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Original Paper

Initiation and Cessation Timing of Renal Replacement Therapy in Patients with Type 1 Cardiorenal Syndrome: An Observational Study

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Keywords
Cardiorenal syndrome · Renal replacement therapy · Initiation timing · Cessation timing · Fluid balance

Abstract
Background/Aims: Renal replacement therapy (RRT) is a rescue therapy for patients with type 1 cardiorenal syndrome (CRS) with poor prognoses. However, the optimal timing for initiation and cessation of RRT remains controversial. The purpose of this study was to determine the optimal timing of initiation and cessation of RRT for patients with type 1 CRS. ***Methods:*** In this retrospective analysis, patients with refractory type 1 CRS receiving RRT were divided into 3 groups according to weaning from RRT and death within 90 days. Baseline characteristics, underlying heart disease, comorbidities, drug use before RRT, indicators of RRT initiation, and prognosis were compared between the 3 groups. ***Results:*** Fifty-two patients were enrolled, which included 27 males and 25 females with a mean age of 70.7 ± 16.1 years and a 90-day mortality rate of 65.4%. The mean urine output before RRT initiation was 800 mL/24 h in the RRT-independent group, 650 mL/24 h in the RRT-dependent group, and 345 mL/24 h in the death group (p = 0.021). Additionally, there were obvious differences in fluid balance between the 3 groups (167, 250, and 1,270 mL, respectively, p = 0.016). Patients could be successfully weaned from RRT when urine output was >880 mL and fluid balance volume was

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<150 mL. ***Conclusion:*** The mean fluid balance of survivors was remarkably less than that of the death group at RRT initiation. RRT termination can be considered when urine output is >880 mL/24 h and volume balance is <150 mL/24 h. © 2017 S. Karger AG, Basel

Introduction

Cardiorenal syndrome (CRS) is defined as a bidirectional disorder between the heart and kidney regardless of which organ has sustained initial damage or has exacerbated the function of the other [1]. Type 1 CRS (acute CRS), which is 1 of the 5 subtypes proposed by Ronco et al. [2], is characterized as worsening renal function (WRF) in the setting of acute decompensated heart failure, chronic heart failure, or de novo heart failure [3]. Although there is no universal consensus on a definition of WRF, it is traditionally recognized as an increase in serum creatinine (SCr) of >26.5 μmol/L (0.3 mg/dL) or >25% during hospitalization as compared with baseline on admission [4].

Type 1 CRS occurs in about 10–40% of patients admitted with acute decompensated heart failure [4–7]. This wide range lies largely in the differences between study patients and variations in initial renal function [4–6]. Current established therapies for type 1 CRS include the use of diuretics, inotropic vasoactive agents, and neurohormonal antagonists [8, 9]. When refractory heart failure symptoms persist despite adequate pharmacological treatment, renal replacement therapy (RRT) is often an effective rescue therapy, although the patients remain at risk of further WRF and may become dependent on dialysis [10]. Moreover, the mortality of refractory acute CRS patients requiring RRT is high, ranging from 11.1 to 62% [11–13]. Because of the high prevalence and mortality of type 1 CRS, treatment remains a great challenge [4, 6].

However, there are no detailed treatment guidelines for RRT in CRS, such as suitable timing of initiation and cessation, therapy dose, ultrafiltration rate, and so on, as treatment is largely based on patient prognosis [14]. Therefore, the aim of this retrospective observational study was to determine the optimal timing of RRT initiation and cessation and to identify associated prognostic factors in patients with type 1 CRS in a tertiary hospital in south-east China.

Patients and Methods

Patients

The cohort of this retrospective study included patients admitted to the internal medicine ward of the First Affiliated Hospital of Nanjing Medical University (Nanjing, China) from May 2009 to April 2015 who met the following inclusion criteria: (1) age ≥18 years; (2) diagnosis of type 1 CRS; and (3) receiving RRT. Exclusion criteria were: (1) pregnancy; (2) receiving RRT before admission; (3) cardiac and vascular surgery-associated acute kidney injury (AKI); (4) contrast nephrology; (5) primary or secondary glomerulonephritis; (6) sepsis-associated AKI; (7) obstructive nephropathy; and (8) type 5 CRS.

RRT Delivery

Central venous catheterization was used for vascular access via the femoral or right-side internal jugular vein. Blood flow was set at 150–200 mL/min in either hemofiltration or hemodiafiltration mode. Replacement fluid was infused at a rate of 30–50 mL/kg/h, and therapy duration ranged from 8 to 24 h per session. Anticoagulant dosage and ultrafiltration volume were formulated jointly by the cardiologists and renal physicians.

Definitions

WRF was defined as an increase in SCr of >26.5 μmol/L or >25% during hospitalization. The definition and stage of AKI were determined according to the Kidney Disease Improving Global Outcomes (KDIGO) guidelines [15]. RRT independence and dependence were defined as weaning from dialysis or not within 90

days. Diuretic resistance was defined as persistent clinical congestion due to inadequate diuresis and natriuresis after daily administration of at least 80 mg of furosemide or an equivalent dose of diuretics [16]. Hyperkalemia was defined as a serum potassium concentration of ≥6.5 mmol/L. Azotemia was defined as a blood urea nitrogen (BUN) concentration of ≥28 mmol/L. Oliguria was defined as urinary volume in 24 h of ≤400 mL. Serious metabolic acidosis was defined by arterial blood pH of <7.25 or bicarbonate concentration of <15 mmol/L. Baseline kidney function in this study was defined as SCr before onset of type 1 CRS at admission or SCr calculated by the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) creatinine formula according to age and sex with the assumption of an estimated glomerular filtration rate of 75 mL/min/1.73 m^2 when type 1 CRS was present at admission [17]. Interval length was defined as the days between type 1 CRS diagnosis and RRT initiation. Chronic kidney disease was diagnosed according to the 2012 KDIGO guidelines [18]. Urine production relative to diuretic dose was described to reflect diuretic efficiency.

Data Collection

Clinical and laboratory data were retrieved from our hospital RRT database and electronic medical records. Underlying heart disease, baseline kidney function, comorbidities, disease severity, echocardiographic findings, RRT-related data, and prognosis within 90 days were recorded. Indices of patients receiving first-time RRT such as SCr, BUN, urine volume within 24 h, fluid balance (input volume minus output volume), and drugs used before RRT initiation within 24 h were recorded. Furthermore, the clinical parameters of cessation timing were recorded on the second day after RRT cessation if the patient was independent of RRT, or collected before the last dialysis during hospitalization if the patient was dependent on RRT.

Statistical Analysis

Data were analyzed using SAS 9.2 software (SAS Institute, Cary, NC, USA). Measurement data are presented as means ± standard deviations. Comparisons between groups were made using the Student *t* test or Kruskal-Wallis test. Categorical data are presented as rates and were compared between groups using the χ^2 test. Univariate and multivariate Cox regression analyses were performed to determine the relationship between initial patient characteristics and 90-day mortality. Receiver operating characteristic (ROC) curves were constructed to predict the prognostic value of urine volume and fluid balance volume. A 2-sided *p* value of <0.05 was considered statistically significant.

Results

Baseline Characteristics of Study Population

A total of 52 patients were enrolled in the study, which included 27 males and 25 females with an average age of 70.7 ± 16.1 years, an average APACHE II score of 14.4 ± 4.2, and a mean SOFA score of 8.7 ± 4.7. The 30- and 90-day mortality rates were 59.6 and 65.4%, respectively.

Patients were divided into 3 groups: death group (n = 34), dialysis-dependent group (n = 9), and dialysis-independent group (n = 9), based on survival and weaning from dialysis within 90 days after initiation of RRT. There were no differences in terms of sex, age, and baseline heart disease between the groups. Twenty-two patients (42.3%) were complicated by chronic kidney disease, and the death group had fewer complications (p = 0.006). Glutamic oxaloacetic transaminase (p = 0.023), total bilirubin (p = 0.033), hemoglobin (p = 0.048), and use of vasopressors (p = 0.014) 24 h prior to dialysis in the survival group were significantly lower than in the death group. In contrast, serum albumin (p = 0.042) and baseline SCr (p = 0.008) levels were higher in the survival group (Table 1).

RRT Parameters

As shown in Table 2, there were no significant differences in the number of treatments (p = 0.710), total treatment time (p = 0.112), treatment duration (p = 0.078), total ultrafiltration volume (p = 0.052), ultrafiltration rate (p = 0.404), and treatment dose (p = 0.636) between the 3 groups.

Table 1. Baseline characteristics of patients

	All (*n* = 52)	RRT independence (*n* = 9)	RRT dependence (*n* = 9)	Death (*n* = 34)	*p* value
Male	27 (51.9)	4 (44.4)	4 (44.4)	19 (55.9)	0.739
Age, years	70.7 ± 16.1	69.2 ± 24.2	72.1 ± 6.2	70.8 ± 15.8	0.669
Comorbidity					
CKD	22 (42.3)	6 (66.7)	7 (77.8)	9 (26.5)	0.006*
Diabetes mellitus	15 (28.8)	3 (33.3)	2 (22.2)	10 (29.4)	0.869
Atrial fibrillation	17 (32.7)	2 (22.2)	5 (55.6)	10 (29.4)	0.259
Baseline heart disease					0.195
Valvular HD	6 (11.54)	0 (0)	1 (11.1)	5 (14.71)	
Pulmonary HD	2 (3.85)	1 (11.1)	0 (0)	1 (2.94)	
Hypertensive HD	7 (13.46)	3 (33.3)	1 (11.1)	3 (8.82)	
Coronary HD	26 (50)	3 (33.3)	5 (55.6)	18 (52.94)	
Cardiomyopathy	8 (15.38)	0 (0)	2 (22.2)	6 (17.65)	
Myocarditis	3 (5.77)	2 (22.2)	0 (0)	1 (2.94)	
APACHE II scores	14.4 ± 4.2	12.8 ± 3.6	13.4 ± 2.4	15.1 ± 4.6	0.358
SOFA scores	8.7 ± 4.7	6.3 ± 4.6	6.3 ± 2.1	10 ± 6.2	0.028*
NYHA classification					0.210
Class II	6 (11.5)	3 (50.0)	0 (0)	3 (50.0)	
Class III	18 (34.6)	3 (16.7)	3 (16.7)	12 (66.7)	
Class IV	28 (53.9)	3 (10.7)	6 (21.4)	19 (67.9)	
AKI stage					0.031
No AKI	6 (11.5)	3 (33.3)	2 (22.2)	1 (2.9)	
1	14 (26.9)	3 (33.3)	2 (22.2)	9 (26.5)	
2	13 (25.0)	2 (22.2)	2 (22.2)	9 (26.5)	
3	19 (36.5)	1 (11.1)	3 (33.3)	15 (44.1)	
Drugs before RRT initiation during 24 h					
Vasopressors	23 (44.2)	1 (11.1)	2 (22.2)	20 (58.8)	0.014*
Vasodilators	15 (28.9)	4 (44.4)	4 (44.4)	7 (20.6)	0.202
Inotropes	21 (40.4)	1 (11.1)	4 (44.4)	16 (47.1)	0.148
Antiarrhythmic	11 (21.1)	1 (11.1)	0 (0)	10 (29.4)	0.119
Furosemide, mg/day	160 (80–240)	80 (60–140)	140 (60–240)	175 (100–260)	0.065
Spirolactone, mg/day	0 (0–20)	0 (0–20)	0 (0–20)	0 (0–20)	0.947
Laboratory data					
WBC, $\times 10^9$/L	10.9 ± 5.9	9.2 ± 3.5	9.5 ± 3.8	11.8 ± 6.8	0.707
Hemoglobin, g/L	101.8 ± 24.9	95.1 ± 23.3	88.0 ± 23.0	107 ± 24.5	0.048*
PLT, $\times 10^9$/L	159 ± 91	202 ± 115	185 ± 105	141 ± 76	0.173
ALT, U/L	26 (13–65)	13 (13–118)	17 (13–26)	39 (16–106)	0.230
AST, U/L	35 (23–102)	23 (13–80)	22 (17–26)	48 (31–115)	0.023*
TBil, μmol/L	10.5 (5.3–22.4)	6.5 (4.1–10.4)	5.2 (3.5–11.5)	13.6 (6.9–26.2)	0.033*
Albumin, g/L	32.7 ± 5.3	35.1 ± 5.0	35.4 ± 4.1	31.3 ± 5.3	0.042*
NT-ProBNP, ng/L	9,000 (3,550–11,883) (*n* = 36)	1,779 (1,360–7,809) (*n* = 6)	8,896 (7,120–9,159) (*n* = 8)	9,564 (4,793–14,222) (*n* = 22)	0.029
Baseline SCr, μmol/L	120 (84–196)	193 (116–248)	226 (153–361)	92 (78–137)	0.003*

Values are *n* (%), means ± standard deviations, or medians with ranges in parentheses. RRT, renal replacement therapy; CKD, chronic kidney disease; HD, heart disease; APACHE, acute physiology and chronic health evaluation; SOFA, sequential organ failure assessment; NYHA, New York Heart Association; AKI, acute kidney injury; WBC, white blood cells; PLT, platelet count; ALT, alanine transferase; AST, aspartate transaminase; TBil, total bilirubin; NT-proBNP, N-terminal pro-B-type natriuretic peptide; SCr, serum creatinine. * $p < 0.05$.

Echocardiographic Parameters

There were significant differences in the left atrial diameter between the RRT-independent group, RRT-dependent group, and death group (31.6 ± 15.1, 49.0 ± 4.5, and 44.4 ± 8.5 mm, respectively, $p = 0.009$). The average left ventricular end-diastolic dimension in the 3 groups was 52.1 ± 7.9, 61.0 ± 10.6, and 56.1 ± 12.5 mm, respectively ($p = 0.302$). The average left ventricular ejection fraction was 52.4 ± 10.9, 51.0 ± 15.8, and 47.9 ± 17.3%, respectively ($p = 0.824$). There were no significant differences in other echocardiographic parameters (online suppl. Table S1; for all online suppl. material, see www.karger.com/doi/10.1159/000454932).

RRT Initiation Timing

The median SCr and BUN at RRT initiation were 307 μmol/L and 25.8 mmol/L, respectively. The median 24-h urine output and fluid balance prior to RRT initiation were 400 mL (interquartile range 270–820 mL) and 740 mL (interquartile range 314–1,620 mL), respec-

Table 2. The RRT parameters of patients

	All (n = 52)	RRT independence (n = 9)	RRT dependence (n = 9)	Death (n = 34)	p value
Number of treatments	4 (2–10)	3 (2–5)	9 (5–11)	3 (2–9)	0.710
Total treatment time, h	28 (17.8–86)	18 (15.2–39.5)	79.8 (52–95)	25.5 (19.5–81)	0.112
Duration, days	6 (3–18)	5 (3–11)	17 (10–20)	4.5 (2–20)	0.078
Total ultrafiltration, per 100 mL	84 (39.5–274)	46 (38–176)	232 (137–322)	77.5 (34–271)	0.052
Ultrafiltration rate, mL/h	282±138	277±159	320±102	274±143	0.404
Treatment dose, L/h	4.0±0.7	4.3±1.0	4.0±0	3.9±0.7	0.636

Values are medians with ranges in parentheses or means ± standard deviations. RRT, renal replacement therapy.

Table 3. RRT indication and initiation timing

	All (n = 52)	RRT independence (n = 9)	RRT dependence (n = 9)	Death (n = 34)	p value
Indication					
Diuretic resistance	10 (19.2)	1 (11.1)	1 (11.1)	8 (23.5)	0.564
Oliguria	34 (65.4)	4 (44.4)	6 (66.7)	24 (70.6)	0.347
Hyperkalemia	6 (11.5)	3 (33.3)	0 (0)	3 (8.8)	0.064
Azotemia	21 (40.4)	1 (11.1)	3 (33.3)	17 (50)	0.100
Severe metabolic acidosis	11 (21.2)	0 (0)	1 (11.1)	10 (29.4)	0.119
Initiation timing					
Interval days[a]	4.4±6.0	1.1±0.6	4.2±6.2	5.4±6.4	0.004*
Diuretic efficiency[b], mL/mg	2.6 (1.2 to 5.0)	7.5 (3.5 to 23.3)	3.7 (2.6 to 9.3)	1.9 (0.9 to 2.9)	0.004*
SBP, mm Hg	124.0±25.5	132.2±34.7	129.3±25.6	120.3±22.6	0.427
DBP, mm Hg	68.4±17.0	72.9±16.2	66.8±13.7	66.7±18.2	0.735
MAP, mm Hg	86.9±17.6	92.7±20.2	87.6±16.9	85.2±17.2	0.599
Heart rate, times/min	84.4±21.0	86.4±23.7	88.2±16.0	82.9±21.8	0.699
BUN, mmol/L	25.8±11.7	18.0±6.6	26.8±14	27.6±11.6	0.083
SCr, μmol/L	307 (194-403)	311 (219 to 350)	343 (193 to 465)	290 (190 to 404)	0.904
BUN/SCr, mg/mg	62.7±36.7	40.9±8.4	60.8±43.2	69.0±38.0	0.091
eGFR, mL/min/1.73 m^2	11.6 (8.6 to 23.7)	11.3 (10.4 to 18.3)	10.4 (7.3 to 21.8)	12.6 (8.6 to 23.9)	0.899
Urine volume, mL/24 h	400 (270 to 820)	800 (350 to 2,100)	650 (400 to 730)	345 (150 to 700)	0.021*
Fluid balance[c], mL/24 h	740 (314 to 1,620)	167 (–650 to 840)	250 (–370 to 480)	1,270 (550 to 1,890)	0.016*

Values are n (%), means ± standard deviations, or medians with ranges in parentheses. RRT, renal replacement therapy; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; BUN, blood urea nitrogen; SCr, serum creatinine; eGFR, estimated glomerular filtration rate, calculated by CKD-EPI creatinine formula. [a] Interval days indicate days between type 1 cardiorenal syndrome diagnosis and RRT initiation. [b] Diuretic efficiency was calculated by urine production relative to furosemide dose (mL/mg). [c] Fluid balance was calculated by intake volume minus output volume. * $p < 0.05$.

tively. There were no significant differences in SCr, BUN, BUN/SCr, and estimated glomerular filtration rate before initiation of RRT between the 3 groups. The average interval between type 1 CRS diagnosis and RRT initiation was significantly shorter in the RRT-independent group than in the death group (1.1 ± 0.6 vs. 5.4 ± 6.4 days, respectively, $p = 0.004$). There were significant differences in diuretic efficiency between the 3 groups ($p = 0.004$). Significant differences were observed in urine output (800, 650, and 345 mL, respectively, $p = 0.021$) and median fluid balance volume (167, 250, and 1,270 mL, respectively, $p = 0.016$) 24 h before initiation of RRT between the 3 groups (Table 3).

Relationship between RRT Initiation Characteristics and Prognosis

Univariate Cox regression analysis showed that the RRT indicators of severe metabolic acidosis (hazard ratio [HR] 2.392, $p = 0.022$), use of vasopressors (HR 2.949, $p = 0.002$), and fluid balance (HR 1.043, $p = 0.008$) were potential mortal risk factors. Potential protective factors included greater urine volume (HR 0.895, $p = 0.023$) and better diuretic efficiency (HR

Table 4. Univariate Cox regression analysis of 90-day mortality including RRT initiation characteristics as independent variables

Variables	HR (95% CI)	*p* value
Interval days[a]	1.031 (0.982–1.083)	0.213
Diuretic resistance	1.337 (0.605–2.954)	0.473
Diuretic efficiency	0.900 (0.810–0.998)	0.048*
Use of vasopressors	2.949 (1.471–5.913)	0.002*
Severe metabolic acidosis	2.392 (1.136–5.035)	0.022*
Oliguria	1.337 (0.605–2.954)	0.364
Hyperkalemia	0.888 (0.270–2.914)	0.884
SCr, μmol/L	1.000 (0.999–1.002)	0.687
BUN, mmol/L	1.019 (0.991–1.047)	0.183
Urine volume, per 100 mL/24 h	0.895 (0.814–0.985)	0.023*
Fluid balance, per 100 mL/24 h	1.043 (1.011–1.075)	0.008*

RRT, renal replacement therapy; HR, hazard ratio; CI, confidence interval; SCr, serum creatinine; BUN, blood urea nitrogen. [a] Interval days indicate days between type 1 cardiorenal syndrome diagnosis and RRT initiation. * $p < 0.05$.

Table 5. Parameters of RRT-independent patients at the second day of terminating RRT and RRT-dependent patients when discharged from hospital

	RRT-independent group ($n = 9$)	RRT-dependent group ($n = 9$)	*p* value
SBP, mm Hg	133.0±26.7	121.1±22.9	0.367
DBP, mm Hg	71.3±14.8	60.4±9.2	0.151
MAP, mm Hg	91.9±15.9	80.7±12.8	0.176
Heart rate, times/min	78.4±7.1	69.3±12.2	0.093
BUN, mmol/L	18.4±6.3	19.9±10.9	0.794
SCr, μmol/L	265 (249 to 306)	424 (351 to 572)	0.189
Urine volume, mL/24 h	1,350 (1,125 to 1,870)	265 (110 to 655)	0.009*
Fluid balance volume, mL/24 h	–350 (–528 to 125)	850 (220 to 990)	<0.001*

Values are medians with ranges in parentheses or means ± standard deviations. RRT, renal replacement therapy; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; BUN, blood urea nitrogen; SCr, serum creatinine. * $p < 0.05$.

0.900, $p = 0.048$). There was no significant difference in the interval length between diagnosis and RRT initiation (HR 1.031, $p = 0.213$) (Table 4). Multivariate Cox regression analysis of initiation timing parameters showed that positive fluid balance (HR 1.043, $p = 0.008$) before RRT initiation was an independent risk factor for 90-day mortality. In addition, interval length between diagnosis and RRT initiation was no risk factor for dialysis dependence (odds ratio 4.689, 95% confidence interval 0.621–35.388, $p = 0.134$). The results of univariate and multivariate Cox regression analyses of other characteristics as independent variables are listed in online supplementary Tables S2 and S3, respectively.

RRT Cessation Timing

The mean urine volume and fluid balance volume 2 days after RRT cessation were 1,350 mL ($p = 0.009$) and –350 mL ($p < 0.001$) in the RRT-independent group, which differed significantly from those (265 and 850 mL, respectively) in the RRT-dependent group before the

Table 6. Prognostic value of urine volume and fluid balance volume

Parameters	AUC (95% CI)	Cutoff value, mL/24 h	Youden index	Sensitivity, %	Specificity, %
Prediction of 90-day mortality					
Urine volume[a]	0.744 (0.608–0.881)	≤320	0.471	47.1	100
Fluid balance volume[a]	0.794 (0.621–0.967)	>314	0.503	86.7	63.6
Prediction of RRT independence					
Urine volume[b]	0.953 (0.851–1.000)	>880	0.875	87.5	100
Fluid balance volume[b]	0.992 (0.970–1.000)	≤150	0.875	87.5	100

RRT, renal replacement therapy; AUC, area under the curve; CI, confidence interval. [a] On the day (24 h) prior to RRT initiation. [b] On the second day (24 h) after the last RRT.

last dialysis during hospitalization. There was no significant difference in SCr (p = 0.189) and BUN (p = 0.794) at RRT cessation between the 2 groups (Table 5).

Prognostic Value of Urine Volume and Fluid Balance Volume

ROC curves showed that urine volume before RRT initiation of ≤320 mL/24 h was associated with a 90-day mortality rate of 100%. Moreover, urine volume of >880 mL/24 h or fluid balance volume of ≤150 mL/24 h on the second day after the last RRT treatment was associated with a rate of 100% for weaning from RRT (Table 6).

Discussion

The prognosis of acute CRS patients receiving RRT is poor. This study showed that the 90-day mortality rate of type 1 CRS patients with RRT was 65.4% and the rate of dialysis dependence was 17.3%. These results were similar to those of the Cleveland Clinic study [19] (43.2% in-hospital mortality rate and 24.3% dialysis dependence for type 1 CRS) and of a study by Prins et al. [11] (in-hospital mortality rate of 62%). Obviously, the severity of illness in our study was greater than that of the CARESS-HF study, which reported a 60-day mortality rate of 17% for acute CRS patients treated with ultrafiltration, and that study excluded patients with advanced renal failure (SCr >310 μmol/L) and hemodynamic instability [12]. Therefore, acute CRS requiring RRT had a poor prognosis, and initiation and cessation of RRT therapy for CRS should be carefully considered.

The accurate timing for RRT initiation for AKI patients, including type 1 CRS patients, remains controversial. Early RRT could improve fluid management and prevent overload volume in AKI patients, thus avoiding aggravated heart failure [20, 21]. On the other hand, AKI self-heals in some patients, and early RRT may necessitate otherwise unnecessary treatment, thereby increasing the risk of RRT complications as well as wasting medical resources [22, 23]. However, studies of RRT timing for CRS patients are scarce [19]. A single-center study of 37 patients with type 1 CRS receiving RRT showed that there were no statistical differences in mean BUN, SCr, and median urine volume at RRT initiation between the survival group and the death group [11]. Similarly, there were no significant differences in BUN and SCr levels between the RRT-independent, RRT-dependent, and death groups in the present study. Differences mainly occurred in the use of vasopressors, diuretic efficiency, urine volume, and fluid balance of 24 h at initiation of RRT between the 3 groups. Besides,

urine output of the 3 groups at RRT initiation decreased successively, and fluid balance was prone to be positive. Moreover, multivariate Cox regression analysis showed that positive fluid balance at RRT initiation was an independent risk factor for 90-day mortality, highlighting the importance of fluid balance [24]. Meanwhile, the results of this study showed that the interval between acute CRS diagnosis and RRT initiation was shorter in the RRT-independent group than in the death group, suggesting that early RRT intervention, when a positive fluid balance occurs, may be associated with improved prognosis. Therefore, urine volume and fluid balance instead of serological markers of renal function were early indices for initiation of RRT intervention.

At present, there is no powerful clinical proof of optimal timing for RRT cessation for AKI patients, including type 1 CRS patients. Previous findings showed that the time of RRT cessation is affected by many factors, including hemodynamic stability, urine volume, and volume overload; thus, a comprehensive assessment is warranted [25]. A study of 304 AKI patients receiving RRT showed that weaning patients had a mean urine volume of 1,435 mL at 2 days after the last session of acute dialysis [26]. The post hoc analysis of the BEST study also indicated that a urine volume of no less than 400 mL/24 h without the use of diuretics was associated with successful weaning from RRT in 78.6% of patients [27]. In the present study, ROC curves showed that a patient could be successfully weaned from RRT when the urine output was >880 mL/24 h or fluid balance was <150 mL/24 h, figures which were similar to those in the 2 above-mentioned studies. Together, these results confirmed that urine volume and fluid balance were the most accurate indices to determine time of RRT cessation, rather than BUN or SCr.

This study investigated the high mortality rate among type 1 CRS patients receiving RRT. Meanwhile, in this single-center study, the current situation of initiation timing and cessation timing for type 1 CRS patients receiving RRT was described. Obviously, this study was limited by the single-center retrospective design, the small sample size, and the observational nature. It cannot represent the general characteristics for all type 1 CRS patients. A larger sample in a prospective study is needed to confirm these results.

Conclusions

The results of this study showed that the prognosis of acute CRS patients receiving RRT was poor. The mean fluid balance of survivors was remarkably less than that of the death group at RRT initiation, suggesting that RRT intervention should be started when positive fluid balance occurs. Patients can be successfully weaned from RRT when the urine volume is >880 mL/24 h or fluid balance is <150 mL/24 h. Urine volume and fluid balance should be carefully monitored due to their importance in the clinical decisions concerning initiation and cessation timing of RRT for type 1 CRS patients.

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Statement of Ethics

The study protocol was approved by the Ethics Committee of the hospital and was conducted in accordance with the World Medical Association's Declaration of Helsinki. Written informed consent was waived due to the retrospective nature of the study and anonymously analyzed data.

Disclosure Statement

There are no conflicts of interest to disclose.

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