



## Original Article

# Admission to surgical intensive care unit in time with intensivist coverage and its association with postoperative 30-day mortality: The role of intensivists in a surgical intensive care unit



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## ABSTRACT

**Background:** This study aimed to investigate the association between postoperative surgical Intensive Care Unit (ICU) admission during a time when there was intensivist coverage and 30-day mortality after ICU admission.

**Methods:** This was a retrospective observational study in a tertiary care academic hospital ICU, with daytime intensivist coverage. We collected the electronic medical records for all patients who were admitted to the postoperative ICU after undergoing a surgery between January 1, 2007 and December 31, 2016. The primary outcome was to examine the differences in 30-day mortality after ICU admission according to ICU admission during times of intensivist or non-intensivist coverage.

**Results:** Overall, 13,906 patients were included (6634 [47.7%] patients were admitted with intensivist coverage, and 7272 [52.3%] patients without intensivist coverage). After performing propensity Score matching, 10,708 patients (5354 patients in each group) were analysed. In the matched cohorts, 30-day mortality after postoperative ICU admission in the group without intensivist coverage was higher than that with intensivist coverage [30-day mortality, 251/5354 (4.7%) and 173/5354 (3.2%) in the groups without and with intensivist coverage, respectively,  $P < 0.001$ ]. Post-operative ICU admission in the group without intensivist coverage was associated with an increased risk of 30-day mortality (risk ratio: 1.45, 95% confidence interval: 1.20–1.75,  $P < 0.001$ ).

**Conclusion:** This study showed an increase in post-operative 30-day mortality, and length of hospital and ICU stay for surgical ICU admission among those without intensivist coverage.

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## 1. Introduction

The intensive care unit (ICU) is a department within hospitals where the most critical patients are monitored and treated continually 24 hours per day, 365 days per year [1]. For this reason, it is important to maintain sufficient physician staffing and workload in the ICU at all times, in order to reduce the risk of ICU-related mortality [2]. However, differences in the medical environment and available resources have led to the development of various ICU staffing models [3]. Therefore, for efficient ICU

management, the allocation of healthcare staff resources needs to be adapted to the unique circumstances in each hospital [4,5].

The surgical ICU is where most patients are admitted after surgery; it differs from the medical ICU, as it involves intensive treatment and monitoring after surgery [6]. In particular, because systemic inflammatory response syndrome and sepsis often occur in patients post-operatively [7], proper care in the ICU is very important. The time of ICU admission is important to consider in the care of post-operative patients in the surgical ICU. The relationship between patient mortality and weekend and night-time admission to the ICU has been at the forefront of many studies to date [8,9]. This is because patients with severe morbidity are more likely to be admitted during the night-time or on weekends, when the ICU staffing is downscaled compared to office hours

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[1,8,9]. Studies have also investigated this relationship for patients with post-operative ICU admission to the surgical ICU; one retrospective study found that after-hours (18:00–05:59) ICU admission was associated with increased mortality, particularly among elective surgical patients [10]. However, the previous study did not consider the staffing model in the surgical ICU; a lack of intensivist coverage during the night-time, legal holidays, and the weekends might be the cause of increased mortality in the surgical ICU. Therefore, the association between surgical ICU admission times during which there was intensivist coverage after surgery and mortality should be investigated.

This study aimed to examine the association between post-operative 30-day mortality, and post-operative surgical ICU admission time during which there was intensivist coverage. We hypothesised that surgical ICU admission when there was intensivist coverage was associated with decreased mortality after ICU admission.

## 2. Material and methods

This was a retrospective observational study conducted with the approval of an Institutional Review Board (IRB approval number: B-1703/388-105). Informed consent was waived, as this was a retrospective review of patient medical records.

We collected the electronic medical records for all patients who were admitted to the post-operative ICU after undergoing a surgery between January 1, 2007 and December 31, 2016. If one patient was admitted to the surgical ICU more than twice during the study period, only the final post-operative ICU admission was considered. We excluded all cases of post-operative neonatal ICU admission and any cases with incomplete medical records. The institution where the study was conducted, is a tertiary care hospital with 1,360 beds, conducting an average of 150 surgeries per day across 38 operating theatres. There are 4 ICUs (Surgical ICU, Emergency ICU, Neurologic ICU and Medical ICU), and they are located on the same floor close to the operating theatres.

### 2.1. Staffing pattern in the ICUs

The majority of post-operative ICU admissions at the hospital were to the Surgical ICU (15 beds), the Emergency ICU (14 beds), and the Neurologic ICU (13 beds). These three ICUs are each staffed by three daytime attending intensivists [11] (an anaesthesiologist, a neuro-intensivist, and a thoracic surgeon) between 08:00 and 18:00, Monday to Friday, except for legal holidays. An attending intensivist receives in-house calls after 18:00 and on the weekends. Additionally, the residents from each surgical department work alongside the intensivists for post-operative patient care in the ICU. There is generally one nurse for every two patients. After 18:00, Duty Residents from each surgical department are in charge of care in each ICU, and the number and experience levels of the nurses is no different than those on duty from 08:00–18:00.

### 2.2. Measurements and outcomes

We collected the following patient data for analysis: sex, age, emergency surgery status, Body Mass Index (BMI,  $\text{kg m}^{-2}$ ), acute physiology and chronic health evaluation (APACHE) II Scores, surgical time (hours), readmission to the ICU due to aggravation in the ward after discharge from the ICU during hospitalisation, date of post-operative ICU admission, time of ICU admission, day of the week of ICU admission, hospital length of stay (days), American Society of Anesthesiologists (ASA) class, surgery type (Cardiothoracic surgery/ General surgery/ Neurosurgery/ Others), and date

of death. Accurate dates of death were collected with approval from the Ministry of Interior and Safety of South Korea.

Post-operative ICU admissions were categorised as follows

- with intensivist coverage (08:00–17:59 Monday to Friday, with the exception of legal holidays) and;
- without intensivist coverage (18:00–07:59, Monday to Friday, and 00:00–24:00 Saturdays, Sundays, and legal holidays).

The primary outcome of this study was to examine the differences in 30-day mortality after ICU admission stratified by the ICU admission with or without intensivist coverage. Secondary outcomes were to examine the differences in length of hospital and ICU stay based on ICU admission with or without intensivist coverage. The outcomes (mortality rate, and length of hospital and ICU stay) are the most commonly used to assess quality performance in ICU [12].

### 2.3. Statistical analysis

The baseline characteristics were expressed as frequencies and proportions for categorical data and means and standard deviations for continuous data. *T*-tests for continuous variables and Chi-square tests for categorical variables were used to compare covariates between the two groups (post-operative ICU admission with and without intensivist coverage). Then, we used Propensity Score (PS) matching methods to balance the covariates between the two groups [13]. We conducted 1-to-1 PS matching using a logistic regression and a calliper width of 0.1 was used to account for covariates potentially associated with treatment selection: age, sex, BMI, APACHE II, ASA classification, cancer diagnosis, occurrence of emergency operations, ICU readmission, surgery time, and type of surgery before ICU admission. A Standardised Mean Difference (SMD)  $< 0.1$  between the two groups was used as criterion for PS matching [14], and the variance estimator proposed by Abadie and Imbens was used [15].

After confirming that all covariates between the two groups were well balanced with the criterion of SMD  $< 0.1$ , Chi-square tests were used to compare 30-day mortality after post-operative ICU admissions. Additionally, Mann Whitney tests were used to compare the length of hospital and ICU stay after post-operative ICU admissions. Lastly, risk ratios for 30-day mortality were calculated after PS matching, and sensitivity analysis for the risk ratios was performed to determine the effect of non-intensivist coverage on ICU admission time. Statistical analyses were performed using IBM SPSS Version 23.0 (IBM Corp., Armonk, NY, USA), and statistical significance was set at  $P < 0.05$ .

## 3. Results

From January 1, 2007 to December 31, 2016, there were 19,363 cases admitted to the ICU. Of these, 4510 post-operative ICU admissions were excluded as they involved multiple admissions of one patient and 947 cases were excluded due to incomplete medical records. The remaining 13,906 patients with post-operative ICU admission were included in the final analysis. The overall post-operative ICU admissions were divided in two groups: post-operative admissions with intensivist coverage (6634 patients, 47.7%), and without intensivist coverage (7272 patients, 52.3%). After performing PS matching, there were 5354 patients in each of the post-operative admission groups (Fig. 1). All covariates were well balanced between the two groups (SMD  $< 0.1$ ). Table 1 shows the differences in covariates between post-operative ICU admission with and without intensivist coverage, before and after PS matching.

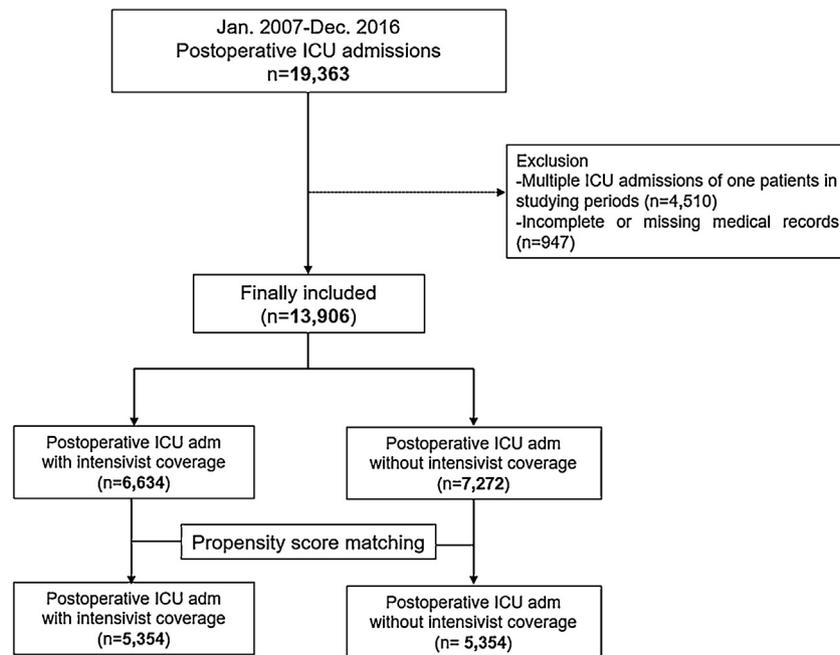


Fig. 1. Flow chart for patient selection.

Table 1

Comparison between surgical ICU admission time under intensivist coverage and non-intensivist coverage before and after propensity Score matching.

Variables	Unmatched cohort (n = 13,906)				Matched cohort (n = 10,708)			
	Non-intensivist coverage n = 7272		Intensivist coverage n = 6634		Non-intensivist coverage n = 5354		Intensivist coverage n = 5354	
			SMD	P			SMD	P
Age, year	58.2 (20.1)	57.3 (21.1)	0.044	0.009	59.4 (19.8)	58.9 (18.6)	0.025	0.192
Sex: Male	4,086 (56.2%)	3,688 (55.6%)	0.012	0.480	3,021 (56.4%)	2,998 (56.0%)	0.009	0.654
BMI, kg m <sup>-2</sup>	23.3 (3.9)	23.4 (4.1)	0.013	0.443	23.4 (4.1)	23.4 (4.0)	0.006	0.768
APACHE II	24.1 (7.3)	21.7 (7.8)	0.313	< 0.001	23.0 (7.3)	23.0 (7.4)	0.009	0.647
ASA classification			0.106	< 0.001			0.009	0.899
1	1220 (16.8%)	1030 (15.5%)			838 (15.7%)	847 (15.8%)		
2	2986 (41.1%)	3070 (46.3%)			2370 (44.3%)	2384 (44.5%)		
≥ 3	3066 (42.2%)	234 (38.2%)			2146 (40.1%)	2123 (39.7%)		
Diagnosis of cancer	2191 (30.1%)	2008 (30.3%)	0.003	0.858	1623 (30.3%)	1620 (30.3%)	0.001	0.950
Emergency operation	835 (11.5%)	269 (4.1%)	0.280	< 0.001	257 (4.8%)	274 (5.1%)	0.015	0.449
ICU readmission <sup>a</sup>	1,288 (17.7%)	1,004 (15.1%)	0.07	< 0.001	884 (16.5%)	856 (16.0%)	0.014	0.463
Surgery time, hours	3.6 (2.5)	3.8 (2.6)	0.013	0.443	3.7 (2.6)	3.7 (2.5)	0.006	0.768
Surgery before ICU admission			0.234	< 0.001			0.046	0.123
Cardiothoracic surgery	2018 (27.8%)	2374 (35.8%)			1827 (34.1%)	1,729 (32.3%)		
General surgery	1682 (23.1%)	1215 (18.3%)			1088 (20.3%)	1,097 (20.5%)		
Neurosurgery	1614 (22.2%)	1691 (25.5%)			1257 (23.5%)	1,346 (25.1%)		
Others	1958 (26.9%)	1354 (20.4%)			1182 (22.1%)	1,182 (22.1%)		

Presented as mean (SD) or number (percentage).

Intensivist coverage time in surgical ICU: 08:00–18:00 on Weekday (Mon–Friday) except legal holiday.

Propensity matching was performed to balance between the two groups with criterion of SMD < 0.1.

ICU: intensive care unit; SMD: standardized mean difference; APACHE: acute physiology and chronic health evaluation; ASA: American society of anesthesiologists; SMD: standardized mean difference.

<sup>a</sup> ICU readmission refers to cases that had a repeated ICU admission due to aggravation in the ward after discharge from the ICU during the same hospitalisation period.

### 3.1. 30-day mortality and length of hospital and ICU stay after post-operative ICU admission

Table 2 shows the results regarding 30-day mortality after post-operative ICU admissions, before and after PS matching. In the matched cohorts, 30-day mortality after post-operative ICU admission in the group without intensivist coverage was higher than that with intensivist coverage [30-day mortality, 251/5354 (4.7%) and 173/5354 (3.2%) in the groups without and with intensivist coverage, respectively,  $P < 0.001$ ]. Post-operative ICU

admission in the group without intensivist coverage was associated with an increased risk of 30-day mortality (risk ratio: 1.45, 95% confidence interval: 1.20–1.75,  $P < 0.001$ ). (Table 3)

### 3.2. Length of hospital and ICU stay after post-operative ICU admission

In the matched cohort (Table 2), the length of hospital stay (days) after ICU admissions was longer for the group without intensivist coverage (median [interquartile range, IQR], 24.0 [17.0–47.0]) than

**Table 2**  
30-day mortality and length of hospital stay after surgical ICU admission.

Variables		Non-intensivist coverage	Intensivist coverage	P-value
30-day mortality	Before PS matching	363/7272 (5.0%)	215/6634 (3.2%)	< 0.001
	After PS matching	251/5354 (4.7%)	173/5354 (3.2%)	< 0.001
Length of hospital stay, day <sup>a</sup>	Before PS matching	24.0 [17.0–61.0]	23.0 [20.0–43.0]	< 0.001
	After PS matching	24.0 [17.0–47.0]	22.0 [18.0–44.0]	< 0.001
Length of ICU stay, day <sup>a</sup>	Before PS matching	16.0 [11.0–31.0]	14.0 [10.0–23.0]	< 0.001
	After PS matching	16.0 [10.0–28.0]	14.0 [10.0–23.0]	< 0.001

Intensivist coverage time in surgical ICU: 08:00–18:00 on Weekday (Mon–Friday) except legal holiday.

ICU: intensive care unit.

<sup>a</sup> Median [IQR], Mann Whitney test were used.

**Table 3**  
Risk ratio for 30-day after surgical ICU admission after propensity Score matching.

Variables	30-day mortality Risk ratio	95% CI		P-value
		lower	upper	
Intensivist coverage	1 (ref)			
Non-intensivist coverage	1.45	1.20	1.75	< 0.001
Sensitivity analysis				
Intensivist coverage	1 (ref)			
Non-intensivist coverage				
ICU admission in holiday	3.15	2.37	4.19	< 0.001
ICU admission in 18:00–19:59	1.15	0.87	1.51	0.327
ICU admission in 20:00–21:59	1.08	0.761	1.53	0.672
ICU admission in 22:00–23:59	1.30	0.848	1.99	0.230
ICU admission in 00:00–01:59	0.61	0.383	0.957	0.029
ICU admission in 02:00–03:59	4.34	2.91	6.47	< 0.001
ICU admission in 04:00–05:59	3.47	2.00	6.03	< 0.001
ICU admission in 06:00–07:59	3.87	1.99	7.51	< 0.001

Intensivist coverage time in surgical ICU: 08:00–18:00 on Weekday (Mon–Friday) except legal holiday.

ICU: intensive care unit; CI: confidence interval.

the group with intensivist coverage (median [IQR], 22.0 [18.0–44.0]) after post-operative admission ( $P < 0.001$ ). The length of ICU stay (days) after ICU admissions was also longer for the group without intensivist coverage (median [IQR], 16.0 [10.0–28.0]) than the group with intensivist coverage (median [IQR], 14.0 [10.0–23.0]) after post-operative admission ( $P < 0.001$ ).

#### 4. Discussion

This study shows that there is a significant association between intensivist coverage for post-operative surgical ICU admission and 30-day mortality as well as the length of hospital and ICU stay. We used PS matching methods to balance the different characteristics of patients who were admitted to the surgical ICU based on intensivist coverage. These findings are significant as they represent a cohort with 10 years of follow-up data focused on post-operative ICU admission time, obtained from medical records at a single tertiary care hospital. Therefore, this study shows that coverage by intensivists when post-operative ICU admissions occur might be an important factor for reducing mortality of surgical patients in the ICU.

There have been numerous previous studies analysing the association and effects of ICU admission time on patient mortality. A meta-analysis published in 2010 [16], which investigated general ICU admission times, showed that weekend admission was associated with increased mortality, while there was no significant association between night-time admission and

mortality. Meanwhile, three other recent studies reported that there were no weekend or night-time effects observed for the association between ICU admission time and mortality [9,17,18]. However, all of these previous studies examined general ICU admissions, whereas our study only analysed post-operative surgical ICU admissions. One study has shown an association between weekend surgical ICU admission and increased patient mortality in a subgroup analysis [19]. However, that study did not specifically analyse post-operative admission, and it was unable to show a difference according to the time of day at which admission occurred.

Another subgroup analysis was performed by Bhonagiri et al. and showed a significant association between mortality and ICU admission time in elective and emergency surgical patients [10]. The study by Bhonagiri et al. is important because it showed that the night-time and weekend effects were even stronger for the ICU admission of post-operative patients when compared to all ICU admission cases. However, the time of ICU admission was divided into two levels, comparing office hours (06:00–17:59) and after-hours (18:00–05:59), and was therefore unable to consider the effect of intensivist coverage.

The findings from our study highlight the issues surrounding the staffing patterns of the attending intensivists at the hospital. It is still controversial whether night-time staffing can improve outcomes in ICU patients [20]. While some studies have reported that there is no association between night-time staffing and patient outcomes [21,22], other studies have reported that night-time staffing improves outcomes [23,24]. The present cohort study was conducted at the hospital, where daytime intensivists have managed the Surgical ICU for 10 years; it is possible that the 'intensivist effect' was associated with the mortality of patients in the surgical ICU. However, further research is required, because no study has demonstrated a relationship between patient mortality and post-operative ICU admission time in a setting with full-time, 24-hour intensivist care. Additionally, the effect of 24-hour intensivist staffing for surgical ICU patients admitted during the weekend, night-time, or holidays remains controversial.

Additionally, this study should take into consideration whether the patient-to-staff ratios are appropriate. Recently, one study reported that the risk of death of patients in the ICU increased 2-fold when the patient-to-physician ratio was greater than 14; this increased to 3.5-fold when the patient-to-nurse ratio was greater than 2.5 [2]. Even though the intensivists were only available in the daytime in our study, the patient-to-daytime intensivist ratio was 14 and the patient-to-nurse ratio was two; thus, the patient-to-staff ratios were not too large.

There was another interesting finding in this study. In the sensitivity analysis, ICU admission in first two hours after midnight

was protective against post-operative 30-day mortality, while admission in the following 6 hours (2:00 am–8:00 am) was a risk factor for post-operative 30-day mortality. These findings can possibly be explained by two assumptions. First, there might have been an effect of fatigue on medical staff, including physicians or nurses, performance during the night-time. Considering duty night-time nurses usually work from 23:00–08:00 (next day), while duty residents work from 18:00–08:00 (next day) in SNUBH, fatigue could affect such a difference in 30-day mortality among patients based on night-time admission. Second, daytime intensivists sometimes receive call-ins after 18:00 for difficult procedures or for very seriously ill patients. Such contact might be difficult during the late night hours.

This study was subject to several limitations. As this was a retrospective cohort study, there may have been some bias. Additionally, the study was based on data collected from medical records at a single centre over a 10-year period, thus generalizability might be a concern. Third, although we matched the characteristics of the patients according to post-operative ICU admissions based on intensivist coverage, the night-time effect or weekend effect might affect our study outcomes. Nevertheless, our study is valuable as it is the first study to show a relationship between post-operative surgical ICU admission with high intensity intensivist coverage and mortality in surgical ICU patients.

## 5. Conclusions

This study showed an increase in post-operative 30-day mortality and length of hospital and ICU stay for the surgical ICU admission group without intensivist coverage versus with intensivist coverage. In future, additional research will be required to investigate the effect of full-time intensivist coverage on mortality for surgical ICU patients.

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This was a retrospective observational study conducted with the approval of the Seoul National University Bundang Hospital (SNUBH) Institutional Review Board (IRB approval number: B-1703/388-105). Informed consent was waived as this was a retrospective review of patient medical records.

## Disclosure of interest

The authors declare that they have no competing interest.

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