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Assessing the clinical impact of cardiac intensivists in cardiac intensivecare units: results from the RESCUE registry

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Abstract

Background The presence of dedicated intensive care unit (ICU) physicians is associated with reduced ICU mortality. However, the information available on the role of cardiac intensivists in cardiac ICUs (CICUs) is limited. Therefore, we investigated the association of cardiac intensivist–directed care with clinical outcomes in adult patients admitted to the CICU.

Methods In this retrospective study, we extracted data from the SMART-RESCUE registry, a multicenter, retrospective, and prospective registry of patients presenting with cardiogenic shock. Overall, 1,247 patients with CS were enrolled, between January 2014 and December 2018, from 12 tertiary centers in Korea. The patients were categorized into two groups based on the involvement of a cardiac intensivist in their care. The primary outcome was in-hospital mortality rate.

Results The all-cause mortality rate was 33.6%. The in-hospital mortality rate was lower (25.4%) in the cardiac intensivist group than in the non-cardiac intensivist group (40.1%). Cardiac mortality rates were 20.5% and 35.4% in the cardiac intensivist and non-cardiac intensivist groups, respectively. In patients undergoing extracorporeal membrane oxygenation, the mortality rate at centers with cardiac intensivists was 38.0%, whereas that at centers without cardiac intensivists was 62.2%. The dopamine use was lower, norepinephrine use was higher, and vasoactive-inotropic score was lower in the cardiac intensivist group than in the non-cardiac intensivist group.

Conclusions Involvement of a cardiac intensivist in CICU patient care was associated with a reduction in in-hospital mortality rate and the administration of a low dose of vasopressors and inotropes according to the cardiogenic shock guidelines.

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Keywords Cardiogenic shock, Cardiac intensive care unit, Cardiac intensivist, Vasopressor, Mechanical circulatory support

Background

The mortality rate associated with acute myocardial infarction is high, highlighting the importance of the coronary care unit (CCU), which became more apparent with the advent of percutaneous coronary intervention, substantially affecting the survival rates that were contingent upon the availability of CCUs in hospitals [1, 2]. Furthermore, myocardial infarctions, acute heart failure, valvular disease; the use of intra-aortic balloon pumps, extracorporeal membrane oxygenation (ECMO), invasive left ventricle (LV) temporary mechanical circulatory supports, and left ventricular assist devices; and the pre- and post-operative management of patients with heart transplantation for cardiogenic shock (CS) have led to an increase in intensive care unit (ICU) admissions associated with heart diseases. Especially timely initiation of advanced mechanical circulatory support (MCS), including devices beyond ECMO, has been shown to significantly improve recovery chances in patients with cardiogenic shock. This underscores the importance of rapid decision-making and specialized expertise, which may be more readily available in centers with cardiac intensivists [3, 4]. This shift prompted the transformation of CCUs into cardiac intensive care units (CICUs), emphasizing the importance of cardiac intensivists and leading to a reduction in mortality rates [5–7]. CICUs are further classified into Level 1 to Level 3 for stratification based on the requirements of the type of treatable cardiac disease, including the requirement for nursing personnel [8].

Despite the growing recognition of the significance of CICUs and cardiac intensivists, a shortage of trained personnel, including cardiac intensivists, exists globally and in South Korea. A previous study compared outcomes based on the presence of cardiac intensivists at a single center [5]; however mortality outcomes and guideline-based management have not been compared based on the presence of cardiac intensivists in multicenter studies. Therefore, in this study, we compared mortality differences and adherence to management guidelines based on the presence or absence of cardiac intensivists in hospitals using a multicenter registry.

Methods

Study population

Overall, 1,247 patients from 12 tertiary centers were enrolled in the RESCUE study (**RE**trospective and prospective observational **S**tudy to investigate **C**linical o**U**tcomes and **E**fficacy of left ventricular assist device for South Korean patients with cardiogenic shock, NCT02985008, Registration Date: 2016-12-07)—a multicenter registry of patients with CS—between January 2014 and December 2018. Detailed information and the prospective and retrospective enrollment process of each center have been previously reported [7]. The inclusion criteria were as follows: (1) age ≥ 19 years, (2) systolic blood pressure < 90 mmHg for 30 min or the requirement for inotrope or vasopressor support to achieve a systolic blood pressure > 90 mmHg, and (3) presence of pulmonary congestion and signs of impaired organ perfusion (altered mental status, cold periphery, oliguria < 0.5 mL/kg/h for the previous 6 h, or blood lactate > 2 mmol/L). The exclusion criteria were (1) out-of-hospital cardiac arrest and (2) evidence of septic or hypovolemic shock. Among the 12 centers, 3 hospitals (*n* = 522 patients), including the Samsung Medical Center (*n* = 249), Samsung Changwon Hospital (*n* = 122), and Severance Cardiovascular Hospital (*n* = 181), had cardiac intensivists. In the other nine hospitals, general cardiologists managed their patients in the CICU without changes in staffing. However, in three of these hospitals, patients admitted to the CICU were treated by cardiac intensivists, providing specialized patient management. Cardiac intensivists are defined as physicians who have completed at least a 2-year cardiology fellowship and specialize in treating patients with CS in the CICU. Accordingly, institutions with a cardiac intensivist are defined as CICU Level 1, because it is capable of a full spectrum of mechanical circulatory support and high-intensity management (care directed by cardiac intensivist), and institutions without a cardiac intensivist are defined as CICU Level 2, because general intensivists are present at all times.

Data collection and outcomes

Data were collected using a web-based case-record form. Additional information was obtained from the medical records or by contacting the patients via telephone, if necessary. The primary outcomes were in-hospital mortality and 30-day mortality. The secondary outcomes were in-hospital cardiac- and non-cardiac-associated deaths, readmission, ECMO-associated deaths, extracorporeal cardiopulmonary resuscitation (ECPR)-associated deaths, distal perfusion, left heart venting, shock-to-ECMO time, ECMO maintenance days, frequency of vasopressor and inotrope use, and total ICU and hospital stay durations. The institutional review board of each hospital approved the study protocol and waived the need for written informed consent from the patients enrolled in the retrospective registry. Informed consent was obtained from all the patients enrolled in the prospective registry.

Statistical analysis

Categorical variables were tested using the chi-square or Fisher's exact test, as appropriate, and are presented as numbers and relative frequencies. Continuous variables were compared using Student's *t*-test and are presented as mean ± standard deviation or 25th – 75th percentile with median. Hazard ratios (HRs) and 95% confidence intervals (CIs) were calculated using logistic regression models. In this study, the primary consideration was the belief that the management by cardiac intensivists during hospitalization would significantly influence outcomes. Therefore, in-hospital mortality was chosen as the primary outcome, which led to the use of a logistic regression model. Pair matching between the two groups was conducted using nearest-neighbor matching without replacement. The balance of covariates was assessed before and after matching by comparing the standardized mean differences. For practical purposes, continuous variables were transformed into categorical variables and assessed using the normal range or cutoff values, as determined in previous studies.

Statistical analyses were performed using R Statistical Software (version 4.3.2; R Foundation for Statistical Computing, Vienna, Austria) and SPSS software (version 25, IBM, Armonk, NY, USA), with values of $p < 0.05$ considered statistically significant.

Results

Baseline characteristics

Among the 1,293 patients enrolled in this study, 46 were excluded due to out-of-hospital cardiac arrest ($n = 44$) or withdrawal of consent ($n = 2$). The remaining 1,247 patients were included in the study. Among them, 954 were enrolled retrospectively and 293 were enrolled prospectively. The cardiac intensivist and non-cardiac intensivist groups included 552 (44.3%) and 695 (55.7%) patients, respectively. The average age of the patients was 65.6 ± 13.8 years, 860 (69.0%) of them were men, and the average body mass index was 23.4 ± 3.6 kg/m^2. To assess the differences between the cardiac intensivist group and the non-cardiac intensivist group, 1:1 propensity score matching was conducted, incorporating factors such as age, male sex, systolic blood pressure, diastolic blood pressure, ischemic cause, ST-segment myocardial infarction, chronic kidney disease, and left ventricular ejection fraction (LVEF). The baseline characteristics of both the cardiac intensivist group and the non-cardiac intensivist group, after propensity score matching, are presented in Table 1. Additionally, the baseline characteristics prior to 1:1 propensity score matching are provided in Supplementary Table 1. Even after 1:1 propensity score matching, the non-intensivist group exhibited a higher prevalence of ischemic cause ($p = 0.003$), a greater incidence of ST-segment elevation myocardial infarction ($p = 0.024$), and a higher proportion of current smokers ($p = 0.007$). Conversely, the LVEF was higher in the non-cardiac intensivist group.

In-hospital mortality and ECMO-related outcomes

In-hospital mortality and ECMO-related outcomes with 1:1 propensity score matching are presented in Table 2. The results prior to the implementation of propensity score matching are provided in Supplementary Tables 2 and Supplementary Fig. 1. The primary outcome of all-cause mortality with 1:1 propensity score matching was observed in 354 (32.1%) patients, and it was significantly lower in the cardiac intensivist group ($n = 140$, 25.4%) than in the non-cardiac intensivist group ($n = 214$, 38.8%; $p < 0.001$, Fig. 1a). When differentiating between retrospective and prospective data to assess all-cause mortality, it was observed that in the retrospective data, the mortality rate in the cardiac intensivist group ($n = 104$, 30.9%) was significantly lower than that in the non-cardiac intensivist group ($n = 264$, 42.8%; $p < 0.001$). However, in the prospective data, there was no significant difference between the two groups (cardiac intensivist group, $n = 36$ [16.7%], non-cardiac intensivist group, $n = 15$ [19.2%]; $p = 0.620$). The mortality rates for each year from 2014 to 2018 are presented in Supplementary Fig. 2. Furthermore, the difference in 30-day mortality rate between the two groups emerged early and persisted (HR 0.80, 95% CI 0.74–0.87, log rank $p < 0.001$, Fig. 1b). Following 1:1 propensity score matching, a total of 303 (27.4%) cardiac-associated deaths were observed, with significantly lower cardiac-associated deaths in the cardiac intensivist group ($n = 113$, 20.5%) than in the non-cardiac intensivist group ($n = 190$, 34.4%; $p < 0.001$). No significant difference was observed in non-cardiac-associated deaths (overall, $n = 51$ [4.7%]; cardiac intensivist group, $n = 27$ [4.9%]; non-cardiac intensivist group, $n = 24$ [4.4%], $p = 0.814$] and readmission (overall, $n = 61$ [5.5%]; cardiac intensivist group, $n = 31$ [5.6%]; non-cardiac intensivist group, $n = 30$ [5.4%], $p = 0.927$] between the two groups.

Overall after 1:1 propensity score matching, 436 (39.8%) patients needed ECMO, including 213 (38.6%) patients in the cardiac intensivist group and 223 (40.7%) patients in the non-cardiac intensivist group ($p = 0.762$). The total number of deaths in patients on ECMO was 223 (51.1%), which was significantly lower in the cardiac intensivist group ($n = 81$, 38.0%) than in the non-cardiac intensivist group ($n = 142$, 63.7%; $p < 0.001$). Distal perfusion was performed in 171 (39.2%) patients, significantly more frequently in the cardiac intensivist group ($n = 122$, 57.3%) than in the non-cardiac intensivist group ($n = 49$, 22.0%; $p < 0.001$). Left heart venting was performed in

Table 1 Baseline patient characteristics after propensity score matching

Variables	Overall (n = 1104)	Intensivist group (n = 552)	Non-intensivist group (n = 552)	p-value
Age (years)	64.7 ± 14.0	64.2 ± 14.4	65.3 ± 13.6	0.185
Male sex	759 (68.8)	375 (67.9)	384 (69.6)	0.559
Body mass index (kg/m^2)	23.5 ± 3.6	23.4 ± 3.7	23.6 ± 3.5	0.372
Systolic blood pressure (mmHg)	75.0 ± 29.4	76.2 ± 31.5	74.0 ± 26.9	0.231
Diastolic blood pressure (mmHg)	47.4 ± 20.2	48.1 ± 20.5	46.8 ± 19.7	0.317
Heart rate (beats/min)	81.7 ± 34.9	83.1 ± 32.1	81.0 ± 36.9	0.503
Clinical presentation				
Ischemic cause	831 (75.3)	394 (71.4)	437 (79.2)	0.003
ST-segment elevation MI	465 (42.1)	214 (38.8)	251 (45.5)	0.024
Comorbidities				
Diabetes mellitus	391 (35.4)	196 (35.5)	195 (35.3)	0.950
Hypertension	575 (52.1)	280 (50.7)	295 (53.4)	0.366
Dyslipidemia	289 (26.2)	150 (27.2)	139 (25.2)	0.451
Current smoker	322 (29.2)	141 (25.5)	181 (32.8)	0.008
Chronic kidney disease	119 (10.8)	65 (11.8)	54 (9.8)	0.286
Peripheral arterial occlusive disease	47 (4.3)	20 (3.6)	27 (4.9)	0.297
Prior MI	116 (10.5)	53 (9.6)	63 (11.4)	0.326
Prior cerebrovascular accident	102 (9.2)	56 (10.1)	46 (8.3)	0.299
Left ventricular ejection fraction, %	37.4 ± 16.5	36.1 ± 16.8	38.9 ± 16.1	0.007
Laboratory parameters				
Hemoglobin (g/dL)	12.7 ± 2.6	12.6 ± 2.6	12.8 ± 2.7	0.111
Platelets (x10^3/μL)	211.4 ± 81.5	208.1 ± 84.2	214.7 ± 78.6	0.186
Total bilirubin (mg/dL)	1.0 ± 1.9	1.1 ± 2.2	1.0 ± 1.4	0.102
Aspartate transaminase (U/L)	258 ± 947	269 ± 811	246 ± 1070	0.687
Alanine transaminase (U/L)	149 ± 471	175 ± 498	123 ± 442	0.071
Serum creatinine (mg/dL)	1.6 ± 1.4	1.6 ± 1.4	1.5 ± 1.5	0.117
Glucose (mg/dL)	222 ± 120	215 ± 114	229 ± 125	0.058
Lactate (mmol/L)	6.7 ± 4.6	6.5 ± 4.4	7.0 ± 4.8	0.115

Values are presented as mean ± standard deviation or n (%)

MI, myocardial infarction

Table 2 In-hospital mortality and ECMO-related outcomes after propensity score matching

Variables	Overall (n = 1,104)	Intensivist group (n = 552)	Non-intensivist group (n = 552)	p-value
All-cause death (%)	354 (32.1)	140 (25.4)	214 (38.8)	< 0.001
Cardiac death (%)	303 (27.4)	113 (20.5)	190 (34.4)	< 0.001
Non-cardiac death (%)	51 (4.7)	27 (4.9)	24 (4.4)	0.814
Readmission	61 (5.5)	31 (5.6)	30 (5.4)	0.895
ECMO				
ECMO death (%)	223 (51.1)	81 (38.0)	142 (63.7)	< 0.001
ECPR death (%)	137 (65.6)	44 (53.1)	93 (72.7)	0.007
Distal perfusion (%)	171 (39.2)	122 (57.3)	49 (22.0)	< 0.001
Left heart venting (%)	26 (6.0)	20 (9.4)	6 (2.7)	0.003
Shock-to-ECMO time (minutes)	403.3	382.4	424.0	0.610
ECMO maintenance period (days)	5.6 (2.0–7.0)	6.1 (2.0–7.0)	4.8 (2.0-6.8)	0.049
ECMO maintenance period of survivors (days)	5.8 (2.0–7.0)	6.4 (2.0–7.0)	4.8 (2.0–6.0)	0.059

ECMO, extracorporeal membrane oxygenation; ECPR, extracorporeal cardiopulmonary resuscitation

26 (5.2%) patients, again more frequently in the cardiac intensivist group ($n = 20$, 9.4%) than in the non-cardiac intensivist group ($n = 6$, 2.7%; $p = 0.003$). No significant difference was observed between the two groups in shock-to-ECMO time (cardiac intensivist group, 382.3 min; non-cardiac intensivist group, 424.0 min; $p = 0.610$). The duration of ECMO maintenance was shorter in the non-intensivist group than in the cardiac

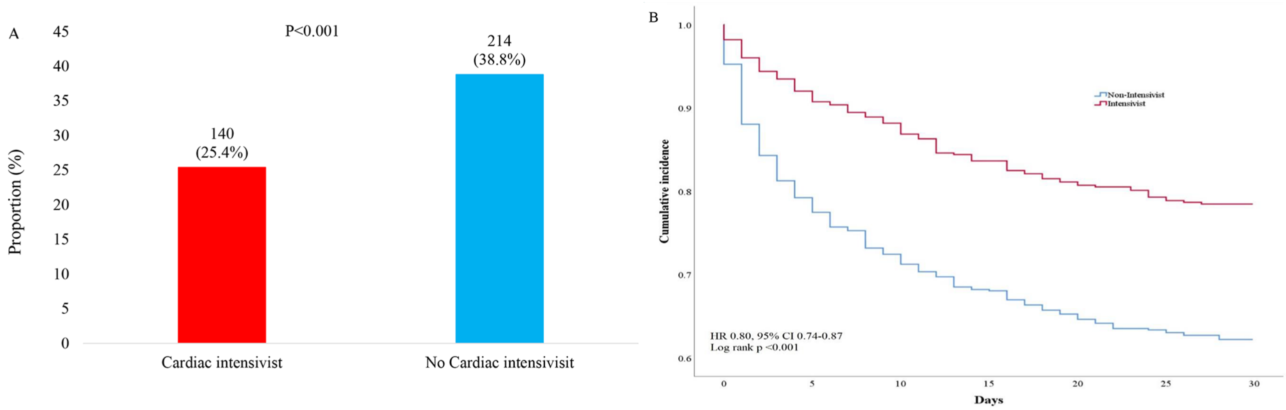

Fig. 1 Primary outcomes. **(A)** Comparison of in-hospital death between the cardiac intensivist and non-cardiac intensivist groups after propensity score matching. (**B**) Cumulative 30-day survival of the patients according to the presence or absence of cardiac intensivists. Cumulative survival was estimated using the Kaplan–Meier method and compared using log-rank tests

Table 3 In-hospital management methods with propensity score matching

Variables	Overall (*n* = 1104)	Intensivist group (*n* = 552)	Non-intensivist group (*n* = 552)	*p*-value
Dopamine	658 (59.6)	209 (37.9)	449 (81.3)	< 0.001
Dobutamine	425 (38.5)	210 (38.0)	215 (38.9)	0.757
Epinephrine	73 (6.6)	25 (4.5)	48 (8.7)	0.005
Norepinephrine	618 (56.0)	362 (65.6)	256 (46.4)	< 0.001
Vasoactive-Inotropic Score	70.4 ± 127.0	65.1 ± 103.3	75.7 ± 146.8	0.165
Mechanical ventilator	612 (55.4)	293 (53.1)	319 (57.8)	0.115
Continuous renal replacement therapy	257 (23.3)	129 (23.4)	128 (23.2)	0.943
Intra-aortic balloon pump	267 (24.2)	137 (24.8)	130 (23.6)	0.623
Extracorporeal membrane oxygenator	436 (39.5)	213 (38.6)	223 (40.4)	0.538
Extracorporeal cardiopulmonary resuscitation	209 (18.9)	81 (14.7)	128 (23.2)	< 0.001
ICU stay, days (Total patients)	9.7 (2.0–12.0)	11.7 (2.0-13.8)	7.7 (1.0–10.0)	< 0.001
Hospital stay, days (Total patients)	15.1 (4.0–18.0)	17.4 (6.0–21.0)	12.8 (4.0–16.0)	< 0.001
ICU stay, days (Survivors)	10.1 (2.0–11.0)	11.9 (3.0–13.0)	7.9 (2.0–9.0)	< 0.001
Hospital stay, days (Survivors)	17.0 (6.0–11.0)	18.3 (7.0–23.0)	15.3 (5.0-17.3)	0.023

Values are mean ± standard deviation or n (%)

ICU, intensive care unit

intensivist group (cardiac intensivist group, 6.1 d; non-cardiac intensivist group, 4.8 d; $p = 0.049$). Overall, 209 (18.9%) patients underwent ECPR, including 81 (14.7%) patients in the cardiac intensivist group and 128 (23.2%) in the non-cardiac intensivist group ($p < 0.001$). ECPR deaths were observed in 137 (66.3%) patients, with a significantly lower mortality rate in the cardiac intensivist group ($n = 44$, 53.1%) than in the non-cardiac intensivist group ($n = 93$, 72.7%; $p < 0.001$).

In-hospital management methods

Management strategies used in the hospitals, including the administration of vasopressors and inotropics following 1:1 propensity score matching, are presented in Table 3. The data prior to propensity score matching is provided in Supplementary Table 3. The frequency of use of the commonly used vasopressors for CS, including dopamine and norepinephrine, are also presented in Table 3. Dopamine was used in 658 (59.6%) patients, at a lower frequency in the cardiac intensivist group ($n = 209$, 37.9%) than in the non-cardiac intensivist group ($n = 49$, 81.3%; $p < 0.001$), and norepinephrine was used in 618 (56.0%) patients, at a higher frequency in the cardiac intensivist group ($n = 362$, 65.6%) than in the non-cardiac intensivist group ($n = 256$, 46.4%; $p < 0.001$). Epinephrine was used in 73 (6.6%) patients, at a lower frequency in the cardiac intensivist group ($n = 25$, 4.3%) than in the non-cardiac intensivist group ($n = 48$, 8.7%, $p = 0.005$). However, no significant difference was observed in dobutamine use between the two groups (overall, $n = 425$ [38.5%]; cardiac intensivist group, $n = 210$ [38.0%]; non-cardiac intensivist group, $n = 215$ [38.9%], $p = 0.757$]. The vasoactive-inotropic score (VIS), which indicates the use of high doses of vasopressors and inotropics, was 70.4 ± 127.0 in the total patient cohort following 1:1 propensity score matching. Within this cohort, the score

Table 4 Predictors of mortality in the cardiac intensive care unit identified through multivariate logistic regression analysis

Variables	OR	95% CI	*p*-value
Cardiac intensivists	0.474	0.311–0.725	0.001
Age (per 1 year)	1.031	1.015–1.047	< 0.001
Female sex	1.231	0.824–1.839	0.310
BMI (per kg/m^2)	0.970	0.921–1.023	0.259
CKD	2.817	1.601–4.957	< 0.001
CPR before ICU admission	0.199	0.717–4.909	0.199
Lactate (per 1 mmol/L)	1.107	1.061–1.156	< 0.001
Dopamine	1.731	1.129–2.655	0.012
Dobutamine	1.197	0.802–1.786	0.378
Epinephrine	1.748	0.833–3.666	0.139
Norepinephrine	2.464	1.615–3.760	< 0.001
Milrinone	0.411	0.061–2.744	0.358
Vasopressin	3.133	1.542–6.363	0.002
STEMI	1.577	1.054–2.361	0.027
ECMO	3.838	2.487–5.925	< 0.001
ICU stay (per days)	0.992	0.978–1.007	0.297

OR, odds ratio; CI, confidence interval; BMI, body mass index; CKD, chronic kidney disease; CPR, cardiopulmonary resuscitation; ICU, intensive care unit; STEMI, ST-elevation myocardial infarction; ECMO, extracorporeal membrane oxygenation

was 65.1 ± 103.3 in the cardiac intensivist group and 80.0 ± 157.8 in the non-cardiac intensivist group, with no significant difference between the two groups ($p = 0.165$).

Regarding the length of stay, the total patient cohort after 1:1 propensity score matching had a longer ICU stay (overall, 9.7 d; cardiac intensivist group, 11.7 d; non-cardiac intensivist group, 7.7 d; $p < 0.001$) and hospital stay (overall, 15.1 d; cardiac intensivist group, 17.4 d; non-cardiac intensivist group, 12.8 d; $p < 0.001$). Moreover, a longer ICU stay was observed among the survivors (overall, 10.1 d; cardiac intensivist group, 11.9 d; non-cardiac intensivist group, 7.9 d; $p < 0.001$).

Prognostic predictors in the CICU

We conducted a multivariate analysis of the 15 factors that could increase mortality in the ICU (Table 4). A higher CICU mortality rate was associated with an older age, chronic kidney disease, high lactate levels, vasopressor use—including dopamine, norepinephrine, and vasopressin—and the need for ECMO. Furthermore, the presence of cardiac intensivists in this group led to a decreased mortality rate.

Discussion

In this study, we analyzed the CS outcomes of heart team approach in centers with and without cardiac intensivists. While the heart team approach is pivotal in managing complex cardiovascular conditions, particularly in the acute and procedural settings, our study underscores the critical role of cardiac intensivists in providing continuous, specialized care within the CICU. Unlike heart team members who often convene during specific decision-making junctures, cardiac intensivists are involved in the day-to-day management of critically ill patients, ensuring adherence to evidence-based guidelines, optimizing the use of advanced monitoring and therapies, and facilitating timely interventions such as mechanical circulatory support (MCS). This sustained, specialized oversight likely complements and enhances the heart team approach by bridging gaps between procedural and longitudinal care, ultimately contributing to improved outcomes in patients with cardiogenic shock.

As hypothesized, the mortality rate was lower in centers with cardiac intensivists. The difference in mortality rate was observed from the initial admission and persisted throughout the hospital stay. A significant difference was observed in mortality rates between patients who underwent ECMO and those who underwent ECPR at centers with cardiac intensivists; ECMO, distal perfusion, and left heart venting were performed more frequently in these centers. Moreover, at the centers with cardiac intensivist, more norepinephrine and less dopamine and epinephrine were administered as vasopressors, resulting in a lower VIS. The reason the mortality rates in 2017 and 2018 were lower than those in 2014–2016 is that the data from 2017 to 2018 primarily consisted of more prospective data. The prospective data collected from 2014 to 2016 were from 24 individuals (2.5%), whereas those from 2017 to 2018 were from 269 individuals (91.8%). Collecting data prospectively can present difficulties in terms of obtaining consent from patients who die early, leading to a difference in mortality rate due to selection bias. Our results also showed a difference in mortality rate in the patient data collected retrospectively versus those collected prospectively.

Our study reported improved short-term outcomes in CICUs with cardiac intensivists and more specialized management compared with centers without cardiac intensivists. Previous studies have reported that the presence of specialized intensivists in medical or surgical ICUs is associated with an improved mortality rate [9–13]. Moreover, similar findings have been reported in a study on high-intensity cardiac intensivists in a single center [5]. Although CICUs have been categorized from Levels 1 to 3 based on the presence of cardiac intensivists, monitoring technology, and therapeutic technology, no studies have evaluated outcomes based on CICU levels [8]. Moreover, no multicenter studies, such as ours, have examined outcomes based on the presence of cardiac intensivists.

Rapid ECMO intervention after detection of CS is crucial for outcomes [14, 15]. In this study, there was no statistical significance in the ECMO administration times between the cardiac intensivist and non-cardiac intensivist groups, but there was a tendency for the cardiac intensivist group to administer ECMO preemptively. This could be attributed to the cardiac intensivist group recognizing CS earlier, serving as evidence that they can lower the mortality rate. The need for left ventricular unloading during ECMO due to increased left ventricular afterload and pulmonary edema [16–18] was more frequently addressed in the cardiac intensivist group through left heart venting. Preventing leg ischemia by near-infrared reflectance spectroscopy monitoring and distal perfusion catheter insertion was more frequently observed in the cardiac intensivist group than in the non-cardiac intensivist group [19–21]. The heart team approach is also essential for ECMO insertion and management, particularly with regard to the procedure of left ventricular unloading. In particular, the collaboration with cardiac surgeons, including their advice and involvement in central ECMO insertion and management, is crucial for ensuring patient safety and effective circulatory support. Regarding as another safety concern of MCS, hemadsorption therapy has demonstrated potential in reducing inflammatory mediators, which may alleviate systemic inflammation and improve outcomes in patients with cardiogenic shock, particularly those on ECMO. Similarly, haptoglobin therapy can mitigate hemolysis-associated complications by scavenging free hemoglobin, reducing oxidative stress, and improving organ function. Incorporating these adjunctive therapies into CICU protocols, especially in centers with specialized care, could further optimize patient outcomes, and future studies should explore their integration into routine management strategies [22, 23].

The SOAP-II trial recommended the use of norepinephrine as the first-line treatment for CS due to a higher risk of critical arrhythmias associated with dopamine use [24]. Our study reported a higher use of dopamine than norepinephrine in the non-cardiac intensivist group, whereas norepinephrine was used more frequently in the cardiac intensivist group. Studies have reported worse outcomes with a higher VIS [25, 26], advocating for careful use of inotropes and vasopressors in shock management. This aligns with our finding of a lower VIS in the cardiac intensivist group compared with that in the non-cardiac intensivist group.

Incorporating advanced monitoring techniques, such as continuous hemodynamic assessments and imaging modalities, is crucial for the timely detection of patient deterioration and recovery during mechanical circulatory support. Centers with cardiac intensivists are more likely to implement these advanced monitoring strategies, potentially leading to improved patient outcomes [27].

It is unclear whether ICU and general ward stay durations decrease in hospitals with intensivists and whether survival rates differ depending on the length of stay [28, 29]. Our study reports longer ICU and overall hospital stay durations in the cardiac intensivist group than in the non-cardiac intensivist groups, whereas no difference in the ECMO maintenance period was observed between the groups. The importance of early rehabilitation in critical care is gaining attention [30, 31]; however, resolving severe issues in the ICU before continuing treatment in the general ward is crucial. Readmissions to the ICU, especially within 48 h, increase mortality; therefore, the duration of ICU stay should be carefully considered [32, 33]. We believe that the longer ICU and hospital stays in the cardiac intensivist group were aimed at reducing readmission rates by providing long-term ICU treatment.

This study included only patients directly admitted to CICUs, ensuring that our findings specifically reflect outcomes in cardiac-focused intensive care settings. However, the regional hub-and-spoke model, commonly used in many healthcare systems, may influence patient referral patterns, with more critically ill patients potentially transferred to tertiary CICUs. This dynamic could affect the generalizability of our findings, as outcomes may vary depending on regional resource allocation and the availability of advanced therapies at referring institutions.

Strengths and limitations

To the best of our knowledge, this is the first multicenter study to investigate the differences in survival rate after CS depending on the presence of cardiac intensivists in the hospitals and to verify the proper implementation of treatment according to the guidelines. Another strength of our study is the comprehensive data including details on the survival or death of all patients and the use of vasopressors and inotropes.

Despite these advantages, this study has some limitations. First, the data were collected both prospectively and retrospectively in a non-randomized study; therefore, the possibility of selection bias and confounding factors exists. Second, we did not assess severe indicators that are typically assessed in ICU. Although various assessment tools for predicting outcomes in ICU exist—including the Acute Physiology and Chronic Health Evaluation II score, Sequential Organ Failure Assessment score, and Survival after Veno-arterial ECMO score—this study did not incorporate these scores. We also did not have access to data regarding pulmonary artery catheterization, which would provide an objective assessment of the condition in patients with cardiogenic shock. Moreover, the non-cardiac intensivist group included older patients with lower blood pressure and a higher incidence of ischemia and ST-segment elevation myocardial infarctions. Despite propensity score matching, the proportion of ischemic cause of shock was higher in the non-intensivist group. Thus, the study could have enrolled more severely ill patients in this group. However, data on lactate levels, one of the primary indicators for determining the stage in the Society for Cardiovascular Angiography and Interventions shock classification [34], were collected from both groups and no significant difference was observed between them. Furthermore, the LVEF was better in the non-cardiac intensivist group than in the cardiac intensivist group. Thus, the effect of this bias may not have been significant. Third, only three cardiac intensive care centers were included in the study. However, few professionals specializing in cardiac critical care reside in South Korea; therefore, the number of centers with cardiac intensivists is limited. Therefore, although 12 centers participated in the registry, only three were analyzed as part of the cardiac intensivist group, and the difference in the number of centers between the cardiac and non-cardiac intensivist groups could have influenced the analysis. Fourth, this study did not include long-term outcomes of patients who underwent MCS, nor were data available for patients who progressed to heart transplantation. We acknowledge this limitation, and future research should address this gap by including such data. Fifth, A notable limitation of this study is its single-nation setting, which may restrict the generalizability of our findings to other healthcare systems. The healthcare infrastructure, availability of cardiac intensive care unit (CICU) resources, staffing patterns, and regional referral systems can vary significantly across countries, potentially influencing patient management and outcomes. Future multicenter studies conducted in diverse international settings would be valuable to validate and expand upon our conclusions. Fifth, in patients with cardiogenic shock accompanied by STEMI, one of the most critical factors is early revascularization. However, we were unable to collect door-to-balloon time data for myocardial infarction patients in our dataset, and therefore could not assess outcomes based on revascularization timing. Finally, it should be noted that this study could not provide data on non-cardiologist medical staffing, multidisciplinary teams, nighttime or weekend staffing differences—including physicians, nurses, and pharmacists—and differences in CICU nursing staff. In 2017, the Korean National Health Insurance provided data on the number of ICU bed-to-nurse ratio. Nursing grades were classified as Grade 1 (bed-to-nurse ratio < 0.5), Grade 2 ($0.5 \leq$ bed-to-nurse ratio < 0.63), and Grade 3 ($0.63 \leq$ bed-to-nurse ratio < 0.77). In the cardiac intensivist group, two institutions were categorized as Grade 1 and one as Grade 3, while in the non-cardiac intensivist group of nine institutions, two were classified as Grade 1 and seven as Grade 2. It is a limitation of the study that this data does not cover all periods and that it is challenging to ascertain whether these differences are significant.

Conclusions

This study revealed that centers with cardiac intensivists had reduced in-hospital all-cause and cardiac mortality rates, as well as deaths related to ECMO and ECPR. More specialized ECMO management was observed in the cardiac intensivist group, and lower doses of inotropes and vasopressors were administered according to the guidelines. If future large-scale prospective multicenter trials yield similar results, the need for cardiac intensivists should be further emphasized.

Abbreviations

CCU	Coronary care unit
ECMO	Extracorporeal membrane oxygenation
CS	Cardiogenic shock
ICU	Intensive care unit
CICU	Cardiac intensive care unit
RESCUE	REtrospective and prospective observational Study to investigate Clinical oUtcomes and Efficacy
ECPR	Extracorporeal cardiopulmonary resuscitation
HR	Hazard ratio
CI	Confidence interval
LVEF	Left ventricular ejection fraction
VIS	Vasoactive-inotropic score

Supplementary Information

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Supplementary Material 1

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Not applicable.

Author contributions

DHB, SYL, and JWB had full access to all the study data and were responsible for the integrity of the data analysis. JWB, JHY, and HCK conceptualized and designed the study. All authors contributed to data analysis and collection. All authors revised and approved the final version of the manuscript for submission.

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Data availability

The datasets generated or analyzed in the current study are available from the corresponding author upon reasonable non-commercial requests.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the "Samsung Medical Center" Ethics Committee (approval no. 2016-03-130, April 06, 2016) and the local ethics committees of all the study centers. Retrospective data were exempted from the requirement for consent. Informed consent was obtained from all patients enrolled in the prospective registry.

Consent for publication

No applicable.

Competing interests

The authors declare no competing interests.

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