Original Article

Improved clinical outcomes following introduction of an attending intensivist for patients admitted to the cardiac surgical intensive care unit after valvular heart surgery: a single-center experience

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Background: Although numerous studies have documented the improved clinical outcomes of patients undergoing cardiac surgery following introduction of attending intensivist, most of these studies included heterogeneous patient populations. We aimed to investigate the impact of an attending intensivist on the clinical outcomes of patients admitted to the cardiac surgical intensive care unit (CSICU) following valvular heart surgery.

Methods: Patients who underwent valvular heart surgery between January 2007 and December 2012 (control group, n=337) were propensity matched (1:1) between January 2013 and June 2017 (intensivist group, n=407).

Results: During the propensity score matching analysis, 285 patients were extracted from each group. Patients in the intensivist group underwent mechanical ventilation for a significantly shorter time than those in the control group (21.8±69.8 *vs.* 39.2±115.3 hours, P=0.021). More patients were extubated within 6 hours in the intensivist group than in the control group (53.7% *vs.* 42.8%, P=0.015). The incidence of ventilator-associated pneumonia (1.4% *vs.* 4.9%, P=0.031), cardiac arrest due to cardiac tamponade associated with post-cardiotomy bleeding (0.4% *vs.* 3.9%, P=0.002), and acute kidney injury (2.8% *vs.* 7.7%, P=0.011) in the intensivist group was significantly lower than that in the control group. The 30-day mortality rate of the intensivist group was significantly lower than that of the control group (2.1% *vs.* 6.7%, P=0.015).

Conclusions: Critical care provided in the CSICU staffed by an attending intensivist is associated with a lower 30-day mortality rate and reduced incidence of postoperative complications.

Keywords: Critical care; thoracic surgery; postoperative complications; mortality; personnel staffing

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Introduction

An open intensive care unit (ICU) model may be the most widely adopted model in the cardiac surgical ICU (CSICU) (1). Although cardiac surgeons are the physicians with the most responsibilities in this model, they cannot always perform prompt postoperative management of patients admitted to the CSICU because they spend most of their time in the operating room (OR). Conversely, attending intensivists are responsible for the critical care of patients in the closed ICU model. This model has the advantage that attending intensivists can immediately respond to patients because they almost always remain within the CSICU during their working hours. Although several studies have revealed that the closed ICU model is associated with better clinical outcomes compared with the open ICU model (2-7), few studies have demonstrated the superiority of the closed model in CSICUs (8-10). In 2013, a transition from an open ICU model with coverage by surgeons and trainees to a closed ICU model with attending intensivist coverage occurred at our institution. The intensivist was board-certified for both cardiothoracic surgery and critical care. The intensivist remained in the CSICU during working hours and immediately made autonomous decisions on most medical issues, but communicated with cardiac surgeons about important surgical decisions, such as re-exploration due to post-cardiotomy bleeding. We hypothesized that the presence of an attending intensivist would be associated with a reduced mortality rate and postoperative complications in patients admitted to the CSICU after valvular heart surgery. We also hypothesized that the patients managed by the attending intensivist would have better clinical outcomes if patients with an equivalent level of predicted mortality underwent a similar type of surgery by the same surgeon. This study aimed to investigate the differences in patient outcomes due to the presence of an attending intensivist using propensity score matching and statistical analysis of patient records. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-581/rc).

Highlight box

Key findings

- We found that the presence of an attending intensivist board-certified for both cardiothoracic surgery and critical care would be associated with a reduction in postoperative complications and 30-day mortality rate of patients admitted to the cardiac surgical intensive care unit (CSICU) following valvular heart surgery.

What is known and what is new?

- This study shows that having a trained intensivist improves clinical outcomes by enabling faster and better decision-making.
- Unlike previous studies that examined heterogeneous patient groups undergoing various surgeries by multiple surgeons, this study focused on a more homogeneous group, demonstrating the benefits of attending intensivist.

What is the implication, and what should change now?

- We believe that attending intensivist would be able to contribute to improving clinical outcomes in patients admitted to CSICU. Encouragement and training of more surgical intensivists are needed to improve CSICUs lacking attending intensivists due to limited manpower.

Methods

Study population and outcomes measured

We retrospectively reviewed the electronic medical records of adult patients admitted to the CSICU following valvular heart surgery between January 2007 and June 2017 (n=808). During this period, several staffing changes occurred in the Department of Cardiac Surgery. However, we included only patients operated on by two cardiac surgeons (n=744), who worked at our institution for the entire study period and had more than 10 years of surgical experience in 2007 (surgeons A and B). The strategy for valvular heart surgery did not change significantly during that period as they were already established cardiac surgeons. The patients were categorized into two groups according to the presence of an attending intensivist. In 2013, our institution transitioned from an open ICU model with trainee coverage to a closed ICU model with attending intensivist coverage. From January 2007 to December 2012, a resident or fellow primarily managed patients admitted to the CSICU following valvular heart surgery with backup from a cardiac surgeon (control group, n=337). From January 2013 to June 2017, one attending intensivist provided postoperative critical care to patients who underwent valvular heart surgery in the CSICU (intensivist group, n=407). The intensivist stayed in the CSICU and managed postoperative patients during the day (08:00–18:00, Monday to Friday, except on holidays). On-duty trainees (resident or fellow) provided coverage for hours excluding weekdays. In order to maintain the continuity of care, guidelines for patient management were decided after discussion with surgeons and shared with on-duty trainees through daily rounds. Even after work, the intensivist backed them up by providing 24 hours home-call consultations. The intensivist worked as a primary decision-maker for all aspects of patient care. The intensivist made his own decisions on most medical issues but communicated with cardiac surgeons about critical surgical decisions, such as re-exploration due to post-cardiotomy bleeding. All parameters included in the European System for Cardiac Operative Risk Evaluation (EuroSCORE) II were used to calculate the predicted mortality rate. We reviewed every type of valvular heart surgery [aortic valve replacement (AVR), aortic valvuloplasty, mitral valve replacement, mitral valvuloplasty, tricuspid valve replacement, or tricuspid valvuloplasty (TVP)], and open heart surgery performed simultaneously with valve surgery [maze procedure, coronary artery bypass grafting (CABG), or aortic surgery]. We investigated whether the presence of an attending intensivist in the CSICU caused a reduction in mortality and the incidence of postoperative complications. The primary outcome was the 30-day mortality rate. We also investigated the rate of postoperative complications by classifying them into the following five categories: (I) mechanical ventilation: duration of mechanical ventilation, rate of prolonged mechanical ventilation for more than 48 hours, rate of early extubation within 6 hours, reintubation within 72 hours after extubation, and ventilator-associated pneumonia (VAP). (II) ICU and hospital stay: length of ICU stay, frequency of prolonged ICU stay for more than 72 hours, length of hospital stay, and rate of prolonged hospital stay for more than 14 days. (III) Post-cardiotomy bleeding: rate of re-sternotomy for bleeding control, cardiac arrest due to cardiac tamponade, and re-exploration in the ICU. (IV) Post-cardiotomy extracorporeal membrane oxygenation (ECMO) support: initiation of veno-arterial (VA) ECMO in the OR or insertion at the ICU bedside, extracorporeal cardiopulmonary resuscitation (ECPR) cases, ECPR time (defined as the time from initiation of cardiac massage to termination of standard CPR due to the initiation of ECMO support), and the number of patients who were successfully weaned from ECMO. (V) Common postoperative complications included delirium, cardiac arrest, deep sternal wound infection, acute kidney injury (AKI, defined as an increase in plasma creatinine greater than 50% over preoperative values), and stroke. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (IRB No. B-2111-721-101). Informed consent was waived because of the retrospective nature of the study and the analysis using anonymized clinical data.

Statistical analysis

Continuous and categorical variables are expressed as mean ± standard deviation and number (%), respectively. The unmatched groups were compared statistically using the Student's *t*-test and χ^2 test for continuous and categorical variables, respectively. The Wilcoxon rank-sum test was used to assess differences in ECPR time between the two matched groups. The differences in the weaning rate from ECMO and percentage of patients who underwent aortic valve (AV) + mitral valve (MV) + maze operation between the two matched groups were compared using the Fisher's exact test. A propensity score was calculated for group assignment to overcome differences in baseline characteristics between the two groups. One-to-one propensity score matching was performed. The following underlying characteristics were used as covariates to calculate the propensity score: age, sex, EuroSCORE II, operator, type of valvular heart surgery, cardiopulmonary bypass (CPB) time, and operative time. The P value obtained during the Hosmer-Lemeshow test and the c-statistic of the propensity score model were 0.56 and 0.69, respectively. These values reflect the calibration and discrimination powers of the propensity score model. To evaluate the balance among covariates, the differences in baseline characteristics between the two groups were calculated before and after propensity score matching. It was considered acceptable if covariates with standardized mean difference (SMD) were less than 0.15. The SMDs of all covariates are presented in *Table 1*. The McNemar's and Wilcoxon signed-rank tests were performed to compare categorical and continuous variables between the two matched groups. The relationships between the presence of an attending intensivist and clinical outcomes are presented as odds ratios (ORs) and 95% confidence intervals (CIs). SPSS 25 (SPSS Inc., Chicago, IL, USA) software was used for the statistical analysis. Statistical significance was set at $P<0.05$.

Results

A total of 285 patients were extracted from each group using a propensity score matching analysis. We considered it acceptable because the SMD of all covariates after matching was less than 0.15. Some baseline characteristics of the two groups differed significantly before propensity score matching was performed. The average age of patients in the intensivist group was higher than that in the control group (63.6±14.5 *vs.* 60.8±13.8 years, $P=0.007$). More patients who were operated by surgeon A were included in the control

Table 1 Demographical and clinical characteristics of patients before and after propensity score matching (used as covariates for matching)

Variables	All patients				Matched patients			
	Control group (n=337)	Intensivist group (n=407)	SMD	P value	Control group (n=285)	Intensivist group (n=285)	SMD	P value
Age (years)	60.8±13.8	63.6±14.5	0.195	0.007	61.9±13.3	61.5±15.1	0.040	0.737
Male	171 (50.7)	196 (48.2)	0.052	0.483	144 (50.5)	139 (48.8)	0.028	0.675
EuroSCORE II	6.6±10.4	7.4±10.5	0.073	0.322	6.7±10.5	6.6±10.1	0.014	0.882
Surgeon A	219 (65.0)	204 (50.1)	0.297	<0.001	171 (60.0)	150 (52.6)	0.140	0.076
AVR	149 (44.2)	210 (51.6)	0.148	0.045	137 (48.1)	143 (50.2)	0.056	0.615
AVP	4 (1.2)	9 (2.2)	0.070	0.288	4 (1.4)	3 (1.1)	0.024	0.704
MVR	124 (36.8)	158 (38.8)	0.042	0.571	107 (37.5)	107 (37.5)	0.022	1.000
MVP	104 (30.9)	100 (24.6)	0.146	0.056	77 (27.0)	72 (25.3)	0.033	0.634
TVR	11 (3.3)	8 (2.0)	0.093	0.264	8 (2.8)	7 (2.5)	0.000	0.794
TVP	95 (28.2)	76 (18.7)	0.244	0.002	62 (21.8)	59 (20.7)	0.045	0.759
Maze procedure	76 (22.6)	83 (20.4)	0.054	0.475	56 (19.6)	64 (22.5)	0.061	0.411
CABG	19 (5.6)	36 (8.8)	0.113	0.096	15 (5.3)	22 (7.7)	0.086	0.234
Aortic surgery	47 (13.9)	48 (11.8)	0.067	0.381	42 (14.7)	37 (13.0)	0.022	0.544
CPB time (min)	135.8±55.7	131.6±44.9	0.093	0.269	130.9±49.1	133.6±49.1	0.054	0.499
Operative time (min)	265.9±76.1	256.9±68.3	0.132	0.090	256.2±68.2	261.3±68.2	0.070	0.383

Values are expressed as mean ± standard deviation or number (%). SMD, standardized mean difference; EuroSCORE, European System for Cardiac Operative Risk Evaluation; AVR, aortic valve replacement; AVP, aortic valvuloplasty; MVR, mitral valve replacement; MVP, mitral valvuloplasty; TVR, tricuspid valve replacement; TVP, tricuspid valvuloplasty; CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass.

group than in the intensivist group (65.0% *vs.* 50.1%, P<0.001). The proportion of patients who underwent AVR in the intensivist group was higher than that in the control group (51.6% *vs.* 44.2%, P=0.045). A higher percentage of patients in the control group underwent TVP compared to those in the intensivist group (28.2% *vs.* 18.7%, P=0.002). In terms of detailed types of surgery before matching, the proportion of patients who underwent aortic valve surgery in combination with CABG in the intensivist group was higher than that in the control group (5.4% *vs.* 2.1%, P=0.032). The percentage of patients who underwent combined mitral and tricuspid valve surgery in the control group was significantly higher than that in the intensivist group (11.0% *vs.* 5.2%, P=0.005). All variables were evenly distributed between the two matched groups after propensity score matching (*Tables 1,2*). Demographic and clinical characteristics, which were not used as covariates for matching, were also examined to confirm whether they were evenly distributed between the two matched groups (*Table 3*). Although most baseline characteristics were evenly distributed, the intensivist group contained more patients with chronic renal failure (CRF) (7.0% *vs.* 3.2%, P=0.036) and lower creatinine clearance levels compared with those of the control group (60.9±28.6 *vs.* 67.7±28.8 mL/min, P=0.005). The primary outcome was the 30-day mortality rate. The intensivist group exhibited a significantly lower 30-day mortality rate compared with that of the control group (2.1% *vs.* 6.7%, P=0.015), which was lower than the predicted mortality calculated using EuroSCORE II. Conversely, the 30-day mortality rate in the control group was similar to that predicted. We also investigated the rate of postoperative complications by classifying them into five categories as described above (*Table 4*). In the intensivist group, patients underwent mechanical ventilation for a significantly shorter duration compared to the control group (21.8±69.8 *vs.* 39.2±115.3 hours, P=0.021). A higher percentage of patients in the intensivist group were extubated within 6 hours compared to the control group

Table 2 Detailed types of surgery before and after propensity score matching

Types of valvular heart surgery	All patients			Matched patients		
	Control group (n=337)	Intensivist group (n=407)	P value	Control group (n=285)	Intensivist group (n=285)	P value
Single valve						
Aortic valve	55 (16.3)	77 (18.9)	0.408	55 (19.3)	52 (18.3)	0.564
Aortic valve + aorta	24 (7.1)	30 (7.4)	1.000	22 (7.7)	24 (8.4)	1.000
Aortic valve + CABG	7 (2.1)	22 (5.4)	0.032	6 (2.1)	11 (3.9)	0.325
Mitral valve	81 (24.0)	91 (22.4)	0.651	75 (26.3)	62 (21.8)	0.240
Mitral valve + maze	19 (5.6)	32 (7.9)	0.294	16 (5.6)	22 (7.7)	0.401
Tricuspid valve	7 (2.1)	9 (2.2)	1.000	4 (1.4)	8 (2.8)	0.381
Double valve						
AV + MV	17 (5.1)	33 (8.1)	0.130	17 (6.0)	21 (7.4)	0.614
AV + MV + maze	2 (0.6)	11 (2.7)	0.057	2 (0.7)	7 (2.5)	0.176
AV + MV + aorta	9 (2.7)	10 (2.6)	1.000	7 (2.5)	5 (1.8)	0.771
MV + TV	37 (11.0)	21 (5.2)	0.005	23 (8.1)	16 (5.6)	0.320
MV + TV + maze	31 (9.2)	26 (6.4)	0.195	18 (6.3)	23 (8.1)	0.517
Triple valve						
AV + MV + TV	9 (2.7)	14 (3.4)	0.696	9 (3.2)	7 (2.5)	0.800
AV + MV + TV + maze	9 (2.7)	5 (1.2)	0.242	8 (2.8)	4 (1.4)	0.381
Elective operation	307 (91.1)	383 (94.1)	0.241	259 (90.9)	268 (94.0)	0.205

Values are expressed as n (%). CABG, coronary artery bypass grafting; AV, aortic valve; MV, mitral valve; TV, tricuspid valve.

(53.7% *vs.* 42.8%, P=0.015). The incidence of ventilator-associated pneumonia (1.4% *vs.* 4.9%, P=0.031), cardiac arrest due to cardiac tamponade associated with post-cardiotomy bleeding (0.4% *vs.* 3.9%, P=0.002), and acute kidney injury (2.8% *vs.* 7.7%, P=0.011) was significantly lower in the intensivist group compared to the control group. Clinical outcomes with meaningful results were selected and expressed as OR plots (*Figure 1*).

Discussion

Over the last three decades, the mean age of patients undergoing cardiac surgery and frequency of their comorbid conditions have increased continuously (11). As the preoperative risk of patients undergoing cardiac surgery increases, a growing number of patients develop complications after surgery, leading to longer ICU stays and increased mortality rates (12). Many studies have been conducted to reduce postoperative complications and improve ICU quality (4-6). Studies comparing open and closed ICU models have revealed that the clinical outcomes of closed ICU models are superior to those of open models (4-7,13). The Society of Critical Care Medicine also recommended a closed ICU model because it was associated with a shorter ICU stay and a reduced mortality rate (14). Many ICUs are gradually changing from open to closed systems in accordance with the outcomes of these studies and recommendations. CSICUs are commonly established as open models, in which cardiac surgeons are the physicians with the most responsibilities who cooperate with consultants. Some studies using closed CSICU models have shown that the presence of a full-time intensivist is associated with reduced complications after cardiac surgery (8-10,15). In our previous study, we revealed that critical care provided by the attending intensivist was associated with improvements in CSICU quality and reductions in postoperative complications in patients who underwent elective isolated CABG (16). The results of our previous

Table 3 Demographical and clinical characteristics of patients before and after propensity score matching (not used as covariates for matching)

Variables	All patients				Matched patients			
	Control group (n=337)	Intensivist group (n=407)	SMD	P value	Control group (n=285)	Intensivist group (n=285)	SMD	P value
Body weight (kg)	61.7±11.6	60.4±11.3	0.122	0.098	61.2±11.2	60.6±11.3	0.050	0.547
Height (cm)	161.1±9.2	160.6±9.2	0.052	0.485	160.6±9.2	161.0±9.4	0.044	0.601
Hypertension	141 (41.8)	191 (46.9)	0.102	0.165	125 (43.9)	130 (45.6)	0.035	0.674
Diabetes	58 (17.2)	83 (20.4)	0.081	0.270	54 (18.9)	52 (18.2)	0.018	0.830
History of stroke	45 (13.4)	60 (14.7)	0.040	0.588	39 (13.7)	39 (13.7)	0.001	1.000
CRF	12 (3.6)	27 (6.6)	0.140	0.061	9 (3.2)	20 (7.0)	0.176	0.036
Preoperative CCr (mL/min)	68.7±28.7	58.3±27.4	0.369	<0.001	67.7±28.8	60.9±28.6	0.237	0.005
PVD	17 (5.0)	31 (7.6)	0.106	0.155	15 (5.3)	19 (6.7)	0.059	0.479
COPD	24 (7.1)	46 (11.3)	0.145	0.052	19 (6.7)	30 (10.5)	0.138	0.100
Endocarditis	48 (14.2)	56 (13.8)	0.014	0.850	44 (15.4)	35 (12.3)	0.091	0.275
Previous cardiac surgery	36 (10.7)	49 (12.0)	0.043	0.563	27 (9.5)	34 (11.9)	0.079	0.343
RVSP (mmHg)	43.0±18.7	41.1±17.9	0.104	0.156	41.5±17.4	40.1±17.8	0.028	0.737
LVEF (%)	56.7±11.5	57.9±11.2	0.109	0.140	57.3±11.7	58.6±10.0	0.124	0.140
LVEF <40%	30 (8.9)	31 (7.6)	0.047	0.525	23 (8.1)	15 (5.3)	0.113	0.179

Values are expressed as mean ± standard deviation or number (%). SMD, standardized mean difference; CRF, chronic renal failure; CCr, creatinine clearance; PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; RVSP, right ventricular systolic pressure; LVEF, left ventricular ejection fraction.

study revealed that the 30-day mortality rate decreased in the intensivist group, but we could not find a statistically significant difference between the two matched groups (0.3% *vs.* 1.7%, P=0.219). These findings may be attributed to the significantly lower mortality rate generally observed in patients undergoing elective isolated CABG compared to other forms of cardiac surgeries. In contrast to patients undergoing elective isolated CABG, those undergoing valvular heart surgery are expected to have more comorbidities and relatively higher operative mortality. We expected to find that the intensivist's critical care was associated with a reduced mortality rate in the group of patients undergoing valvular heart surgery. However, we had to consider confounding factors associated with the heterogeneity of the included patients. Additionally, we need to consider that postoperative outcomes can vary greatly depending on the type of surgery, the difficulty of operation, and the surgeon. To solve this problem, we applied propensity score matching techniques to match patients with an equivalent level of predicted mortality and who underwent similar surgeries by the same surgeon. We used the EuroSCORE II risk-scoring system to compare patients with similar levels of predicted mortality. After propensity score matching was performed, the mean EuroSCORE II of the two matched groups did not differ significantly. Although we have several cardiac surgeons at our institution, we only included patients operated on by two cardiac surgeons (surgeons A and B) who worked at our institution throughout the research period and had more than 10 years of surgical experience in 2007. Although the surgical or anesthetic policy for performing valvular heart surgery did not change significantly during the research period, we matched patients according to every type of valvular heart surgery, including co-operations such as the Maze procedure, CABG, and aortic surgery. We also used CPB and operative times as covariates for matching to reflect the difficulty of the operation. Through these processes, we expected that the differences between the two matched groups, except for the presence of an attending surgical intensivist, would be minimized.

The primary outcome was the 30-day mortality rate. In contrast to the results of our previous study, we found that the 30-day mortality rate in the intensivist group was significantly lower than that of the control group. We

Table 4 Comparison of clinical outcomes between control group and intensivist group after propensity score matching

Clinical outcomes	Control group (n=285)	Intensivist group (n=285)	P value	OR (95% CI)
Mechanical ventilation				
Duration of mechanical ventilation (hours)	39.2±115.3	21.8±69.8	0.021	–
Mechanical ventilation >48 hours	34 (11.9)	20 (7.0)	0.066	0.56 (0.31–0.99)
Extubation within 6 hours	122 (42.8)	153 (53.7)	0.015	1.55 (1.11–2.16)
Re-intubation within 72 hours after extubation	12 (4.2)	6 (2.1)	0.238	0.49 (0.18–1.32)
Ventilator-associated pneumonia	14 (4.9)	4 (1.4)	0.031	0.28 (0.09–0.85)
ICU and hospital stay				
Length of ICU stay (hours)	71.9±143.7	56.3±117.6	0.146	–
ICU stay >72 hours	49 (17.2)	37 (13.0)	0.201	0.72 (0.45–1.14)
Length of hospital stay (days)	14.3±13.2	14.1±12.8	0.835	–
Hospital stay >14 days	80 (28.1)	75 (26.3)	0.638	0.92 (0.63–1.32)
Post-cardiotomy bleeding				
Re-sternotomy for bleeding control	20 (7.0)	15 (5.3)	0.458	0.74 (0.37–1.47)
Cardiac arrest due to cardiac tamponade	11 (3.9)	1 (0.4)	0.002	0.09 (0.01–0.68)
Re-exploration in the ICU	13 (4.6)	3 (1.1)	0.013	0.22 (0.06–0.79)
Post-cardiotomy ECMO support				
VA-ECMO initiated in the OR	6 (2.1)	5 (1.8)	1.000	0.83 (0.25–2.75)
Bedside VA-ECMO insertion in the ICU	12 (4.2)	2 (0.7)	0.013	0.16 (0.04–0.73)
ECPR cases	7 (2.5)	2 (0.7)	0.180	0.28 (0.06–1.37)
ECPR time (minutes)	31.0±10.7	16.5±2.1	0.040	–
Successful weaning from ECMO	6 (33.3)	4 (57.1)	0.378	2.56 (0.32–23.7)
Postoperative complications				
Delirium	13 (4.6)	5 (1.8)	0.077	0.37 (0.13–1.06)
Cardiac arrest	15 (5.3)	6 (2.1)	0.078	0.39 (0.15–1.01)
Deep sternal wound infection	6 (2.1)	2 (0.7)	0.219	0.33 (0.07–1.64)
Acute kidney injury	22 (7.7)	8 (2.8)	0.011	0.35 (0.15–0.79)
Stroke	17 (6.0)	8 (2.8)	0.078	0.46 (0.19–1.07)
30-day mortality	19 (6.7)	6 (2.1)	0.015	0.30 (0.12–0.77)

Values are expressed as mean ± standard deviation or number (%). OR, odds ratio; CI, confidence interval; ICU, intensive care unit; VA-ECMO, veno-arterial extracorporeal membrane oxygenation; OR, operating room; ECPR, extracorporeal cardiopulmonary resuscitation.

assumed that this finding would be related to a decreased incidence of postoperative complications and improved quality of care in CSICU. We investigated the related variables in both groups by dividing them into five categories: mechanical ventilation, ICU and hospital stay, post-cardiotomy bleeding, VA-ECMO support, and postoperative complications. The mean duration of mechanical ventilation was significantly shorter in the intensivist group than in the control group. The frequency of prolonged mechanical ventilation was also reduced in the intensivist group; however, this difference was not statistically significant. These findings were likely due to

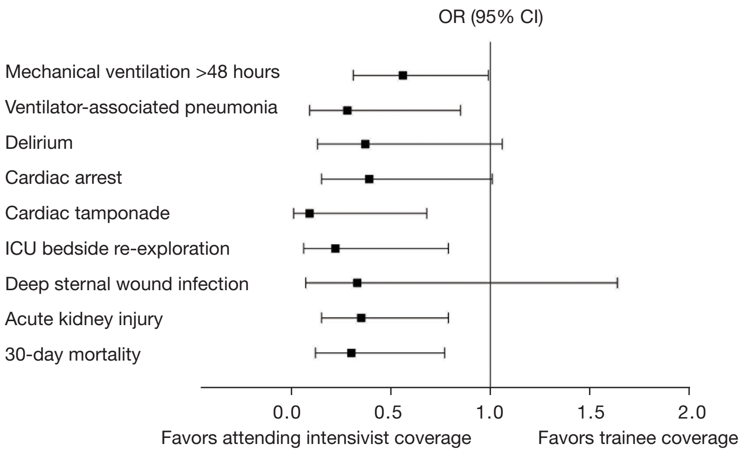

Figure 1 OR plot of clinical outcomes in trainee coverage and attending intensivist coverage. OR, odds ratio; CI, confidence interval; ICU, intensive care unit.

earlier extubation in the intensivist group (17). In fact, we found that significantly more patients were extubated within 6 hours in the intensivist group than in the control group. Extubation within 6 hours was considered a criterion for a successful fast-track ventilator weaning protocol (18). Since the introduction of attending intensivist, a protocol for fast-track ventilator weaning has been employed. Once the patient meets criteria (elective surgery, awake, hemodynamically stable, minimal bleeding), a spontaneous-breathing trial is initiated. The trial involves the utilization of pressure support ventilation, with a pressure support level of 8 cmH_2O and a positive end-expiratory pressure of 5 cmH_2O. Patients who tolerate the spontaneous-breathing trial for 30 minutes without tachypnea, hypoxia, or hemodynamic instability are subsequently extubated. The number of patients who required reintubation within 72 hours after extubation did not differ significantly between the two matched groups, even though the rate of early extubation was higher in the intensivist group. This may indicate that the decision to extubate in the intensivist group was more appropriate. Because VAP and delirium are associated with prolonged mechanical duration (19,20), we expected a reduced rate of both complications. As expected, the incidence of VAP was significantly lower in the intensivist group compared with that in the control group. Although we could not find statistical significance, the incidence of delirium in the intensivist group was lower than that in the control group. These results may be very meaningful because the rate of reintubation and the incidence of VAP are among the indicators related to ICU quality that are recommended by the European Society of Intensive Care Medicine (21). The two matched groups did not differ significantly in terms of ICU and hospital stays, in contrast to the results of our previous study (16). Prolonged ICU stay, especially that longer than 72 hours, in patients undergoing cardiac surgery is associated with higher hospital mortality and lower long-term survival rates (22). Although we found that the average length of ICU stay was shorter and the proportion of patients with prolonged ICU stay was lower in the intensivist group, the difference was not statistically significant. One possible explanation for these findings is that shortening the ICU stay only by early extubation in patients undergoing valvular heart surgery may be difficult because they had more comorbid conditions and a higher perioperative risk than those undergoing elective isolated CABG. In fact, when we compared the average EuroSCORE II of patients in the intensivist group between this study and our previous study, the average EuroSCORE II of patients who underwent valvular heart surgery was higher than that of patients who underwent elective isolated CABG (6.6 *vs.* 1.9, after matching). Post-cardiotomy bleeding was one factor that prolonged the length of ICU stay in patients undergoing valvular surgery, besides mechanical ventilation, in relation to their higher perioperative risk. Compared with the results of our previous study, the rate of re-sternotomy for bleeding control in patients undergoing valvular surgery was higher than that in those undergoing elective isolated CABG (5.3% *vs.* 1.0%, intensivist group, after matching). In the present study, although the rate of re-sternotomy for bleeding control did not differ significantly between the two matched groups, the rate of cardiac arrest due to cardiac tamponade was significantly lower in the intensivist group. The intensivist group also exhibited a lower rate of re-exploration in the ICU due to hemodynamic instability. These findings may be due to the early diagnosis of critical post-cardiotomy bleeding prior to the development of cardiac tamponade. Although the protocol for re-exploration was not different between the two groups (mediastinal bleeding exceeding 200 mL/h for 4 hours or suspected cardiac tamponade), a notable change became evident in the diagnostic approach for cardiac tamponade after the introduction of intensivist. While the diagnosis of cardiac tamponade primarily depends on its characteristic physiology rather than echocardiography, the latter could serve as a valuable tool in assessing the need for re-exploration. Because the attending intensivist in this study was a certified echocardiologist, he performed regular echocardiograms and communicated with cardiac surgeons regarding the test results. Echocardiographic examination was performed more frequently in patients who were likely to develop cardiac tamponade due to postoperative bleeding. If the test results suggested impending cardiac tamponade, the result was promptly reported to the cardiac surgeon, and the decision to transfer the patient to the OR for re-exploration was made immediately. We believe that the reduced number of cases of cardiac arrest or re-exploration at the ICU bedside due to cardiac tamponade may be associated with regular echocardiographic examinations by the attending intensivist. These results may also have been attained because the attending intensivist thoroughly understood cardiac surgery and could communicate clearly with the cardiac surgeons, since the attending intensivist was board-certified in both cardiothoracic surgery and critical care. The advantage of an attending intensivist could also be found in the group of patients who were supported with VA-ECMO postoperatively. Although the number of cases of VA-ECMO initiated in the OR did not differ between the two matched groups, the incidence of VA-ECMO inserted at the ICU bedside, including ECPR cases, was significantly lower in the intensivist group. These findings may also be due to immediate intervention by the attending intensivist in response to changes in the patient's vital signs, which led to the achievement of hemodynamic stability (23). Because the attending intensivist, as a primary decision maker, always remained in the CSICU during the daytime, the decision on most medical issues was made quickly. As a result, most patients were stabilized without ECMO insertion. Even if ECMO support was required, it was possible to proceed quickly, as evidenced by the significantly shorter ECPR time in the intensivist group. We also found that the incidence of AKI in the intensivist group decreased significantly. In the same context as mentioned above, these results might be because the attending intensivist immediately corrected electrolyte and metabolic abnormalities with appropriate management including fluid replacement, although further research is needed to support this hypothesis. In addition, we believe that the introduction of attending intensivist would be helpful for the management of human resources at our department. While the intensivist worked, the residents and fellows could concentrate on their work in the OR, improving the quality of training. Because the attending intensivist was in charge of not only medical management but also family care in the CSICU, surgeons could be free from concerns about CSICU patients and were able to focus on their original duties, such as surgery and research. Perfusionists were also able to significantly reduce the burden of ECMO-related work, which led to improved work efficiency. However, these benefits will need to be verified with specific data through future studies.

Our study has several limitations. First, we included all patients who underwent valvular surgery regardless of the type of operation. Although we used the propensity score matching technique to overcome the heterogeneity of the included patient population, it would be difficult to minimize the differences between the two matched groups, except for the presence of an attending intensivist. However, in our previous study, despite including more homogeneous patient populations who underwent elective isolated CABG, we failed to find a significant difference in 30-day mortality rate between the two matched groups (16). Although it could be pointed out that the heterogeneity of the population might lead to problems when interpreting our results, we included all patients who were managed postoperatively by the attending intensivist and finally succeeded in determining whether the presence of the attending intensivist positively affected 30-day mortality rate in patients undergoing valvular heart surgery using the same method as that in our previous study. It should also be taken into account that this study involved a much more homogeneous group of patients than previous studies including patients who underwent all types of heart surgery, including CABG, valve surgery and transplantation (9,10). The second limitation is that it is difficult to clearly distinguish the specific impact of an intensivist's presence from other time-dependent factors, because we divided patients into two groups based on the time period. These factors encompass various aspects, such as the progressive improvement of surgical skills, advancements in the surgical environment, development in medications and equipment as well as improvements in postoperative care standards and the competency of nursing staff. It is widely acknowledged that surgical outcomes tend to exhibit an overall improvement as time progresses, a trend consistently observed across various databases (24). To overcome this problem, we included patients operated on by only two established cardiac surgeons who already had more than 10 years of surgical experience in 2007. Nevertheless, the reduction in 30-day mortality rate could be interpreted not because of the presence of an attending intensivist, but because the surgeons' surgical skill improved over time. However, when comparing the two groups of patients after matching, we found that the intensivist group had lower preoperative creatinine clearance and a higher incidence of chronic renal failure. It could be interpreted that patients in the intensivist group had a higher preoperative risk despite propensity score matching. Nevertheless, reduced incidence of AKI in the intensivist group could be a basis for stating that the presence of the attending intensivist reduced mortality in addition to the gradual improvement of the cardiac surgeon's skill. In addition, although it is true that this propensity-matched retrospective before-and-after observational study has statistical weaknesses, it should be considered that the same analysis method was applied in previously published studies (8,9). Finally, only one intensivist was included in this study. This limitation is the same as that mentioned in our previous study. More meaningful results could have been obtained if a homogeneous group of intensivists had been included in this study. However, recruiting ICU staff who are board-certified in both cardiothoracic surgery and critical care is a difficult task due to the lack of intensivists. For the same reason, previous studies have evaluated the impact of a heterogeneous group of intensivists with different specialties (8,10). It would be interesting to investigate whether homogeneous groups of intensivists with the same specialty had a greater impact on the clinical outcomes of patients admitted to the CSICU.

Conclusions

We found that transitioning from an open ICU model with trainee coverage to a closed ICU model with attending intensivist coverage resulted in improved clinical outcomes. Our findings suggest that the presence of an attending intensivist board-certified in both cardiothoracic surgery and critical care would be associated with a reduction of postoperative complications and 30-day mortality rate in patients undergoing valvular heart surgery.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-581/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (IRB No. B-2111-721-101). Informed consent was waived because of the retrospective nature of the study and the analysis using anonymized clinical data.

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