Original Article

The prognosis and risk factors for acute kidney injury in high-risk patients after surgery for type A aortic dissection in the ICU

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Background: Acute kidney injury (AKI) is a major complication of cardiac surgery, with high rates of morbidity and mortality. The aim of this study was to identify risk factors for the incidence and prognosis of AKI in high-risk patients before and after surgery for acute type A aortic dissection (TAAD) in the intensive care unit (ICU).

Methods: We performed a retrospective cohort study from April 2018 to April 2019. The primary end points of this study were morbidity due to AKI and risk factors for incidence, and the secondary end points were mortality at 28 days and risk factors for death.

Results: We enrolled 60 patients, 52 (86.67%) patients developed postoperative AKI, 28 (53.84%) patients died. Preoperative lactic acid level (P=0.022) and cardiopulmonary bypass (CPB) duration (P=0.009) were identified as independent risk factors for postoperative AKI. The 28-day mortality for postoperative patients with TAAD was 46.67%, 53.84% for those with TAAD and AKI, 67.5% for those who required continue renal replacement therapy (CRRT). The risk factors for 28-day mortality due to postoperative AKI for patients requiring CRRT were CPB duration (P=0.019) and norepinephrine dose upon diagnosis of AKI (P=0.037).

Conclusions: Morbidity due to AKI in postoperative patients with TAAD was 86.67%, and preoperative lactic acid level and CPB duration were independent risk factors. The 28-day mortality of postoperative patients with TAAD was 46.67%, 53.84% for those with TAAD and AKI, and 67.5% for those requiring CRRT. CPB duration and norepinephrine dose upon diagnosis of AKI may influence patients' short-term prognosis.

Keywords: Intensive care unit (ICU); acute kidney injury (AKI); type A aortic dissection (TAAD); continue renal replacement therapy (CRRT)

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Introduction

Acute kidney injury (AKI) is a major complication and an independent risk factor for high morbidity and mortality in critically ill patients (1,2). According to previous studies, the prevalence of AKI after cardiac surgery ranges from 19.3% to 54% (3-5), which was higher than that reported for type A aortic dissection (TAAD) patients (6). Insufficient tissue perfusion, cellular oxygenation, and heart dysfunction may be the leading causes of this kind of kidney injury (7). Other studies have shown that high body mass index (BMI),

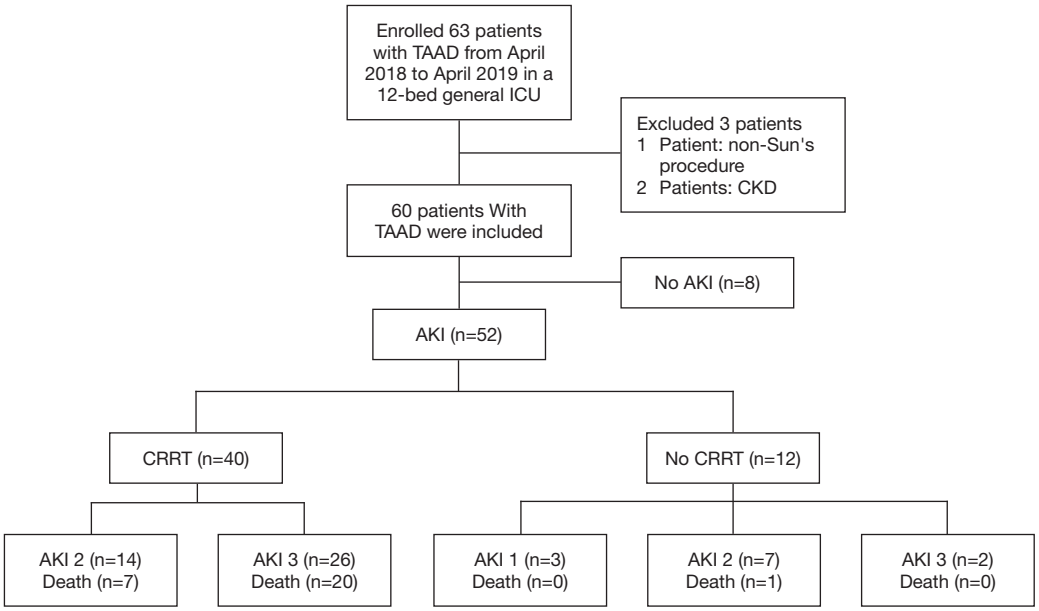

Figure 1 Flowchart of study participants. TAAD, type A aortic dissection; CKD, chronic kidney disease; ICU, intensive care unit; CRRT, continue renal replacement therapy.

advanced age, perioperative peak serum C-reactive protein (CRP) concentration, perioperative sepsis, preexisting renal impairment, and cardiopulmonary bypass time were independent risk factors for postoperative AKI (6,8-10). Recent data has also revealed that postoperative AKI is associated with increased rates of morbidity, cost, and mortality at 30 or 90 days (3,11,12).

By regulating fluid balance, acid-base homeostasis, and electrolyte disorder, continue renal replacement therapy (CRRT) has been considered an effective therapy for AKI (13,14). However, the survival of patients with AKI remains low (15-17), with mortality rates of 12.2% for none renal replacement therapy (non-RRT) AKI and 46.9% for RRT-AKI patients (18). Previous studies have documented that approximately 2–9% of TAAD patients require CRRT after surgery, and the mortality of this cohort is up to 64% (6,9,19).

Most of the aforementioned data were obtained from general patients after cardiothoracic surgery. However, critically ill patients who were transferred to intensive care unit (ICU) after TAAD surgery had relatively severe illness, and the incidence, outcomes, and risk factors for postoperative AKI were unknown. In our daily work, we observed a high incidence of AKI and poor prognosis in patients who underwent cardiac surgery, especially in those with TAAD. Therefore, we designed a retrospective study to explore the risk factors for developing AKI as well as its prognostic factors in patients who underwent surgery for TAAD. This study aimed to provide some guidance to clinicians for improving the outcomes of patients with TAAD. We present the following article in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/jtd-21-823).

Methods

Design and setting

This retrospective cohort study initially enrolled 63 patients with TAAD in a 12-bed general ICU in the Fourth Hospital of Hebei Medical University from April 2018 to April 2019 (*Figure 1*). The exclusion criteria were as follows: (I) patients younger than 18 years; (II) patients undergoing chronic dialysis due to chronic kidney disease (CKD); and (III) patients that did not undergo Sun's procedure for TAAD (20). Finally, 60 patients were included (two patients were excluded due to of CKD, and one patient was excluded as they did not undergo Sun's procedure). AKI was defined by the Kidney Disease Improving Global Outcomes (KDIGO) criteria (*Table 1*) (21). This study was approved by Ethics Committee of the Fourth Hospital of Hebei Medical University (2017MEC106), and complied with the Helsinki Declaration guidelines (as revised in 2013). All patients

Table 1 Kidney Disease Improving Global Outcomes (KDIGO) criteria for AKI

Stage	Serum creatinine increase	Urine output decrease
1	1.50–1.90 times baseline or ≥0.30 mg/dL (26.50 μmol/L) increase	Urine output <0.5 mL/kg/h for 6–12 hours
2	2.00–2.90 times baseline	Urine output <0.5 mL/kg/h for ≥12 hours
3	≥3.00 times baseline or increase in serum creatinine to ≥4.00 mg/dL (353.60 μmol/L) or initiation of renal replacement therapy	Urine output <0.3 mL/kg/h for ≥24 hours or Anuria for ≥12 hours

AKI, acute kidney injury.

signed the informed consent at admission.

Data collection

We collected preoperative demographic parameters including age, gender, baseline serum creatinine (sCr), blood urea nitrogen (BUN), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), heart rate (HR), respiratory rate (RR), percutaneous arterial oxygen saturation (SpO_2), body temperature (T), and central venous pressure (CVP). The APACHE II score was recorded upon admission to the ICU, and laboratory results were recorded at the time of AKI diagnosis. We also calculated the estimated glomerular filtration rate (eGFR) using the Modification of Diet in Renal Disease (MDRD) equation (22). Daily fluid balance and CVP in the ICU were reviewed. We also recorded positive end expiratory pressure (PEEP) and inspired oxygen concentration (FiO_2) for patients who used a ventilator.

Statistical analyses

Data were analyzed with SPSS 22.0 (SPSS IBM Corp., Armonk, NY, USA). All statistics were expressed as mean ± standard for continuous variables. The Student's *t*-test was used to compare continuous variables, and the chi squared (χ^2) or Fisher exact tests was used to compare categorical variables of different groups. Logistic regression models were used to identify univariate and multivariate risk factors for AKI and mortality of patients undergoing CRRT. The multivariate model included variables that were significant in the univariate analysis. All statistical tests were two-sided and P<0.05 was considered statistically significant.

Results

Patient characteristics

The mean age of the 60 included patients was 54.95±13.81 years (range, 28–78 years), and 43 (71.67%) were men. Previous medical histories of the patients included hypertension (75.00%), diabetes (5.00%), coronary heart disease (8.33%), cerebrovascular disease (16.67%), and chronic obstructive pulmonary disease (3.33%). The mean durations of the operation, cardiopulmonary bypass (CPB), and aortic cross-clamping (ACC) were 8.00 (6.50, 9.05) hours, 171.00 (151.50, 196.25) minutes, and 107.00 (81.50, 126.75) minutes, respectively. The baseline sCr was 79.38±23.19 mmol/L (*Table 2*).

Incidence and risk factors for postoperative AKI

According to the KDIGO criteria, 52 (86.67%) patients developed postoperative AKI; 3 patients (5.00%) were in stage 1, 21 patients (35.00%) were in stage 2, and 28 patients (46.70%) were in stage 3. The risk factors for postoperative AKI are shown (*Table 3*). The identified risk factors for postoperative AKI were preoperative lactic acid level [odds ratio (OR), 1.409; 95% confidence interval (CI), 1.051–1.890; P=0.022] and CPB duration (OR, 1.024; 95% CI, 1.006–1.042; P=0.009) (*Table 4*).

Outcomes of the postoperative patients

CRRT was required in 40 (66.67%) patients with AKI; of these, 14 (23.33%) patients were in stage 2 and half of them died, while 26 (43.34%) patients were in stage 3, and 76.92% of them died. The CRRT patients were divided into two groups: a survival group and a non-survival group. Univariate analysis (*Table 5*) found six variables that were associated with the 28-day mortality of patients with postoperative AKI requiring CRRT. Multivariate analysis revealed that the risk factors for 28-day mortality in patients with postoperative AKI requiring CRRT were CPB duration (OR, 1.037; 95% CI, 1.006–1.068; P=0.019) and norepinephrine dose upon diagnosis of AKI (OR, 1.523;

Table 2 Patient characteristics

Variables	Value (n=60)
Demographic data	
Age (year)	54.95±13.81
Male (%)	43 (71.67)
Medical history, n (%)	
Hypertension	45 (75.00)
Diabetes	3 (5.00)
Coronary heart disease	5 (8.33)
COPD	2 (3.33)
Cerebrovascular disease	10 (16.67)
Preoperative condition	
Temperature (℃)	36.5 (36.1, 36.7)
Heart rate (bpm)	80 (71, 88)
Respiration rate (bpm)	19 (17, 20)
Systolic blood pressure (mmHg)	133±29
Diastolic blood pressure (mmHg)	76±16
Leukocyte ($\times10^9$/L)	11.91±3.62
Hemoglobin (g/L)	130.05 (121.45, 141.75)
Platelet ($\times10^6$/L)	169.90±51.21
Blood urea nitrogen (mmol/L)	6.30 (4.98, 7.83)
Baseline serum creatinine (μmol/L)	79.38±23.19
Troponin I (ng/mL)	0.06 (0.01, 1.91)
Lactic acid (mmol/L)	2.30 (1.70, 4.65)
Operative details	
Duration of operative (h)	8.00 (6.50, 9.05)
Duration of CPB (min)	171.00 (151.50, 196.25)
Duration of ACC (min)	107.00 (81.50, 126.75)
Postoperative condition	
APACHE II	19 (17, 24)

The data are shown as n (%) or median (IQR) or mean ± SD. CPB, cardiopulmonary bypass; ACC, aortic cross-clamping; APACHE II, Acute Physiology and Chronic Health Evaluation II.

95% CI, 1.026–2.261; P=0.037) (*Table 6*).

Discussion

In this retrospective study, the incidence and risk factors for AKI were investigated in patients who were transferred to the ICU after surgery for TAAD. Moreover, the prognosis and factors that influenced the 28-day mortality were evaluated. The results showed that 86.67% of patients developed postoperative AKI, and 66.67% of them required CRRT. The 28-day mortality in the postoperative patients with TAAD was 46.67%, which increased to up to 53.84% in those who developed AKI, and to 67.50% in those who required CRRT. The independent risk factors for postoperative AKI were preoperative lactic acid level and CPB duration, and the independent risk factors for 28-day mortality in those who developed AKI and required CRRT were norepinephrine dose upon diagnosis of AKI and CPB duration.

Previous studies have reported the incidence and risk factors for postoperative AKI in cardiovascular surgery departments (6,23,24). Ko *et al*. (6) reported that the incidence of AKI in TAAD patients was 44%, and only 9% patients required CRRT. In that study, CPB, high BMI, perioperative peak serum CRP concentration, renal malperfusion, and perioperative sepsis were identified as independent risk factors for postoperative AKI. However, Englberger *et al*. (25) reported a lower incidence of AKI (17.7%) and RRT (2.1%) in patients who had undergone elective thoracic aortic surgery. The reason for this discordance might be the exclusion of emergency surgery and TAAD patients. In one recent meta-analysis (8), the average incidence of AKI in TAAD was 46.3%, and a relatively high morbidity of 66.7% was observed in overweight patients. Their data demonstrated that high BMI, advanced age, and perioperative sepsis were the independent risk factors for postoperative AKI. Compared with the previous research, our study showed a higher incidence of AKI. This difference may be partly explained by our different target population, which included only patients who underwent Sun's procedure for TAAD, in order to minimize the confounding factors. In addition, compared with the patient population studied in cardiovascular surgery departments, those transferred to the ICU had relatively severe illnesses; for this reason, surgeons made a wise decision to transfer these patients to the ICU.

According the results of previous studies, the preoperative risk factors for developing AKI after cardiac surgery were advanced age, female sex, hypertension, hyperlipidemia, CKD, liver disease, peripheral vascular disease, previous stroke, smoking history, diabetes, and anemia (26). In this study, we collected as many risk factors as possible in order to determine the risk factors

Table 3 Patient characteristics

Variables	AKI (n=52)	No AKI (n=8)	P
Demographic data			
Age (year)	55.15±13.88	53.63±14.15	0.773
Male (%)	37 (71.15)	6 (75.00)	0.740
Medical history, n (%)			
Hypertension	42 (80.77)	3 (37.50)	0.009
Diabetes	3 (5.77)	0 (0.00)	1.000
Coronary heart disease	5 (9.61)	0 (0.00)	1.000
COPD	1 (1.92)	1 (12.50)	0.251
Cerebrovascular disease	9 (17.31)	1 (12.50)	1.000
Preoperative condition			
Temperature (℃)	36.5 (36.1, 36.7)	36.5 (36.3,36.7)	0.993
Heart rate (bpm)	85±17	78±7	0.281
Respiration rate (bpm)	19 (17, 21)	18 (17, 19)	0.373
Systolic blood pressure (mmHg)	135±29	116±18	0.091
Diastolic blood pressure (mmHg)	76±15	68±15	0.183
Leukocyte ($\times10^9$/L)	12.13±3.69	10.50±2.86	0.238
Hemoglobin (g/L)	130.10 (122.65, 143.28)	121.70 (107.58, 136.83)	0.414
Platelet ($\times10^6$/L)	170.19±49.31	168.00±66.20	0.912
Blood urea nitrogen (mmol/L)	6.60 (5.40, 7.93)	4.75 (4.60, 6.03)	0.569
Baseline serum creatinine (μmol/L)	78.22±20.90	86.93±35.80	0.327
Troponin I (ng/mL)	0.06 (0.01, 1.91)	0.03 (0.01, 1.77)	0.615
Lactic acid (mmol/L)	2.60 (1.70, 5.05)	1.7 (1.15, 2.43)	0.001
Operative details			
Duration of operative (h)	8.15 (6.95, 9.50)	6.5 (5.95, 7.40)	0.039
Duration of CPB (min)	175.50 (152.00, 206.00)	161.00 (145.5, 175.00)	0.004
Duration of ACC (min)	106.00 (78.75, 128.50)	112.50 (103.25, 125.75)	0.992
Postoperative condition			
APACHE II	20 (18, 24)	17 (14, 21)	0.030

The data are shown as n (%) or median (IQR) or mean ± SD. AKI, acute kidney injury; COPD, chronic obstructive pulmonary disease; CPB, cardiopulmonary bypass; ACC, aortic cross-clamping; APACHE II, Acute Physiology and Chronic Health Evaluation II.

Table 4 Multivariate analysis of risk factors for postoperative AKI

Variables	OR	95% CI	P
Hypertension	0.413	0.064–2.654	0.351
Lactic acid	1.409	1.051–1.890	0.022
Duration of operative	1.086	0.806–1.464	0.588
Duration of CPB	1.024	1.006–1.042	0.009

AKI, acute kidney injury; CPB, cardiopulmonary bypass.

Table 5 Univariate analysis for 28-day mortality of postoperative AKI with CRRT

Variables	Survival (n=13)	Death (n=27)	P
Demographic data			
Age (year)	51.38±13.31	55.37±15.05	0.421
Male [%]	10 [77]	20 [74]	0.845
Medical history, n (%)			
Hypertension	11 (84.61)	19 (70.37)	0.330
Diabetes	1 (7.69)	1 (3.70)	0.588
Coronary heart disease	0 (0.00)	4 (14.81)	0.284
COPD	0 (0.00)	1 (3.70)	1.000
Cerebrovascular disease	3 (23.07)	4 (14.81)	0.519
Preoperative condition			
Temperature (℃)	36.5 (36.2, 36.7)	36.7 (36.1, 36.7)	0.621
Heart rate (bpm)	89±18	84±18	0.389
Respiration rate (bpm)	22±7	19±2	0.092
Systolic blood pressure (mmHg)	132±43	134±23	0.870
Diastolic blood pressure (mmHg)	78±21	76±15	0.795
Leukocyte ($\times10^9$/L)	14.90±3.54	11.04±3.17	0.001
Hemoglobin (g/L)	143.50 (131.00, 148.10)	128.60 (122.60, 134.85)	0.421
Platelet ($\times10^6$/L)	183.92±47.17	167.80±48.35	0.326
Blood urea nitrogen (mmol/L)	7.10 (5.40, 8.00)	7.00 (6.15, 9.15)	0.605
Baseline serum creatinine (μmol/L)	83.83±20.19	75.94±20.76	0.263
Troponin I (ng/mL)	0.16 (0.05, 5.51)	0.06 (0.01, 1.41)	0.645
Lactic acid (mmol/L)	2.60 (1.90, 3.50)	3.4 (2.10, 5.85)	0.776
Operative details			
Duration of operative (h)	8.41±1.46	9.59±2.99	0.437
Duration of CPB (min)	185.00 (152.00, 212.00)	177.00 (151.00, 269.50)	0.001
Duration of ACC (min)	107±29	118±55	0.574
Postoperative condition			
APACHE II	22±7	22±3	0.875
Duration of postoperative to ICU (h)	53.30 (0.60, 156.00)	42.30 (0.25, 126.45)	0.437
Duration of postoperative to AKI (h)	2.40 (1.70, 4.70)	4.20 (2.80, 16.4)	0.172
Diagnosed AKI condition			
Total input (mL)	406.80 (305.50, 599.00)	1,093.00 (518.00, 2,345.80)	0.401
Total output (mL)	160.00 (125.00, 380.00)	141.00 (37.50, 1,500.00)	0.273
Total fluid balance (mL)	−206±960	−491±581	0.249
Urine volume (mL/h)	6.00 (0.00, 30.00)	10.00 (0.00, 17.50)	0.842

Table 5 (*continued*)

Table 5 (*continued*)

Variables	Survival (n=13)	Death (n=27)	P
Temperature (℃)	37.35±1.06	37.04±1.12	0.423
Heart rate (bpm)	104±28	105±23	0.954
Respiration rate (bpm)	18 (15, 21)	16 (15, 21)	0.519
Systolic blood pressure (mmHg)	123±23	123±25	0.923
Diastolic blood pressure (mmHg)	70±14	70±17	0.960
SpO_2 (%)	96 (94, 100)	96 (92, 100)	0.954
CVP (mmHg)	15±4	12±3	0.015
FiO_2 (%)	100 (45, 100)	70 (50, 100)	0.222
PEEP (cmH_2O)	5 (5, 10)	5 (5, 8)	0.013
Norepinephrine dose (μg/kg/min)	0.08 (0.00, 0.50)	0.38 (0.11, 1.05)	0.023
Leukocyte ($\times10^9$/L)	13.52±5.39	11.45±5.91	0.294
Hemoglobin (g/L)	119.37±16.12	118.29±20.38	0.869
Platelet ($\times10^6$/L)	96.15±54.47	99.00±86.06	0.914
PCT (ng/mL)	3.43 (1.19, 20.00)	22.28 (4.81, 66.32)	0.437
CRP (mg/L)	162.00 (111.00, 201.00)	120.00 (75.20, 272.50)	0.619
Lactic acid (mmol/L)	2.60 (2.00, 3.40)	2.6 (1.95, 5.25)	0.807
Transfer out of ICU condition			
Stay in ICU (h)	404.80 (14.60, 624.40)	45.80 (17.90, 211.45)	0.355
Total fluid input in ICU (mL)	34,564.00 (21,773.00, 65,680.00)	25,086.00 (7,713.50, 53,635.00)	0.307
Total fluid output in ICU (mL)	58,268±33,624	47,447±32,573	0.336
Total fluid balance in ICU (mL)	−15,270±12,860	−12,325±11,687	0.474
ΔCVP in ICU (cmH_2O)	−5±5	−1±4	0.028

The data are shown as n (%) or median (IQR) or mean ± SD. CRRT, continue renal replacement therapy; COPD, chronic obstructive pulmonary disease; CPB, cardiopulmonary bypass; ACC, aortic cross-clamping; APACHE II, Acute Physiology and Chronic Health Evaluation II; ICU, intensive care unit; AKI, acute kidney injury; SpO_2, pulse oxygen saturation; CVP, central venous pressure; FiO_2, fraction of inspiration O_2; PEEP, positive end expiratory pressure; PCT, procalcitonin; CRP, C-reactive protein.

Table 6 Multivariate analysis for 28-day mortality of postoperative AKI with CRRT

Variables	OR	95% CI	P
Preoperative leukocyte	0.470	0.208–1.064	0.070
Duration of CPB	1.037	1.006–1.068	0.019
CVP of diagnosed AKI	0.731	0.516–1.034	0.077
PEEP of diagnosed AKI	0.695	0.469–1.029	0.069
Norepinephrine dose of diagnosed AKI	1.523	1.026–2.261	0.037
ΔCVP in ICU	1.367	0.750–2.494	0.308

CRRT, continue renal replacement therapy; CPB, cardiopulmonary bypass; CVP, central venous pressure; AKI, acute kidney injury; ICU, intensive care unit.

for postoperative AKI in patients with TAAD. Our results showed that hypertension, preoperative lactic acid, operative duration, CPB duration, and APACHE II score may be the risk factors for postoperative AKI in patients with TAAD. Further analyses identified preoperative lactic acid level as one of the independent risk factors for postoperative AKI in patients with TAAD; this had been seldom reported in previous studies. Lactic acid level is frequently used in clinical practice to reflect tissue perfusion and disease severity. We noted a correlation between insufficient tissue perfusion and perioperative complications, as in the published reports, which mentioned that 16–33% of cases with TAAD presented with visceral hypoperfusion (27,28). Preoperative lactic acid level was cited as an indicator of malperfusion. We surmised that the degree of laceration was one of the causes of increased lactic acid level during the preoperative preparation for TAAD surgery. In addition, there might have been problems in the fluid management from the onset of aortic dissection to surgery. The influence of these factors for hypoperfusion may have resulted in postoperative AKI. This result reminded us to pay more attention to hemodynamic monitoring and tissue perfusion during the preoperative preparation for cardiac surgery, as this might prevent renal insufficiency and reduce the risk of postoperative AKI in patients with TAAD.

In this study, another independent risk factor for postoperative AKI in patients with TAAD was CPB duration, which was consistent with current literature. CPB can result in systemic inflammation and oxidant stress response, which had been generally believed to be the cause of multi-organ dysfunction. Furthermore, hypoperfusion, ischemia-reperfusion injury, and neurohumoral activation may lead to organ damage, such as renal injury (29). Numerous studies and reports have documented prolonged CPB duration as an independent risk factor for postoperative AKI in patients with aortic dissection (9,30,31). Xu *et al*. (9) studied 115 patients who underwent emergent thoracic aortic surgery and found that a 10-minute increase in CPB time was associated with a 17.1% higher risk for postoperative AKI. Some would argue, however, that the incidence of postoperative AKI was not affected by CPB duration (19,32). These controversial results might be attributed to the different study populations and the confounding factors in heterogeneous patient cohorts. Another reason is that some studies did not include CPB duration in the multivariate logistic regression equation, although the baseline CPB duration was higher in patients with AKI than in those without AKI. Therefore, to reduce the duration of CPB, we suggest improvement of the surgical techniques for TAAD and a high degree of anesthesiologist proficiency in CPB.

Subsequently, we investigated the mortality rate of patients with TAAD after cardiac surgery. Our results showed mortality rates of 46.67% in patients with TAAD and 53.84% in those who developed AKI. Unfortunately, 66.67% of AKI patients required CRRT, and their 28-day mortality was up to 67.50%. Three large randomized controlled trials on the timing of CRRT in AKI showed that 39.3–58.5% of AKI patients who received CRRT eventually died (33-35). The results of a retrospective study demonstrated that 58.6% of patients with cardiac surgery-associated AKI died at 30 days (36). Several studies reported that postoperative AKI itself was an independent predictor of in-hospital mortality after surgery for TAAD and that there was a linear correlation between the AKI severity/stage and mortality (37,38). Another study by Ghoreishi *et al*. (39) on the preoperative demographics and laboratory values of 269 patients with TAAD showed that lactic acid level, preoperative sCr, and liver malperfusion were the significant independent predictors of postoperative mortality. A similar study by Jiao *et al*. (40) demonstrated that age ≥60 years, high lactic acid level at 12 hours after CRRT, and long CPB duration were the independent prognostic factors of in-hospital mortality. In this study, there were no independent risk factors for overall postoperative mortality and postoperative mortality in patients with AKI. Also, further analysis showed that preoperative leukocyte level, PEEP, norepinephrine dose upon diagnosis of AKI, CPB duration, and ΔCVP in the ICU may be the risk factors for 28-day mortality in postoperative AKI patients who received CRRT. Further analyses identified CPB duration as the independent risk factor for mortality; this was similar to the results in most of the cases studied. There was a significant difference in CPB duration between the survival and non-survival groups, which implied that longer low-flow, low-pressure, non-pulsatile perfusion with hemodilution and hypothermia may be advantageous. Furthermore, the decrease in CVP during the ICU stay was significantly higher in the survival group than in the non-survival group (P=0.028). Redfors *et al*. (41) measured the cardiac index (CI), renal blood flow (RBF), and glomerular filtration rate in 12 patients who underwent cardiac surgery and found that the RBF increased as the CI increased.

Norepinephrine dose upon diagnosis of AKI was another independent risk factor for mortality in this study; no similar data were found in previous research. We analyzed

the results and considered three reasons. Firstly, compared with patients who did not require CRRT, those who needed CRRT had a more clinically severe disease course and more unstable circulation, and thus, required a larger dose of norepinephrine. This point was consistent with a previous view that the mortality rate was higher with more severe disease (38). Secondly, patients in this cohort had severe intravascular volume depletion, as well as insufficient attention and fluid resuscitation. Thirdly, norepinephrine itself may have aggravated renal ischemia and made the kidney injury more serious, which may have led to the increased mortality. A recent study demonstrated that the use of norepinephrine was associated with a relatively high mortality in AKI patients who received CRRT (42). An animal study that evaluated the effects of norepinephrine on kidney circulation in septic AKI found that medullary ischemia and hypoxia were exacerbated after norepinephrine infusion (43). In addition, a high dose of norepinephrine has been associated with an increased mortality due to its catecholamine effects on the cardiovascular system (44). Therefore, the influence of norepinephrine on postoperative AKI patients with TAAD should be considered, as it may induce further deterioration of renal function by increasing renal microvascular resistance and ischemia.

This study had some limitations that should be noted. Firstly, this was a retrospective, single-center, observational study, with relatively few patients. Secondly, this study had some problems in the acquisition of data, such as pre- and post-operative cardiac function parameters, RBF, fluid management before and during CRRT, as well as changes in the hemodynamics and renal microcirculation. Therefore, we plan to conduct a further prospective multicenter study on this topic.

Conclusions

The incidence and mortality of postoperative AKI in patients with TAAD in the ICU were higher than those in patients in the department of cardiovascular surgery, with varying and multifactorial risk factors. Preoperative lactic acid level and CPB duration were the independent risk factors for postoperative AKI. CPB duration and norepinephrine dose upon diagnosis of AKI may influence the short-term prognosis of such patients. These results tell us that more attention should be paid to the preoperative tissue perfusion of patients, and more mature surgical procedures may be able to reduce the incidence of postoperative AKI in patients. The use of norepinephrine in critically ill patients who have already developed AKI and transferred to the ICU needs to be more cautious. The results of our study can be used for future research and may contribute to the improvement of patient outcomes.

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Footnote

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