0.872–0.899)
Quintile 5 (highest)	0.88 (0.862–0.888)	0.85 (0.838–0.862)
Mechanical ventilation	4.94 (4.886–4.989)	6.28 (6.215–6.341)
Renal replacement	2.87 (2.829–2.904)	3.12 (3.075–3.161)
Vasopressor and inotropic drugs	2.28 (2.256–2.302)	2.35 (2.323–2.37)
Nursing grade		
Grade 1*	1.00	1.00
Grade 2	1.57 (1.535–1.597)	1.65 (1.619–1.683)
Grade 3	1.76 (1.729–1.798)	1.82 (1.787–1.857)
Grade 4	1.89 (1.848–1.939)	1.98 (1.932–2.025)
Grade 5	2.33 (2.271–2.399)	2.38 (2.321–2.448)
Grade 6	2.62 (2.552–2.68)	2.68 (2.62–2.748)
Grade 7	2.76 (2.693–2.836)	2.81 (2.739–2.882)
Grade 8	2.56 (2.484–2.643)	2.62 (2.544–2.701)
Grade 9†	2.86 (2.778–2.952)	2.80 (2.717–2.882)
Hospitalization type		
Tertiary	1	1
General	1.06 (1.05–1.077)	1.05 (1.039–1.065)
Other type	1.60 (1.562–1.646)	1.61 (1.568–1.648)
Intensivist	0.91 (0.901–0.921)	0.90 (0.893–0.912)
Length of hospital stay, days	0.41 (0.408–0.412)	0.90 (0.898–0.9)

HR, hazard ratio; CI, confidence interval; CCI, Charlson Comorbidity Index; ICU, intensive care unit.
*Nursing grade 1=total nursing staff-to-total ICU beds >2, †Nursing grade 9=total nursing staff-to-total ICU beds ≤0.5.

As reported in several previous studies, the need for mechanical ventilation, vasopressor and inotropic drugs, and renal replacement treatment were shown to be risk factors of ICU mortality in our study.[10-12] These factors by themselves indicated that patients had multiple organ dysfunction, unstable vital signs, and high risk of mortality. Unfortunately, this study did not have data about the admission cause and management methods for individual patients. Therefore, we focused on the preventable and changeable factors. In our study, nursing grade (total ICU bed numbers/total nursing staff) and presence of intensivists were identified as changeable factors.

Many studies have reported that lower number of nursing staffs was associated with higher in-hospital mortality rate.[13,14,21] Our study showed a similar trend in that the mortality risk increased with fewer nursing staffs. Previous studies reported an optimal nurse-to-ICU patient ratio.[13,14,21] Although some differences exist, the American Nurse Association and British Association of Critical Care Nurses recommend a ratio of 1:2 or less.[22,23] Another study reported that a nurse-to-patient ratio exceeding 1:1.5 was associated with a lower in-hospital mortality rate than that with a 1:2 ratio.[13] The authors of the previous study assumed that working nurses with limited resources and time constraints were associated with a decreased nurse-to-patient ratio, which may increase the likelihood of mistakes by creating a stressful environment with distractions and interruptions that adversely affect quality of care.[13] A recent study of cohort data reported that even 1 day of high staffing ratio is associated with increased mortality rates of critically ill patients.[24] In this study, nursing grade 1 was defined as a nurse-to-patient ratio of less than 1:2.5; and it is a sad reality that nursing grade 1 accounted for 13.6% of total ICU hospitalizations in South Korea. However, this means that if the nurse-to-patient ratio increases, the ICU mortality rate can be decreased. Actually, in this study, the proportion of nursing grades 1 and 2 increased from 29.5% to 43.8% from 2011 to 2015, and mortality decreased accordingly (Supplementary Table 3, only online).

The second related factor was the presence of intensivists in the ICU. Several studies have recommended the involvement of intensivists, since the majority of ICU patients tend to have multiple problems that require complex management.[15,25-27] A large meta-analytic study reported that the presence of an intensivist could reduce the in-hospital mortality risk to 0.83.[15] Our study also showed that the presence of an intensivist could significantly lower the in-hospital mortality risk to 0.91. In particular, patients treated with mechanical ventilation or vasopressor and inotropic drugs showed decreased mortality rates. This result may have been influenced by the fact that the use of mechanical ventilator, vasopressor, and inotropic drugs are adjusted in real-time according to a patient’s condition, and that the presence of an intensivist might satisfy this need. In the case of renal replacement therapy, it is supposed that the

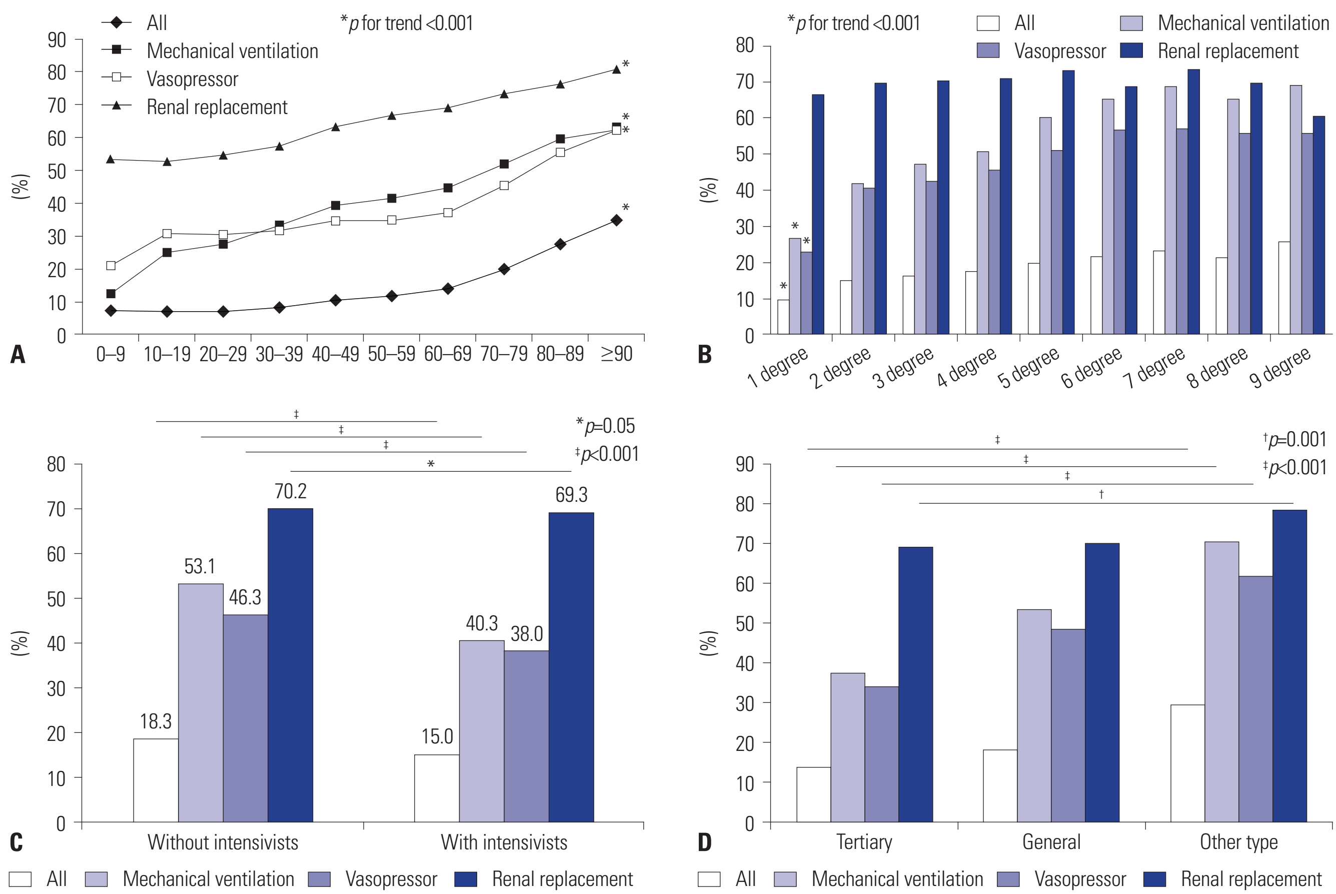

Fig. 3. In-hospital mortality by (A) age, (B) nurse-to-patient ratio, (C) presence of intensivist, and (D) hospital type.

patient already had multiple organ failures and high severity; therefore, we could assume that the intensivist was less effective due to the patient's high severity condition. Since less than 50% of the patients in our study received management by intensivists, increasing the proportion of intensivists in ICU settings would decrease the in-hospital mortality rate. It should also be noted that, in South Korea, the definition of intensivist is one daytime worker per 30 ICU beds. In a previous statement from the Society of Critical Care Medicine (SCCM) taskforce, the intensivist-to-patient ratio in a closed ICU was discussed; however, the optimal ratio was not determined, due to too many variables.[28] The SCCM advertised that an academic medical ICU with a ratio less favourable than 1:14 negatively affected education, staff's well-being, and patient care.[28] In a recent study in the United Kingdom, the optimal intensivist-to-patient ratio was 1:7.5, while the mortality rate increased when the intensivist-to-patient ratio decreased to less than 1:7.5.[29] Although it is difficult to generalize the current ICU findings to other countries, this study showed that an optimal patient-to- intensivist ratio was associated with decreased in-hospital and ICU mortality rates.[29,30] Therefore, in addition to the presence of intensivists, achieving the optimal intensivist-to-patient ratio will decrease the in-hospital mortality rate.

Our study's main strength is that it is the first to investigate the factors associated with in-hospital mortality, including nursing grade and the presence of intensivist, among ICU patients using large cohort data in South Korea. This study may have important implications for critical care management in South Korea and other countries with similar medical environments. Nevertheless, our study also had some limitations. First, it used a homogeneous Asian cohort; therefore, our findings may not be generalizable. The reproducibility and applicability should be tested in future studies with other cohorts. Second, since our cohort data consisted of claims data for a single-insurer system, we could not adjust for severity using ICU mortality scores, such as the Acute Physiology and Chronic Health Evaluation score or the Sequential Organ Failure Assessment score. These factors might have affected the multivariate analysis. Third, the facilities included in this study did not reflect the characteristics of specialized ICU settings such as medical, coronary, surgery, neurosurgery, and emergency, as they were not distinguished. Finally, the risk factor analysis associated with individual patients did not include the data regarding the cause of admission, rate of hospital visitation, or management method of individual patients. For example, the patient's income level might be associated with mortality due to the rate of hospital visitation and prevalence of comorbidities; however this was difficult to prove due to the limitations of data. Therefore, prospec-

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tive multicenter cohort studies involving various patient data should be performed.

In conclusion, the number of nursing staffs and the presence of an intensivist at ICU were associated with the ICU mortality rate. Therefore, optimal nurse-to-patient ratio, intensivist presence, and optimal intensivist-to-patient ratio would reduce the mortality rate among ICU patients.

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REFERENCES

1. World Health Organization. Global Health and Aging. NIH Publication no 11-7737; 2011 [Internet]. Geneva: World Health Organization [accessed on 2018 Agust 1]. Available at: https://www.who.int/ageing/publications/global_health/en.
2. Gill TM, Allore HG, Holford TR, Guo Z. Hospitalization, restricted activity, and the development of disability among older persons. JAMA 2004;292:2115-24.
3. Dwyer R, Stoelwinder J, Gabbe B, Lowthian J. Unplanned transfer to emergency departments for frail elderly residents of aged care facilities: a review of patient and organizational factors. J Am Med Dir Assoc 2015;16:551-62.
4. Sprung CL, Artigas A, Kesecioglu J, Pezzi A, Wiis J, Pirracchio R, et al. The Eldicus prospective, observational study of triage decision making in European intensive care units. Part II: intensive care benefit for the elderly. Crit Care Med 2012;40:132-8.
5. Bagshaw SM, Webb SA, Delaney A, George C, Pilcher D, Hart GK, et al. Very old patients admitted to intensive care in Australia and New Zealand: a multi-centre cohort analysis. Crit Care 2009;13:R45.
6. Halpern NA, Pastores SM. Critical care medicine in the United States 2000-2005: an analysis of bed numbers, occupancy rates, payer mix, and costs. Crit Care Med 2010;38:65-71.
7. Curtis JR, Engelberg RA, Bensink ME, Ramsey SD. End-of-life care in the intensive care unit: can we simultaneously increase quality and reduce costs? Am J Respir Crit Care Med 2012;186:587-92.
8. Lerolle N, Trinquart L, Bornstain C, Tadié JM, Imbert A, Diehl JL, et al. Increased intensity of treatment and decreased mortality in elderly patients in an intensive care unit over a decade. Crit Care Med 2010;38:59-64.
9. Kramer AA, Dasta JF, Kane-Gill SL. The impact of mortality on total costs within the ICU. Crit Care Med 2017;45:1457-63.
10. Chen YC, Lin SF, Liu CJ, Jiang DD, Yang PC, Chang SC. Risk factors for ICU mortality in critically ill patients. J Formos Med Assoc 2001;100:656-61.
11. Bickenbach J, Fries M, Rex S, Stitz C, Heussen N, Rossaint R, et al. Outcome and mortality risk factors in long-term treated ICU patients: a retrospective analysis. Minerva Anestesiol 2011;77:427-38.
12. Mukhopadhyay A, Tai BC, See KC, Ng WY, Lim TK, Onsiong S, et al. Risk factors for hospital and long-term mortality of critically ill elderly patients admitted to an intensive care unit. Biomed Res Int 2014;2014:960575.
13. Sakr Y, Moreira CL, Rhodes A, Ferguson ND, Kleinpell R, Pickkers P, et al. The impact of hospital and ICU organizational factors on outcome in critically ill patients: results from the Extended Prevalence of Infection in Intensive Care study. Crit Care Med 2015;43:519-26.
14. Vincent JL, Rello J, Marshall J, Silva E, Anzueto A, Martin CD, et al. International study of the prevalence and outcomes of infection in intensive care units. JAMA 2009;302:2323-9.
15. Wilcox ME, Chong CA, Niven DJ, Rubenfeld GD, Rowan KM, Wunsch H, et al. Do intensivist staffing patterns influence hospital mortality following ICU admission? A systematic review and meta-analyses. Crit Care Med 2013;41:2253-74.
16. Kim JH, Hong SK, Kim KC, Lee MG, Lee KM, Jung SS, et al. Influence of full-time intensivist and the nurse-to-patient ratio on the implementation of severe sepsis bundles in Korean intensive care units. J Crit Care 2012;27:414.e11-21.
17. Park J, Jeon K, Chung CR, Yang JH, Cho YH, Cho J, et al. A nationwide analysis of intensive care unit admissions, 2009-2014 - The Korean ICU National Data (KIND) study. J Crit Care 2018;44:24-30.
18. Seong SC, Kim YY, Park SK, Khang YH, Kim HC, Park JH, et al. Cohort profile: the National Health Insurance Service-National Health Screening Cohort (NHIS-HEALS) in Korea. BMJ Open 2017;7:e016640.
19. Sundararajan V, Henderson T, Perry C, Muggivan A, Quan H, Ghali WA. New ICD-10 version of the Charlson comorbidity index predicted in-hospital mortality. J Clin Epidemiol 2004;57:1288-94.
20. World Health Organization. The anatomical therapeutic chemical classification system with defined daily doses (ATC/DDD) (2004) [Internet]. Geneva: World Health Organization [accessed on 2020 July 1]. Available at: https://www.who.int/classifications/atcddd/en.
21. Penoyer DA. Nurse staffing and patient outcomes in critical care: a concise review. Crit Care Med 2010;38:1521-8.
22. McMenamin P, Peterson C, McHugh MD, Sochalski J. Optimal Nurse Staffing to Improve Quality of Care and Patient Outcomes: Executive Summary. American Nurses Association, Avalere Health LLC, 2015.
23. Bray K, Wren I, Baldwin A, St Ledger U, Gibson V, Goodman S, et

al. Standards for nurse staffing in critical care units determined by: The British Association of Critical Care Nurses, The Critical Care Networks National Nurse Leads, Royal College of Nursing Critical Care and In-flight Forum. Nurs Crit Care 2010;15:109-11.
24. Lee A, Cheung YSL, Joynt GM, Leung CCH, Wong WT, Gomersall CD. Are high nurse workload/staffing ratios associated with decreased survival in critically ill patients? A cohort study. Ann Intensive Care 2017;7:46.
25. Costa DK, Wallace DJ, Kahn JM. The association between daytime intensivist physician staffing and mortality in the context of other ICU organizational practices: a multicenter cohort study. Crit Care Med 2015;43:2275-82.
26. Angus DC, Shorr AF, White A, Dremsizov TT, Schmitz RJ, Kelley MA, et al. Critical care delivery in the United States: distribution of services and compliance with Leapfrog recommendations. Crit Care Med 2006;34:1016-24.
27. Lilly CM, Zuckerman IH, Badawi O, Riker RR. Benchmark data from more than 240,000 adults that reflect the current practice of critical care in the United States. Chest 2011;140:1232-42.
28. Ward NS, Afessa B, Kleinpell R, Tisherman S, Ries M, Howell M, et al. Intensivist/patient ratios in closed ICUs: a statement from the Society of Critical Care Medicine Taskforce on ICU Staffing. Crit Care Med 2013;41:638-45.
29. Gershengorn HB, Harrison DA, Garland A, Wilcox ME, Rowan KM, Wunsch H. Association of intensive care unit patient-to-intensivist ratios with hospital mortality. JAMA Intern Med 2017;177:388-96.
30. Viglianti EM, Iwashyna TJ. Toward the ideal ratio of patients to intensivists: finding a reasonable balance. JAMA Intern Med 2017;177:396-8.

https://doi.org/10.3349/ymj.2021.62.1.50