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ORIGINAL RESEARCH

Is emergency renal replacement therapy in the emergency department as effective and safe as in the intensive care unit? A retrospective observational study

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Abstract

Patients needing renal replacement therapy (RRT) are usually admitted to the intensive care unit (ICU); however, due to limited beds in ICU, emergency RRT is often performed in the emergency department (ED). This study aimed to investigate whether emergency RRT performed in the ED is as effective and safe as in the ICU. This single-center retrospective observational study was conducted at a tertiary medical institution. Among patients who visited the ED from 01 March 2016, to 28 February 2021, the data of those who received RRT within 12 hours of visiting the ED were assessed. The patients were classified into an ICU and an ED group according to the location the first emergency dialysis was performed. In addition, a log-rank test was used to compare the survival rates of the ICU and ED groups. A total of 181 patients were included in this study, and there were no statistically significant differences between the demographic and clinical characteristics of the two groups. The proportion of patients with chronic kidney disease was higher in the ED group ($p = 0.011$), but there was no statistically significant difference in comorbidity rates of diabetes mellitus, hypertension, heart failure, coronary artery disease, and liver disease between the two groups. Additionally, no statistically significant difference was observed in the cumulative survival rate between the two groups (ICU group: 85.3% *vs.* ED group: 82.2%; $p = 0.529$). In conclusion, there was no difference in survival rate between patients who underwent emergency RRT in the ICU and ED and those who received emergency RRT in the ED, indicating that emergency RRT performed in the ED seems to be as effective and safe as in the ICU.

Keywords

Intensive care unit; Emergency department; Renal replacement therapy; Cumulative survival rate

1. Introduction

The intensive care unit (ICU) is an important resource of the medical system and a key location for managing critically ill patients [1, 2]. However, due to the limited number of ICU beds [3, 4], many patients are forced to receive intensive care treatment in the emergency department (ED) [4–6] because delayed admission might worsen their outcomes, leading to increased mortality risks [7, 8]. Further, considering that an ED is specialized for urgent treatments rather than inpatient treatments, depending on hospital settings, it might have insufficient functions for intensive care treatments compared to ICU [9]. Previous studies of patients requiring mechanical ventilation and those with sepsis have shown that longer ED stays worsened their prognoses [5, 6].

Renal replacement therapy (RRT) is a treatment that replaces renal function using a machine and is performed in the ICU [10]. It is indicated for critically ill patients to correct severe electrolyte or acid-base abnormalities due to failing kidney conditions, such as acute kidney injury (AKI), which might be complicated by sepsis, hypovolemia and shock [11]. Among patients visiting the ED, emergency RRT is often required for various reasons, including AKI, pulmonary edema, hyperkalemia, severe metabolic acidosis, and drug poisoning [12–15]. Usually, patients needing RRT are admitted to the ICU, but when the ICU capacity is insufficient, they are referred to the ED for emergency RRT. However, the effects of early RRT on patient prognosis remain controversial [14–17], and there is no literature on the efficacies and safety of RRT between the ED and ICU.

This study assessed the differences in clinical characteristics and outcomes between the patients who received emergency RRT in the ICU with those in the ED to determine whether emergency RRT performed in the ED is as effective and safe as emergency RRT performed in the ICU.

2. Materials and methods

2.1 Study population and setting

This single-center retrospective observational study was conducted at a tertiary medical institution in Incheon, Republic of Korea. The medical institution is a regional emergency medical center, with approximately 70,000 patients visiting the ED annually. Among the patients who visited the ED from 01 March 2016, to 28 February 2021, those who received RRT within 12 hours in the ED were included. Patients who had previously undergone RRT due to end-stage renal disease (ESRD), discontinued RRT due to do-not-resuscitate (DNR) orders and those who had cardiac arrest before RRT were excluded because these data could affect the study outcomes. Patients who were transferred to another hospital during acute treatment and those lost to follow-up were also excluded because their outcomes could not be confirmed.

Patients included in this study were admitted to the ICU if they could be admitted immediately and undergo the first emergency RRT. The first emergency RRT was performed in the ED only when hospitalization was not possible due to shortage of ICU beds. The patients were divided into two groups based on the location where the first RRT was performed. Those admitted and received their first RRT in the ICU were defined as the ICU group, and those who received their first RRT in the ED were defined as the ED group.

The ICUs of the hospital where this study was conducted are divided into medical ICUs and surgical ICUs, and emergency RRT was performed in the medical ICUs. These medical ICUs consist of 30 beds, and there are 66 nurses, with 14–15 per duty working in shifts. There are four nephrologists and four critical care medicine specialists belonging to this hospital. When emergency RRT is performed within the medical ICU, the on-call nephrologist or critical care medicine specialist checks the patient's condition and decides whether to implement RRT. In addition, there are always at least three internal medicine residents on duty in the hospital to help manage the hospitalized patients.

There are a total of 33 beds in the ED of this hospital, and the treatment areas are divided into red (critical), yellow (semi-critical), and green (non-critical) zones. The red and yellow zones consist of two and ten beds, respectively, to treat severe emergency cases. There are a total of 69 nurses in ED, with 12–13 per duty working in shifts, and a total of 12 emergency medicine specialists, with two per duty working in shifts. In addition, there are 11 emergency medicine residents, three of whom are always on duty through shift work to manage the emergency patients. If emergency RRT is needed within the ED due to the shortage of ICU, the emergency medicine specialist on duty assesses the patients' conditions and indications for the RRT. Indications for emergency RRT in our hospital include refractory metabolic acidosis, refractory hyperkalemia, uremic encephalopathy, uremic pericarditis, refractory pulmonary edema and drug intoxication requiring dialysis.

In the red and yellow ED zones, there are patient monitoring equipment to assess the patient's vital signs for each bed for continuous monitoring of patients' blood pressure, pulse rate and respiration rate. Continuous arterial blood pressure monitoring was performed for patients with unstable vital signs. If a patient's vital signs are out of the set range, an alarm is sounded so that the medical staff can quickly intervene. Moreover, it is possible to observe the patient's vital signs not only through each monitoring device in the patient's bed but also through the monitor at the nurse station.

2.2 Data collection

Data were extracted by reviewing the patients' medical records. For vital signs and PaO_2/FiO_2 (P/F) ratio, the values initially measured at the time of the ED visit were used, and laboratory findings were based on the results of the initial examination performed in the ED. To compare the severity of the two groups, the cases who underwent mechanical ventilation and treated with vasoactive agents before starting RRT were recorded for each group, and the worst value of the sequential organ failure assessment (SOFA) score was applied during the first 24 hours after visiting the ED.

The time to visit the ED and the start time of the first RRT of the patients was confirmed by reviewing the medical records, and the door-to-dialysis time was calculated. The elapsed time from ED visit to death was determined through the death records of deceased patients. Mortality outcome was based on patients who died within 7 days since admission to the ED. The length of hospitalization was evaluated only for the surviving patients, excluding those who died within 28 days.

2.3 Statistical analysis

Nominal variables were analyzed using Pearson's chi-squared test or Fisher's exact test and are expressed as frequencies and percentages. Continuous variables were confirmed to have no normal distribution through the Shapiro-Wilk normality test, analyzed using the Mann-Whitney U test, and expressed as median and quartiles. The 7- and 28-day cumulative survival rate between the two groups was estimated using the Kaplan-Meier method and compared using the log-rank test. p values were 2-tailed, and statistical significance was set at $p < 0.05$. Data analysis was conducted using SPSS (version 25.0, SPSS, Inc., Chicago, IL, USA) and SAS 9.4 (IBM Corp., Armonk, NY, USA) software.

3. Results

3.1 Study population

In total, 272 patients underwent emergency RRT in the ED during the study period. Among them, 67 were excluded due to previous ESRD diagnosis and were on regular dialysis, 15 due to discontinued RRT from DNR, 4 due to cardiac arrest before starting RRT, 3 due to transfer to another hospital during acute treatment and 2 due to loss to follow up. Finally, 181 patients were included, among whom 136 were in the ICU group and 45 in the ED group (Fig. 1).

3.2 Diagnosis of emergency RRT patients

The main diagnosis was confirmed by reviewing the medical records of the patients. AKI was the most common

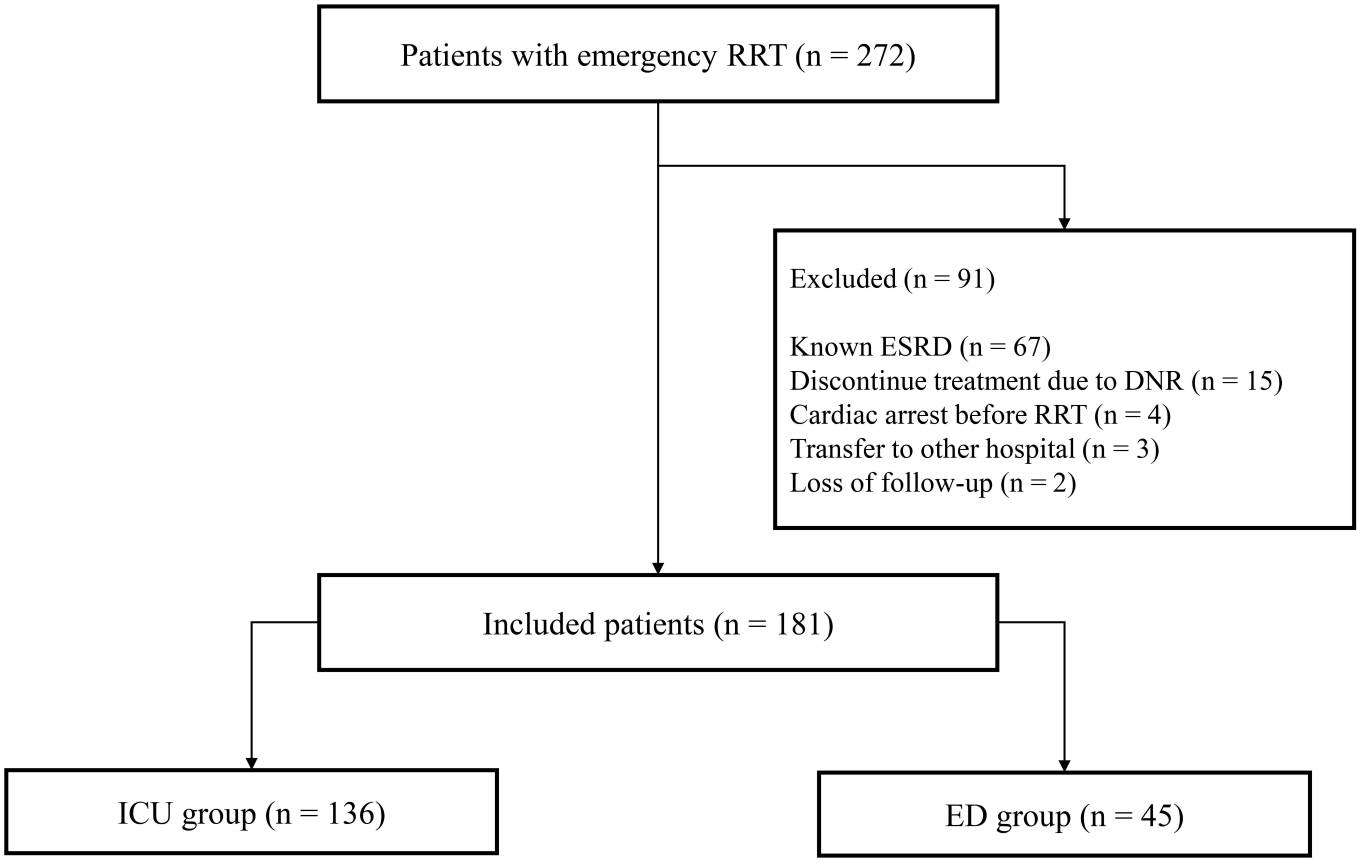

FIGURE 1. Flowchart of study. RRT: renal replacement therapy; ESRD: End-stage renal disease; DNR: Do not resuscitation; ICU: Intensive care unit; ED: Emergency department.

diagnosis in both groups. In addition, pulmonary edema, hyperkalemia, sepsis, chronic kidney disease, metabolic acidosis and drug intoxication were reported, and our analysis showed no statistically significant difference in the distribution of diagnoses between the ICU group and the ED group (p = 0.915) (**Supplementary Table 1**).

3.3 Baseline characteristics

The demographic and clinical characteristics are described in Table 1. There were no differences in age and sex between the ICU and ED groups. Comorbidities assessment between the two groups showed that the proportion of patients with chronic kidney disease was higher in the ED group (p = 0.011), and there was no statistically significant difference in the comorbidity rates of diabetes mellitus, hypertension, heart failure, coronary artery disease and liver disease. There were also no statistical differences in vital signs, P/F ratio and laboratory parameters at the time of the ED visit, and no statistically significant differences in the application of mechanical ventilation and vasoactive agents and the SOFA score between the two groups.

3.4 Clinical results

The clinical results of the two groups are shown in Table 2. The door-to-dialysis time was shorter in the ED group and they received RRT earlier (p = 0.002) than in the ICU group. Comparison of RRT modality showed that the ICU group performed more continuous hemodiafiltration (CHDF), whereas the ED group underwent more hemodialysis, and the length of RRT was longer in the ICU group. The ED length of stay (EDLOS) was longer in the ED group, while both the length of ICU stay and total length of hospital stay were shorter in the ED group. There was no difference in mortality outcomes (within 7 days and 28 days) between the two groups, and there was no statistically significant difference in the cause of death and complications.

3.5 Survival analysis

The 7-day survival curve for the ICU and ED groups is shown in Fig. 2. A total of 28 deaths occurred over the 7 days, with 20 (14.7%) and 8 (17.8%) deaths in the ICU and ED groups, respectively. The 7-day cumulative survival rate between the two groups was 85.3% *vs.* 82.2%, respectively (p = 0.529). The 28-day survival curve for the ICU and ED groups is shown in **Supplementary Fig. 1**.

4. Discussion

Critically ill patients require meticulous management, and the ICU is a specialized setting specially designed for these patients. It offers quick admission and timely systematic treatment. ICU physicians and nursing staff require specialized education and training and cannot be easily replaced by other medical personnel [18]. However, since shortage of ICU beds is frequent, it is not uncommon for some of these less critically

TABLE 1. Comparison of demographic and clinical characteristics between the ICU and ED groups.

Variables	ICU group (n = 136)	ED group (n = 45)	*p*-value
Age (yr)	66.5 (55.0–78.8)	69.0 (57.0–77.0)	0.837
Sex, n (%)			
Male	90 (66.2)	28 (62.2)	0.629
Female	46 (33.8)	17 (37.8)	
Comorbidities, n (%)			
Hypertension	99 (72.3)	29 (64.4)	0.286
Diabetes mellitus	78 (57.4)	24 (53.3)	0.637
Chronic kidney disease	61 (44.9)	30 (66.7)	0.011*
Liver disease	26 (19.1)	5 (11.1)	0.217
Coronary artery disease	13 (9.6)	6 (13.3)	0.575
Heart failure	7 (5.2)	6 (13.3)	0.092
Cancer	5 (3.7)	0	0.334
Vital sign			
Systolic blood pressure, mmHg	119.0 (86.0–152.0)	110.0 (80.5–154.0)	0.580
Diastolic blood pressure, mmHg	62.0 (50.0–83.8)	62.0 (44.0–77.5)	0.297
Body temperature, °C	36.2 (35.5–36.7)	36.2 (35.2–36.8)	0.802
Heart rate, min^{-1}	88.5 (71.0–106.8)	85.0 (65.5–108.0)	0.653
Respiratory rate, min^{-1}	22.0 (18.0–25.0)	20.0 (18.0–25.5)	0.187
P/F ratio	394.8 (272.6–508.3)	336.7 (202.4–504.8)	0.097
Laboratory finding			
White blood cell, 10^9/L	10.0 (7.2–15.3)	11.7 (7.7–14.2)	0.537
Hemoglobin, g/dL	10.1 (8.4–12.2)	9.7 (8.2–11.7)	0.625
Hematocrit, %	31.3 (26.4–37.4)	29.7 (26.0–36.8)	0.821
Platelet, 10^9/L	191 (133.5–255.0)	211 (149.0–265.0)	0.416
Blood urea nitrogen, mg/dL	68.4 (39.7–102.3)	69.6 (33.5–124.6)	0.661
Creatinine, mg/dL	5.0 (3.1–10.4)	5.9 (2.1–11.9)	0.758
Arterial pH	7.22 (7.07–7.32)	7.19 (7.00–7.30)	0.134
Bicarbonate, mmol/L	11.4 (6.2–15.8)	10.8 (5.6–15.9)	0.942
Sodium, mmol/L	133.8 (130.0–137.1)	133.3 (129.8–137.3)	0.629
Potassium, mmol/L	5.8 (4.5–6.9)	5.6 (4.8–7.5)	0.271
Chloride, mmol/L	97.8 (92.4–103.0)	100.1 (92.6–105.7)	0.208
Lactic acid, mmol/L	3.2 (1.2–10.6)	1.8 (1.0–8.6)	0.293
C-reactive protein, mg/dL	1.5 (0.3–4.9)	0.7 (0.2–4.0)	0.100
Medical support, n (%)[a]			
Mechanical ventilation	52 (38.2)	17 (37.8)	0.956
Vasoactive agents	48 (35.3)	16 (35.6)	0.975
SOFA score	6.0 (5.0–9.0)	6.0 (4.5–9.0)	0.950

*Data are presented as number (%) or median (interquartile range). [a]: Medical support applied before starting RRT. ICU: Intensive care unit; ED: Emergency department; SOFA score: Sequential organ failure assessment score; * p value < 0.05.*

TABLE 2. Comparison of the clinical variables between the ICU and ED groups.

Variables	ICU group (n = 136)	ED group (n = 45)	*p*-value
Door-to-dialysis time, hr	6.3 (4.6–7.9)	5.2 (3.1–6.0)	0.002*
Modality of RRT, n (%)			
Hemodialysis	61 (44.9)	28 (62.2)	0.043*
CHDF	75 (55.1)	17 (37.8)	
Length of RRT, hr	6 (3.0–22.25)	3 (2.0–4.0)	<0.001*
Length of stay in ED, min	279.0 (208.5–340.5)	587.0 (442.0–963.5)	<0.001*
Length of stay in ICU[a], day	4.0 (2.0–7.0)	1.5 (1.0–4.0)	0.001*
Length of hospital stay[a]	14.0 (9.0–26.0)	8.0 (6.0–15.0)	0.001*
Location of second RRT, n (%)			
ICU	90 (92.78)	21 (65.63)	<0.001*
Hemodialysis Unit	7 (7.22)	10 (31.25)	
ED	0	1 (3.13)	
Mortality outcome, n (%)			
Death within 7 days	20 (14.7)	8 (17.8)	0.621
Death within 28 days	29 (21.32)	11 (24.4)	0.662
Cause of Death, n (%)			0.780
Metabolic acidosis	14 (48.2)	5 (45.4)	
Sepsis	10 (34.5)	4 (36.4)	
ARDS	3 (10.3)	1 (9.1)	
Gastrointestinal bleeding	1 (3.5)	0	
Liver failure	1 (3.5)	0	
AAA rupture	0	1 (9.1)	
Complications			
Bleeding	67 (49.3)	20 (44.4)	0.575
Thrombocytopenia	47 (34.6)	18 (40.0)	0.51
Hypophosphatemia	37 (27.2)	8 (17.8)	0.205
Hypoglycemia	12 (8.8)	8 (17.8)	0.106
Hypotension	10 (7.4)	3 (6.7)	1
Arrhythmia	5 (3.7)	3 (6.7)	0.413
Catheter site hematoma	3 (2.2)	0	0.576

*Data are presented as number (%) or median (interquartile range). [a]: Evaluated only in the 28-day survival group. ICU: Intensive care unit; ED: Emergency department; RRT: Renal replacement therapy; CHDF: Continuous hemodiafiltration; ARDS: Acute respiratory distress syndrome; AAA: Abdominal aortic aneurysm. * p value < 0.05.*

ill patients to receive intensive care in the ED. Several studies previously reported that critically ill patients treated in the ED had worse clinical outcomes [4–7].

A study by Hung *et al.* [5] reported that for patients on mechanical ventilation, delayed admission to the ICU resulted in worse outcomes, with overcrowding of the ED and insufficient management suggested as causes compared to the ICU. Medical personnel in the ED, including emergency medicine doctors, can also provide critical care, including mechanical ventilation; however, if the number of patients increases due to overcrowding, treatment may be compromised and this might become a major factor that could worsen the clinical outcomes of patients with ED, as well as those critically ill [19, 20]. In addition, a study by Zhang *et al.* [6] reported the association between EDLOS and in-hospital mortality in patients with sepsis. They showed that an EDLOS >12 hours is an independent factor that increases in-hospital mortality.

We compared the clinical course of patients who underwent the first emergency RRT in the ED with those in the ICU. Previous studies showed that a long stay in the ED due to a shortage of ICU beds was associated with worse clinical outcomes. Therefore, similar results were expected in this study. However, we found that EDLOS was significantly higher in the ED group than in the ICU group, and no significant difference was observed in mortality between the two groups. Moreover, the length of stay in the ICU and the

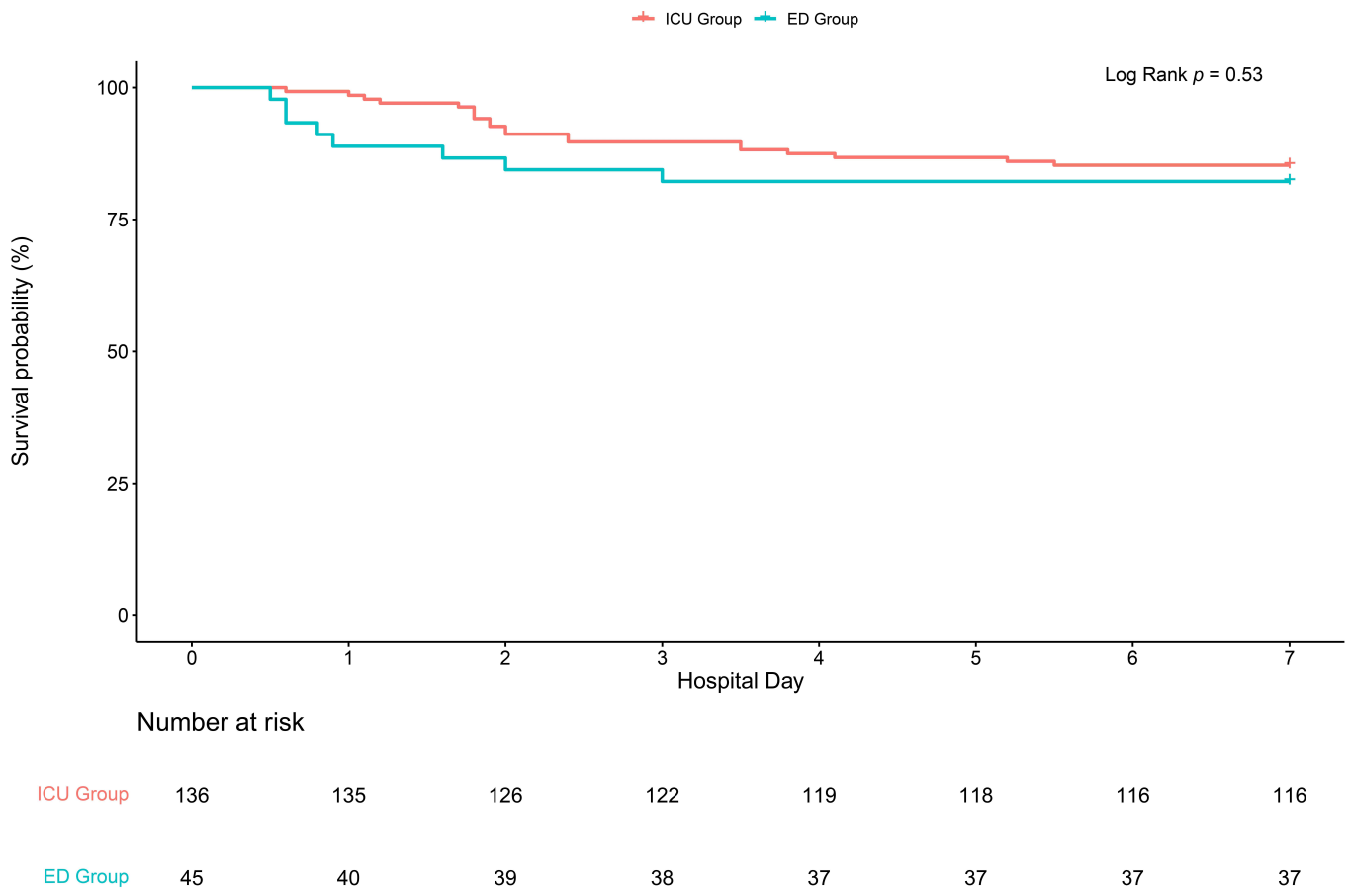

FIGURE 2. Survival analysis by Kaplan-Meier curve. ED: Emergency department; ICU: Intensive care unit.

total hospital stay in the ED group was shorter than in the ICU group. Various factors may have contributed to this finding. First, the implementation of emergency RRT in the ED may be as appropriate as that in the ICU. At the medical institution where this study was conducted, emergency RRT was performed within the ICU under the supervision of an internist who majored in nephrology or critical care medicine. However, if RRT is performed in the ED owing to the shortage of ICU beds, it might be performed under the supervision of an emergency medicine specialist. Considering the specificity of RRT, the competency of an emergency medicine specialist might be insufficient compared to that of a nephrologist; however, emergency medicine specialists can provide critical care with close observation of the patients, similar to the ICU. To allow proper care and monitoring of the patients, it is essential to have equipment and systems equivalent to those in the ICU. Second, it is possible to perform treatment faster in patients receiving emergency RRT in the ED. In our study, the door-to-dialysis time was significantly shorter in the ED group than in the ICU group, which was probably related to the shorter time required for administrative procedures. According to previous studies, it is unclear whether early RRT improves prognosis. Barbar *et al.* [15] reported that early RRT did not improve the prognosis of the patients, and it was controversial whether door-to-dialysis time had a positive effect on mortality. However, providing faster treatment to patients needing RRT does not adversely affect the clinical course. In addition, in the ED group, the length of stay in the ICU may have been shortened because they were admitted to the ICU after a longer period of intensive care in the ED. Moreover, chronic kidney disease was more common as a comorbidity in the ED group, whereas liver disease was relatively more in the ICU group. Differences in these comorbidities may also have contributed to the need for longer intensive care in the ICU group.

Several previous studies have reported that delayed EDLOS was not associated with worse clinical outcomes in patients [21, 22]. Elmer *et al.* [22] reported that prolonged EDLOS was not associated with a worse outcome in patients with intracranial hemorrhage. In this study, a lower GCS score, larger hematoma volume, and endotracheal intubation were associated with poorer neurologic outcomes; however, prolonged EDLOS did not contribute to these outcomes. Interestingly, the more severe the disease, the more rapidly the patient was transferred to the ICU. Conversely, in our study, there was no difference in the severity between the ED and ICU groups. The difference from previous studies might be because it is a study that not only evaluated EDLOS but also observed differences in clinical outcomes of patients depending on the location where the first RRT was performed.

This study compared the prognosis of patients according to the location where the first emergency RRT was performed. Several previous studies reported that prolonged stay in the ED due to the shortage of ICU beds adversely affected the clinical

outcome. However, in our study, there was no significant difference in mortality rate between the ED group and the ICU group. In this study, we inevitably performed RRT in ED only in cases where immediate hospitalization was not possible due to a shortage of ICU beds, and these patients were classified into the ED group. Therefore, it might not be reasonable to interpret the results of this study as ED being a better place to perform emergency RRT than the ICU. However, based on these results, professional techniques, including RRT, can be expanded to ED and emergency medicine in the future. Emergency medicine specialists and nursing staff are specialized personnel who treat emergency patients in the ED and, in some cases, may also need to provide appropriate intensive care. For this, adequate education and training of emergency medical personnel are required, and appropriate patient monitoring equipment and systems should also be supported.

In the Republic of Korea, as the internal medicine residency training period has changed from a 4-year system to a 3-year system since 2017, the number of internal medicine doctors in university hospitals has decreased [23], leading to difficulty in maintaining internal medical personnel in the ED, and the number of hospitals where emergency medicine doctors can make internal medicine admission decisions is increasing [24, 25]. We believe that these changes are urging us to expand beyond the role of emergency medicine, which was limited to resuscitation, to wider areas such as intensive care. In this regard, this study may serve as an opportunity to rethink the role of emergency medicine.

Our study had several limitations. First, as a retrospective study, the selection of variables was limited; in particular, the effect of ED overcrowding could not be investigated. As mentioned above, overcrowding of the ED may affect the treatments and clinical outcomes of the patients. Second, this was a single-center study, which limits the generalizability of the results. This is because the procedure for implementing emergency RRT may be different for each medical institution, and the patient monitoring system in the ED may also be different, further affecting the treatments and potential outcomes of patients undergoing emergency RRT. Despite these limitations, this is the first study to compare the survival rate of emergency RRT patients between the ICU and ED. Multicenter prospective studies with larger cohorts of patients are still needed to analyze more variables and overcome the limitations of this present study.

5. Conclusion

There was no difference in the survival rate between patients who underwent emergency RRT in the ICU and those who received emergency RRT while in the ED. Based on this, emergency RRT performed in the ED could be as effective and safe as emergency RRT in the ICU, suggesting the need for ED medical staff to become familiar with emergency RRT. However, validation studies are needed to confirm our results.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

DSB—designed the study, wrote original draft. TKA—designed the study, analyzed the data, wrote original draft, reviewed and edited. SK—designed the study, analyzed the data, supervised, reviewed and edited. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study protocol was reviewed and approved by the Institutional Review Board of Inha University College of Medicine (IRB No.: 2022-01-023). Informed consent was waived owing to the retrospective nature of the study. The study was conducted in compliance with the principles of the Declaration of Helsinki.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.signavitae.com/mre-signavitae/article/16156252014808104 96/attachment/Supplementary%20material.pdf.

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