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ORIGINAL ARTICLE

Admission to the surgical intensive care unit during intensivist coverage is associated with lower incidence of postoperative acute kidney injury and shorter ventilator time

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Abstract

Purpose This study aimed to assess the impact of intensivist coverage on the incidence of acute kidney injury (AKI) and ventilator time among patients postoperatively admitted to the intensive care unit (ICU).

Methods Adult patients postoperatively admitted to the ICU between January 2012 and December 2017 were retrospectively enrolled. The incidence of AKI within 72 h of surgery and the postoperative ventilator time were compared between the groups covered by intensivists and non-intensivists.

Results After propensity score (PS) matching, 5650 patients were included in the final analysis (2825 patients in each group). The incidence rate of AKI was significantly higher in the non-intensivist coverage group than in the intensivist coverage group (22.7% vs. 20.2%; $P = 0.023$). Moreover, logistic regression analysis in the PS-matched cohort showed that the incidence of postoperative AKI in the non-intensivist coverage group increased by 16% compared to that in the intensivist coverage group (odds ratio 1.16, 95% confidence interval 1.02–1.32; $P = 0.023$). Additionally, the median time of ventilator use in the non-intensivist coverage group was significantly longer than that in the intensivist coverage group [7.8 (interquartile range, IQR 2.6–13.8) h vs. 5.3 (1.8–8.3) h; $P < 0.001$].

Conclusion High-intensity intensivist coverage is associated with a lower risk of postoperative AKI and shorter postoperative ventilator times. These findings suggested that in addition to medical trainees, initial management of surgical ICU patients by intensivists may lower the risk of AKI and facilitate early weaning from mechanical ventilation.

Keywords Acute kidney injury · Critical illness · Intensive care units · Ventilators · Mechanical

Introduction

High-intensity daytime staffing of intensivists (i.e., physicians specializing in intensive care medicine [1] has been reported to lower mortality and shorten length of stay among patients admitted to the intensive care unit (ICU) [2, 3]. However, a recent meta-analysis has demonstrated that full-time (24-h) intensivist staffing does not improve mortality among ICU patients [4],the most appropriate model of intensivist staffing therefore remains a controversial issue [4–6].

More than 300 million surgeries are performed worldwide [7], and approximately 9.6% of these patients are postoperatively admitted to the ICU for various reasons [8]. In our previous study [9], intensivist coverage in the surgical ICU was associated with improved 30-day mortality and shorter lengths of ICU and hospital stay, indicating that full-time high-intensity staffing of intensivists may improve patient outcomes in the surgical ICU. However, we had focused only on patient mortality and length of ICU and hospital stay. A study had reported that intensivist staffing of the surgical ICU may influence the incidence of postoperative acute kidney injury (AKI), which is a common postoperative complication [10]. In addition, another study reported a 38% failure rate in early weaning

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from mechanical ventilation after emergency surgery in the critically ill [11], this demonstrates that intensivist coverage may reduce the incidence of delayed weaning in patients who have been postoperatively admitted to the ICU. However, data are lacking in this regard.

Therefore, this study aimed to assess the impact of intensivist coverage on the postoperative incidence of AKI and ventilator time in a cohort of patients admitted to the ICU after surgery. We hypothesized that high-intensity intensivist coverage is associated with a lower postoperative incidence of AKI and shorter ventilator times.

Methods

Study design, setting, and ethical statement

This retrospective cohort study was approved by the Institutional Review Board (IRB) of the Seoul National University Bundang Hospital (SNUBH) (IRB approval number: B-1806/474-105). The need for informed consent was waived owing to the retrospective study design.

Study population

Data of all adult patients who were postoperatively admitted to the ICU between January 2012 and December 2017 were collected from the electronic health records [12] by medical record technicians blinded to the purpose of this study. If a patient was postoperatively admitted to the ICU more than twice during the time period, only the last ICU admission (when the patient is likely to be in the most severe condition) was included in the analysis. The exclusion criteria were as follows: age < 18 years, preoperative renal replacement therapy (RRT) or end-stage renal disease (i.e., estimated glomerular filtration rate (eGFR) of < 15 mL/min/1.73 m^2), and incomplete or missing data. In this study, the patients were divided into two groups, namely, the intensivist coverage group [i.e. those who were admitted to the ICU during the time of high-intensity intensivist coverage (08:00–18:00 hours on weekdays)] and the non-intensivist coverage group [i.e., those who were admitted in the absence of intensivist coverage (18:00–08:00 hours on weekdays and on weekends and holidays)]. During the study period, postoperative ICU admission was indicated according to the complexity of the surgery and the severity of the patient's condition. The decision for ICU admission was made after consultation with the intensivists, who were also authors (I.A.S. and T.K Oh) in the present study.

Staffing pattern in ICUs as an independent variable

As reported recently [9], the majority of postoperative ICU admissions were to the surgical, emergency, and neurological ICUs. These three ICUs are individually staffed by three daytime attending intensivists comprising an anesthesiologist, neuro-intensivist, and thoracic surgeon between 08:00 and 18:00 hours from Monday to Friday, except holidays. An attending intensivist is then on call after 18:00 hours, and on weekends. All intensivists are officially certified for primary and high intensity management in the ICU by the Korean Society of Critical Care Medicine. Residents from each surgical department also work with intensivists for postoperative patient care in the ICU. Additionally, in most surgical departments, one main duty resident (1st or 2nd year resident in-training) and one senior resident (3rd or 4th year resident in-training), are usually assigned to manage 1–10 ICU patients. These resident to ICU patient ratios are variable, as the number of ICU patients in individual surgical departments differ on a daily basis. In general, one nurse cares for every two ICU patients. After 18:00 hours, residents on duty from each surgical department are in charge of patient care in each ICU, and the number and experience levels of the nurses are similar to those on duty from 08:00 to 18:00 hours. Although intensivists supervise medical trainees (residents) during ICU patient care, they do not initially treat patients admitted postoperatively to the ICU, until their duties commence. For instance, a patient admitted postoperatively to the ICU at 2:00 a.m., will be cared for by a duty resident during the initial 6 h of admission from 2:00 to 8:00 a.m.; the intensivists commence treatment after 8:00 a.m.

Postoperative acute kidney injury and ventilator time as dependent variables

In this study, AKI was diagnosed according to the criteria and grading outlined in Kidney Disease: Improving Global Outcomes (creatinine only) (Table S1) [13]. In general, the serum creatinine level was measured at least 1 month prior to surgery, and this value was used as the baseline value for diagnosing AKI. In cases where the creatinine level was measured multiple times within one month prior to surgery, the value obtained on the date nearest to the surgery was used as the baseline value. Postoperative AKI was diagnosed using the creatinine value measured within 72 h of ICU admission. Among patients who died within 72 h of ICU admission, the creatinine value measured before death was used for diagnosis.

The postoperative ventilator time (h) was defined as the duration between ICU admission and extubation, among patients in whom the endotracheal tube was not removed after surgery. Among patients who were extubated and required repeat intubation, the duration of ventilation for the second intubation was not included in the postoperative ventilator time. Among patients who died prior to extubation, the postoperative ventilator time was defined as the duration from intubation in the ICU until death.

Confounders

Data collected included: (1) physical characteristics [sex, age, body mass index (kg/m^2)], (2) socioeconomic status [type of insurance (medical aid program or national health insurance program)], (3) acute Physiology and Chronic Health Evaluation II score, (4) preoperative American Society of Anesthesiologists physical status, (5) preoperative eGFR (mL/min/1.73 m^2), (6) comorbidities at postoperative ICU admission [hypertension, diabetes mellitus, history of coronary disease and cerebrovascular disease, liver disease (hepatitis, liver cirrhosis, and fatty liver), anemia (< 10 g/dL of haemoglobin), dyslipidemia, and chronic obstructive lung disease, and cancer), (7) surgical characteristics [type of surgery (cardiac, major vascular, gastrointestinal tract, hepatobiliary and pancreatic, thoracic, neurosurgery, obstetric and gynecologic, urologic surgery, orthopedic and spine, and other surgeries), type of anesthesia, emergency surgery, duration of surgery, estimated blood loss, and total fluid intake on postoperative day 0 (POD)], and (8) patient management during POD 0–3 (postoperative ventilator use, hydroxyethyl starch use, nephrotoxic antibiotic use, vasopressor infusion, exposure to hypotension, and transfusion of packed red blood cells).

Preoperative eGFR (mL/min/1.73 m^2) was calculated using the Modification of Diet in Renal Disease formula [14] as follows: eGFR (mL/min/1.73 m^2) = 186 × (preoperative creatinine)$^{-1.154}$ × (age)$^{-0.203}$ (× 0.742 for women). Data regarding comorbidities were obtained from the International Classification of Disease-10 diagnostic system. Nephrotoxic antibiotics included aminoglycosides, cephalosporins, vancomycin, and sulfonamides, while vasopressors included norepinephrine, dobutamine, dopamine, vasopressin, and epinephrine. Exposure to hypotension on POD 0–3 was defined by a mean blood pressure of < 80 mmHg, since organ injury is likely with a mean blood pressure reduction of < 80 mmHg for ≥ 10 min [15]. Patients classified in the low income group in Korea are listed in the medical aid program, and the majority of their hospital charges are paid by the government. Among patients in the national health insurance program, the government covers approximately two-thirds of their hospital charges.

Study endpoints

The primary endpoint of this study was postoperative AKI, and the secondary endpoint was postoperative ventilator time.

Statistical analysis

We first performed propensity score (PS) matching, which is a known to effectively reduce the effects of confounders in an observational study [16], using the nearest neighbor method under the following conditions: 1:1 ratio, without replacement, and caliper set at 0.2. The absolute value of standardized mean difference (ASD) was used to evaluate the balance between the intensivist coverage and the non-intensivist coverage groups before and after PS matching. Based on PS matching, we decided to minimize the ASD of all confounders between the two groups to less than 0.1. After confirming the balance between the two groups via PS matching, the Chi-square test was used to assess the difference in the incidence rate of postoperative AKI between the two groups. Furthermore, the difference in the incidence rate of AKI between the two groups (PS-matched cohort) was assessed via logistic regression analysis, and the outcome of this analysis was presented using the odds ratio (OR) with 95% confidence intervals (CI). The analysis for AKI stage ≥ 2 was similar. For comparison of postoperative ventilator times between the two groups (PS-matched cohort), the Mann–Whitney test was used, considering that the distribution of ventilator time did not exhibit normality ($P < 0.05$ on the Kolmogorov–Smirnov test). Generalized linear regression analysis was used to assess the significance of the difference in the postoperative ventilator time between the groups. In this generalized linear model, the postoperative ventilator time was hypothesized to exhibit gamma distribution; therefore, the log link function was used. Additionally, we performed three sensitivity analyses. First, considering that patients in the non-intensivist coverage group were postoperatively admitted to the ICU at night or on weekends and holidays, the ICU admission time of the non-intensivist coverage group was divided in two-hour segments. We then assessed the difference in the incidence rate between total AKI and AKI stage ≥ 2, and the postoperative ventilator time between the intensivist coverage and non-intensivist coverage groups was divided based on the time segment. Second, to investigate whether or not the outcomes obtained using the PS-matched cohort were generalizable in the entire cohort, multivariable logistic regression analysis or generalized multivariable log-linear regression analysis was performed, with all covariates included for adjustment. Lastly, considering that cardiac and major vascular surgery is an important risk factor for postoperative AKI [17], identical analyses were performed in the cohort who underwent cardiac surgery. All statistical analyses were performed using R software (version 3.6.0, R Foundation for Statistical Computing, Vienna, Austria); $P < 0.05$ was considered statistically significant.

Results

Among 17,748 cases of postoperative ICU admission, 5295 duplicate admissions of the same patient were initially excluded, leaving 12,453 cases. Subsequently, 1782 patients aged < 18 years, 189 patients who were receiving preoperative RRT or had eGFR levels of < 15 mL/min/1.73 m^2, 257 patients with missing preoperative creatinine levels, and 912 patients with incomplete or missing data, were excluded. In the remaining 9313 patients, 5710 and 3603 were admitted to the ICU with and without intensivist coverage, respectively. After PS matching, 2825 subjects from each group were included in the final analysis (Fig. 1). Table 1 shows that all confounders after PS matching had ASD ≤ 0.05 between the two groups, suggesting equal distribution. In addition, the distribution of PS was better balanced after PS matching (Figure S1).

Postoperative acute kidney injury

Table 2 summarizes the incidence rates of AKI in the PS-matched cohort. The incidence rate of AKI in the non-intensivist coverage group was significantly higher than that of the intensivist coverage group [640 of 2825 (22.7%) vs. 570 of 2825 (20.2%); $P = 0.023$]. Logistic regression analysis also demonstrated that the incidence rate of AKI in the non-intensivist coverage group increased by 16% compared to that in the intensivist coverage group (OR 1.16, 95% CI 1.02–1.32; $P = 0.023$). Additionally, sensitivity analysis showed that compared to the intensivist coverage group, the risk of AKI was significantly increased among patients admitted during holidays or weekends (OR 1.21, 95% CI 1.04–1.42; $P = 0.014$) and 22:00–23:59 h (OR 2.72, 95% CI 1.26–5.89; $P = 0.011$) in the non-intensivist coverage group. Analysis of the incidence of AKI stage ≥ 2 in the PS-matched cohort is outlined in Table 3. There was no significant difference in the incidence rate between the two groups; AKI was observed in 159 of 2825 (5.6%) in the intensivist coverage group and 171 of 2825 (6.1%) in the non-intensivist coverage group ($P = 0.496$). This was further validated on logistic regression analysis ($P = 0.496$). However, sensitivity analysis showed that patients admitted postoperatively during 22:00–23:59 h (OR 5.87, 95% CI 2.45–14.09; $P < 0.001$) had a significantly higher risk of AKI stage ≥ 2. Multivariable logistic regression analysis in the entire cohort yielded similar results to logistic regression in the PS-matched cohort (Table S2). Sensitivity analysis in the cohort who underwent cardiac and major vascular surgery showed no significant difference in total AKI or the risk of AKI stage ≥ 2 between the non-intensivist and intensivist

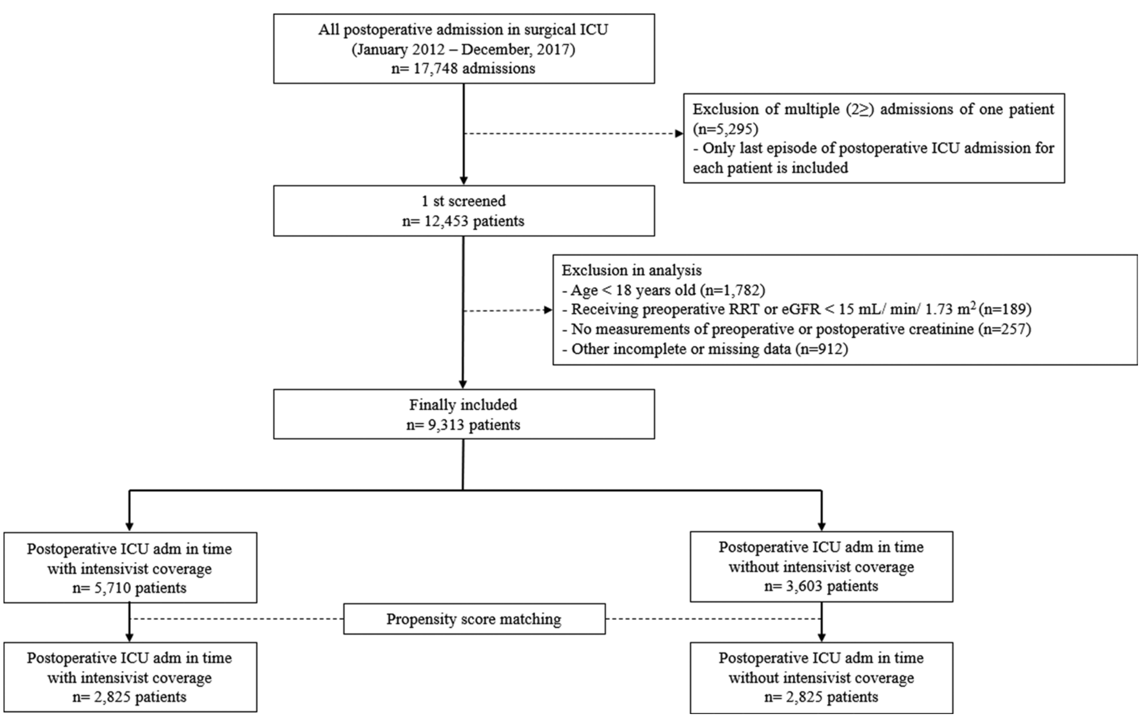

Fig. 1 Flow chart of patient selection

Table 1 Comparison of characteristics between postoperative ICU admission with and without intensivist coverage

Variables	Entire cohort ($n=9313$)			PS-matched cohort ($n=5650$)		
	ICU adm with intensivist coverage	ICU adm without intensivist coverage	ASD	ICU adm with intensivist coverage	ICU adm without intensivist coverage	ASD
	$n=5710$	$n=3603$		$n=2825$	$n=2825$	
Age, years	61.8 (15.5)	60.6 (15.7)	0.08	60.7 (16.0)	60.8 (15.3)	< 0.01
Sex, male	3061 (53.6)	1917 (53.2)	0.01	1497 (53.0)	1479 (52.4)	0.01
Body mass index, kg/m^2	24.0 (3.7)	23.9 (3.6)	0.03	23.8 (3.7)	23.9 (3.6)	0.02
Insurance type[a]			< 0.01			< 0.01
Medical aid program	197 (3.5)	123 (3.4)		98 (3.5)	96 (3.4)	
National health insurance program	5513 (96.5)	3480 (96.6)		2727 (96.5)	2729 (96.6)	
APACHE II	21.2 (8.9)	21.3 (9.20)	0.02	21.2 (9.1)	21.2 (9.1)	< 0.01
Preoperative ASA physical status			0.11			0.03
1	839 (14.7)	591 (16.4)		474 (16.8)	470 (16.6)	
2	2985 (52.3)	1748 (48.5)		1457 (51.6)	1452 (51.4)	
3	1782 (31.2)	1125 (31.2)		824 (29.2)	819 (29.0)	
≥ 4	104 (1.8)	139 (3.9)		70 (2.5)	84 (3.0)	
Preoperative eGFR,[b] mL/min /1.73 m^2			0.09			0.02
≥ 90	4244 (74.3)	2610 (72.4)		2122 (75.1)	2097 (74.2)	
60–90	1106 (19.4)	660 (18.3)		479 (17.0)	503 (17.8)	
30–60	292 (5.1)	265 (7.4)		181 (6.4)	181 (6.4)	
15–30	68 (1.2)	68 (1.9)		43 (1.5)	44 (1.6)	
Comorbidity at postoperative ICU adm						
Hypertension	2500 (43.8)	1447 (40.2)	0.07	1164 (41.2)	1176 (41.6)	< 0.01
Diabetes mellitus	428 (7.5)	303 (8.4)	0.03	225 (8.0)	233 (8.2)	0.01
Coronary artery disease	164 (2.9)	63 (1.7)	0.09	56 (2.0)	55 (1.9)	< 0.01
Cerebrovascular disease	234 (4.1)	142 (3.9)	0.01	116 (4.1)	111 (3.9)	< 0.01
Liver disease[c]	163 (2.9)	134 (3.7)	0.05	99 (3.5)	99 (3.5)	< 0.01
Anemia (hemoglobin < 10 g/dL[1])	2020 (35.4)	1553 (43.1)	0.16	1196 (42.3)	1185 (41.9)	< 0.01
Dyslipidemia	413(7.2)	235 (6.5)	0.03	189 (6.7)	197 (7.0)	0.01
Chronic obstructive lung disease	328 (5.7)	139 (3.9)	0.10	117 (4.1)	122 (4.3)	< 0.01
Cancer	1533 (26.8)	1002 (27.8)	0.02	815 (28.8)	822 (29.1)	< 0.01
Type of surgery			0.15			0.03
Cardiac surgery	982 (17.2)	392 (10.9)		357 (12.6)	358 (12.7)	
Major vascular surgery	398 (7.0)	219 (6.1)		149 (5.3)	157 (5.6)	
Gastrointestinal tract surgery	699 (12.2)	553 (15.3)		356 (12.6)	366 (13.0)	
Hepatobiliary and pancreatic surgery	243 (4.3)	191 (5.3)		153 (5.4)	159 (5.6)	
Thoracic surgery	460 (8.1)	172 (4.8)		170 (6.0)	150 (5.3)	
Neurosurgery	1912 (33.5)	1296 (36.0)		1032 (36.5)	1033 (36.6)	
OBGY and Urologic surgery	174 (3.0)	148 (4.1)		113 (4.0)	111 (3.9)	
Orthopedic and spine surgery	564 (9.9)	417 (11.6)		326 (11.5)	326 (11.5)	
Other surgery	278 (4.9)	215 (6.0)		169 (6.0)	165 (5.8)	
Duration of surgery, min	271.4 (163.3)	307.7 (192.0)	0.19	303.2 (181.9)	306.3 (177.2)	0.02
General anesthesia	5542 (97.1)	3539 (98.2)	0.09	2753 (97.5)	2769 (98.0)	0.04
Emergency surgery	297 (5.2)	1014 (28.1)	0.51	291 (10.3)	355 (12.6)	0.05
Estimated blood loss, mL	548.5 (831.5)	805.2 (1464.6)	0.18	687.4 (1057.0)	759. 4 (1429.9)	0.05
Total fluid intake in POD 0, mL	4051.1 (2347.4)	4103.5 (3122.9)	0.02	4089.2 (2376.0)	4123.3 (3118.5)	0.01
Year of postoperative ICU admission			0.07			0.01
2012	514 (9.0)	408 (11.3)		302 (10.7)	300 (10.6)	
2013	698 (12.2)	467 (13.0)		363 (12.8)	371 (13.1)	

Table 1 (continued)

Variables	Entire cohort ($n = 9313$)			PS-matched cohort ($n = 5650$)		
	ICU adm with intensivist coverage	ICU adm without intensivist coverage	ASD	ICU adm with intensivist coverage	ICU adm without intensivist coverage	ASD
	$n = 5710$	$n = 3603$		$n = 2825$	$n = 2825$	
2014	1014 (17.8)	665 (18.5)		533 (18.9)	520 (18.4)	
2015	1061 (18.6)	625 (17.3)		483 (17.1)	484 (17.1)	
2016	1215 (21.3)	668 (18.5)		551 (19.5)	538 (19.0)	
2017	1208 (21.2)	770 (21.4)		593 (21.0)	612 (21.7)	
Patients management during POD 0–3						
Postoperative ventilator use	3040 (53.2)	2083 (57.8)	0.09	1585 (56.1)	1606 (56.8)	0.02
Hydroxyethyl starch infused	3566 (62.5)	2601 (72.2)	0.22	1992 (70.5)	2010 (71.2)	0.01
Nephrotoxic antibiotics[d] use	303 (5.3)	273 (7.6)	0.09	190 (6.7)	180 (6.4)	0.01
Vasopressor[e] infusion	4342 (76.0)	2773 (77.0)	0.02	2172 (76.9)	2190 (77.5)	0.02
Exposure to hypotension[f]	2396 (42.0)	1443 (40.0)	0.04			<0.01
Transfusion of packed red blood cell	3243 (56.8)	2447 (67.9)	0.24	1866 (66.1)	1887 (66.8	0.02

Data are presented as number (percentage) or mean (standard deviation)

ICU, intensive care unit; SMD, standardized mean difference; APACHE, acute physiology and chronic health evaluation; ASA, American Society of Anesthesiologists; eGFR, estimated glomerular filtration rate; OBGY, obstetrics and gynecology; POD, postoperative day

[a]The patients in the medical aid program are those who are classified to have low income, and most of their hospital charges are paid by the government. Meanwhile, for the patients in the national health insurance program, approximately two-thirds of their hospital charges are covered by the government

[b]eGFR (mL/min/1.73 m^2) = 186 × (preoperative creatinine)$^{-1.154}$ × (age)$^{-0.203}$ (× 0.742 if female)

[c]Liver disease includes acute or chronic hepatitis, liver cirrhosis, and fatty liver

[d]Nephrotoxic antibiotics include aminoglycoside, cephalosporin, vancomycin, and sulfonamide

[e]Vasopressor include norepinephrine, dobutamine, dopamine, vasopressin, and epinephrine

[f]Exposure to hypotension on POD 0–3 was defined by a mean blood pressure of < 80 mmHg

Table 2 Postoperative acute kidney injury in the propensity score-matched cohort

Variables	Event (%)	OR (95% CI)	*P* value
Postoperative ICU admission			
Intensivist coverage	570/2825 (20.2)	1	
Non-intensivist coverage	640/2825 (22.7)	1.16 (1.02, 1.32)	0.023
Sensitivity analysis			
Intensivist coverage	570/2825 (20.2)	1	
Non-intensivist coverage			
ICU admmision in holiday or weekend	322/1371 (23.5)	1.21 (1.04, 1.42)	0.014
ICU admission in 18:00–19:59	172/788 (21.8)	1.11 (0.91, 1.34)	0.311
ICU admission in 20:00–21:59	77/349 (22.1)	1.12 (0.86, 1.47)	0.409
ICU admission in 22:00–23:59	11/27 (40.7)	2.72 (1.26, 5.89)	0.011
ICU admission in 00:00–01:59	2/26 (7.7)	0.33 (0.08, 1.40)	0.132
ICU admission in 02:00–03:59	6/25 (24.0)	1.25 (0.50, 3.14)	0.636
ICU admission in 04:00–05:59	5/21 (23.8)	1.24 (0.45, 3.39)	0.680
ICU admission in 06:00–07:59	45/218 (20.6)	1.03 (0.73, 1.45)	0.869

OR, odds ratio; CI, confidence interval; ICU, intensive care unit

coverage groups ($P = 0.192$ and $P = 0.256$, respectively; Table S3).

Postoperative ventilator time

The median time of ventilator use in the non-intensivist

Table 3 Postoperative acute kidney injury stage ≥ 2 in the propensity score-matched cohort

Variables	Event (%)	OR (95% CI)	*P* value
Postoperative ICU admission			
Intensivist coverage	159/2825 (5.6)	1	
Non-intensivist coverage	171/2825 (6.1)	1.08 (0.87, 1.35)	0.496
Sensitivity analysis			
Intensivist coverage	159/2825 (5.6)	1	
Non-intensivist coverage			
ICU admmision in holiday or weekend	64/1371 (4.7)	0.82 (0.61, 0.11)	0.194
ICU admission in 18:00–19:59	55/788 (7.0)	1.26 (0.92, 1.73)	0.156
ICU admission in 20:00–21:59	21/349 (6.0)	1.07 (0.67, 1.72)	0.767
ICU admission in 22:00–23:59	7/27 (25.9)	5.87 (2.45, 14.09)	< 0.001
ICU admission in 00:00–01:59	1/26 (3.8)	0.67 (0.09, 4.98)	0.696
ICU admission in 02:00–03:59	2/25 (8.0)	1.46 (0.34, 6.24)	0.611
ICU admission in 04:00–05:59	2/21 (9.5)	1.77 (0.41, 7.64)	0.447
ICU admission in 06:00–07:59	19/218 (8.7)	1.60 (0.97, 2.63)	0.064

OR, odds ratio; CI, confidence interval; ICU, intensive care unit

coverage group was significantly longer than that of the intensivist coverage group [7.8 (IQR 2.6–13.8) h vs. 5.3 h (IQR 1.8–8.3) h; $P < 0.001$]. Table 4 shows the results on analysis of the postoperative ventilator time in the PS-matched cohort. On generalized log-linear regression analysis, the ventilator time in the non-intensivist coverage group showed a significant 1.61-fold increase compared to that in the intensivist coverage group (exponentiated regression coefficient: 1.61, 95% CI 1.45–1.78; $P < 0.001$). The results of multivariable generalized log-linear regression analysis in the entire cohort after adjusting for all covariates were similar to the outcomes of generalized log-linear regression analysis in the PS-matched cohort (Table S2). These findings were also observed in the cardiac surgery cohort (Table S3).

Discussion

In a cohort of patients who were postoperatively admitted to the ICU, this study found that the patients who were admitted with intensivist coverage had a lower risk of postoperative AKI compared to those admitted without intensivist coverage. The postoperative ventilator time was also significantly shorter in patients admitted with intensivist coverage than in those admitted without intensivist coverage. The outcomes of the current and our previous study [9] indicate that initial management for surgical ICU patients by certified intensivists in addition to medical trainees may lower the

Table 4 Postoperative ventilator time (h) in the propensity score-matched cohort ($n = 3191$)

Variables	Median [IQR]	Exp. coef. (95% CI)	*P* value
Postoperative ICU admission			
Intensivist coverage ($n = 1585$)	5.3 [1.8, 8.3]	1	
Non-intensivist coverage ($n = 1606$)	7.8 [2.6, 13.8]	1.61 (1.45, 1.78)	< 0.001
Sensitivity analysis			
Intensivist coverage	5.3 [1.8, 8.3]	1	
Non-intensivist coverage			
ICU admmision in holiday or weekend	6.2 [2.1, 10.6]	2.65 (2.02, 3.47)	< 0.001
ICU admission in 18:00–19:59	9.2 [4.3, 14.8]	4.28 (1.67, 10.94)	0.002
ICU admission in 20:00–21:59	12.7 [4.5, 18.9]	14.52 (6.94, 30.39)	< 0.001
ICU admission in 22:00–23:59	17.3 [10.0, 79.8]	7.93 (3.68, 17.10)	< 0.001
ICU admission in 00:00–01:59	15.9 [0.1, 179.0]	4.76 (2.62, 8.65)	< 0.001
ICU admission in 02:00–03:59	12.4 [1.5, 161.2]	1.80 (1.45, 2.23)	< 0.001
ICU admission in 04:00–05:59	11.6 [1.4, 126.4]	1.38 (1.19, 1.60)	< 0.001
ICU admission in 06:00–07:59	8.0 [2.7, 29.4]	1.08 (0.95, 1.22)	0.239

IQR, interquartile range; Exp, exponentiated; Coef, coefficient; CI, confidence interval;ICU, intensive care unit risk of AKI and facilitate early weaning from mechanical ventilation.

In this study, we used PS matching for hydroxyethyl starch infusion, nephrotoxic antibiotic use, vasopressor infusions, exposure to hypotension, and transfusion of packed red blood cells during POD 0–3 between the two groups, since these factors are known to be related to AKI development [18]. The results showed that intensivist coverage during postoperative ICU admission is associated with a lower incidence of postoperative AKI, despite adjusting for these risk factors. These results might be explained by two assumptions. First, there was a relatively thin level of medical staffing in the nighttime or weekends, because surgical ICU patients were only usually treated during these times by medical trainees while senior intensivists work together with medical trainees in the daytime. Furthermore, a previous study reported that in addition to medical trainee, nighttime intensivist staffing is associated with better outcomes compared to day-time intensivist coverage [6]. Therefore, the finding of this previous study may affect how the results of this study is interpreted. However, considering the fact that a more recent study reported that the nighttime intensivist staffing is not associated with the outcomes of ICU patients [4], more study is needed to confirm the findings of our study. Second, the medical staffs, including medical trainees and nurses, might suffer from fatigue or sleep deprivation during the nighttime compared to the daytime, and this might have affected the outcomes of this study. It is well known that the medical trainees often suffer from sleep deprivation due to nighttime work [19, 20],thus, this could have been related to increased risk of human errors [21].

Another pertinent finding from this study was that the postoperative ventilator time in the patients admitted with intensivist coverage was shorter than that of those admitted without intensivist coverage. Certain salient considerations may be made from two different aspects. First, weaning ICU patients from mechanical ventilators at appropriate times is an extremely challenging task [22]. Since various factors are associated with postoperative delayed weaning [23], trainees probably found it difficult to decide on the extubation in the absence of intensivist coverage. Moreover, since extubation failure requires immediate re-intubation, and may lead to dangerous situations if appropriate treatment is not provided in time [24], trainees may have delayed weaning, even in suitable patients, until senior intensivists were available. Second, patients postoperatively admitted to the ICU without an attending intensivist may demonstrate poorer overall conditions than those admitted with intensivist coverage,this may be related to the poorer overall management of ICU patients by trainees in the absence of intensivist coverage. Consequently, ventilator weaning and extubation may have been delayed in our cohort.

Interestingly, in this study, the risk for AKI was not associated with intensivist coverage in patients who underwent cardiac or major vascular surgery. This may have been related to the unique characteristics of cardiac surgery. Remarkably, cardiac or major vascular surgery is an important risk factor for postoperative AKI in surgical ICU patients, and may contribute to approximately 30% of these cases [17]. Therefore, among patients who were postoperatively admitted to the ICU after cardiac or major vascular surgery, intensivist coverage was probably insufficient to improve clinical outcomes in terms of AKI. Nevertheless, the role of intensivists may still be crucial for patients who undergo cardiac or major vascular surgery in terms of postoperative ventilator time, as the intensivist coverage in this population was greater than that of the entire cohort. Additional studies are needed to further validate these hypotheses.

Despite these novel findings, this study has a few limitations. First, owing to the retrospective nature of this study, the probability of selection bias cannot be eliminated; the patients with missing or incomplete data were therefore excluded. Secondly, the difference in ICU admission times or day among patients in the intensivist and non-intensivist coverage groups is another limitation. However, we performed sensitivity analysis and reported outcomes on the difference, based on times in the non-intensivist coverage group. Thirdly, the PS matching could only control for known confounders; thus, there might have been residual confounders, which might have affected the results of this study. Lastly, this was a single-center study and the generalizability of our findings may be limited. Moreover, the experience or ability of the intensivists or trainees may differ between institutions.

In conclusion, this study showed that high-intensity intensivist coverage is associated with a lower risk of AKI and shorter ventilator times among patients postoperatively admitted to the ICU. These findings suggest that initial management of surgical ICU patients by certified intensivists in addition to medical trainees, may lower the risk of AKI and facilitate early weaning from mechanical ventilation. Further studies are needed to validate our findings.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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