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Reduced Early Urinary Output Volume of Patients Undergoing Cardiac Surgery Correlates with the Durations of Hospitalization and Ventilation

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Abstract

Background: Urinary Output (UO) is an important observation among patients following cardiac surgery that has been linked to adverse cardiovascular events in various populations. However, its correlation with durations of hospitalization and ventilation has rarely been reported among patients following cardiotomy. In addition, how does the timing of UO correlate with durations of hospitalization and ventilation? This question has also not been addressed.

Methods: This retrospective study included the medical records of 458 patients who underwent various types of cardiovascular surgery between March 2015 and May 2017. Hospitalization and ventilation durations were analyzed as indicators to estimate patient status. Patients were grouped according to the means of continuous variables. Correlation between UO values obtained at 6 h, 12 h, and the first, second, and third 24 h with the durations of hospitalization and ventilation were analyzed. In addition, the risk factors affecting impaired UO were also analyzed.

Results: We analyzed 77 patients who had undergone Coronary Artery Bypass Grafting (CABG) (16.8%), 231 with heart valve surgery (50.4%), 16 with congenital heart surgery (3.5%), 41 with thoracic aorta surgery (9%), 61 with CABG plus valve surgery (13.3%), 13 with congenital heart plus valve surgery (2.8%), and 19 who underwent other types of heart surgery involving cardiopulmonary bypass (4.1%). The overall mortality rate was 2.8%; the mean postoperative hospitalization duration was 21.7 days, and the mean duration of ventilation was 30.6 h. Mean UO values at 6 h, 12 h, and the first, second, and third 24 h were 1286.5 mL, 1906.5 mL, 3308.9 mL, 3181.5 mL, and 3451.0 mL, respectively. Univariate analysis indicated that reduced UO values at 6 h, 12 h, and the first 24 h were significantly correlated with hospitalization and ventilation durations. A multiple linear regression analysis showed that preoperative albumin level and cross-clamping time were risk factors predicting impaired UO values at 6 h, 12 h, and the first 24 h.

Conclusion: This study indicated that reduced UO values at 6 h, 12 h, and the first 24 h were correlated with the durations of hospitalization and ventilation, patients with poor early UO extended durations of hospitalization and ventilation. Thus, UO as an observation of patients following cardiotomy might serve as a meaningful predictor of their status.

Keywords: Urinary output volume; Cardiotomy; Prognosis

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Introduction

Acute Kidney Injury (AKI) can impair Urinary Output (UO). The associations between cardiac surgery, AKI, and clinical outcomes have been studied [1,2] and cardiac surgery and cardiopulmonary bypass procedures were important factors contributing to postoperative AKI [3-5]. However, patients with reduced left ventricular systolic function and/or low cardiac output syndrome also show oliguria, which is associated with poor clinical outcomes after cardiac surgery [6-8]. This kind of UO can increase with improved heart function and the circulating creatinine levels are normal or slightly elevated. Decreased cardiac function is a common complication in patients undergoing cardiac surgery and can affect clinical outcomes, as AKI [8,9] and oliguria are common features. Thus, poor UO as a observation of patients following cardiotomy might serve as a predictor of their status. Here, we analyzed the relationships between the early UO values of patients undergoing cardiac surgery with the durations of hospitalization and ventilation.

Methods

Patient information and data collection

Between March 2015 and May 2017, we collected 488 consecutive complete cases of patients diagnosed with coronary artery disease, heart valve disease, congenital heart disease, or aortic disease. The patients received cardiovascular surgery, including CABG, valve replacement, CABG plus valve replacement, thoracic aorta replacement, or congenital heart surgery. All patients were managed by the same treatment team. Patients presenting with preoperative chronic renal insufficiency, those aged <18 years, or with missing medical records were excluded from this study; finally, 458 patients were enrolled. The following data were analyzed: patient characteristics; surgery category; cross-clamping, cardiopulmonary bypass, and operation durations; UO values at 6 h, 12 h, the first, second and third 24 h, and any use of diuretics. The preoperative levels of creatinine and albumin were also recorded after admission. The study outcomes were ventilation and hospitalization durations. Patients were grouped according to the mean durations of ventilation or hospitalization.

Clinical management

After patients had been sent to the intensive care unit, ventilation was applied to all of them with tidal volumes of 8 mL/kg and positive end-expiratory pressure 5 cm to 10 cm H_2O. After 12 h, patients were able to be removed from ventilation provided they showed hemodynamic stability, adequate muscle strength, were conscious, had an oxygen saturation >92% and an oxygen partial pressure >8.2 mmHg. Almost all patients had detectable pulmonary arterial pressure, and according to their intraoperative cardiac function status, we recorded the appropriate pulmonary arterial pressure, thus providing monitoring information for postoperative blood volume management. With the aim of complementing blood volume, different dose regimens of inotropic agents (adrenaline, milrinone, or simendan) were utilized for hemodynamically compromised patients. Temporary pacemakers were placed routinely with a frequency of 70-100 stimuli/min according to the left ventricular pathological changes. Because of increased vascular permeability after cardiopulmonary bypass surgery, furosemide was usually used after 24 h according to UO and blood volume. When furosemide was ineffective, a small dose of dopamine was added (3 μg/kg per min).

Statistical analysis

Patients were grouped according to the means of continuous or dichotomized variables. The UO values obtained at 6 h, 12 h, and the first, second, and third 24 h were compared in patients grouped by in-hospital mortality, and hospitalization and ventilation durations. Variables were tested for normal distribution using the Kolmogorov–Smirnov test. Student's *t* test was used for comparing means of normally distributed data; otherwise, a Wilcoxon–Mann–Whitney nonparametric test was used. Categoric data were tested by Pearson's χ^2 test or Fisher's exact test. The risk factors were assessed for their impact on impaired UO at 6 h, 12 h and the third 24 h by univariate analysis. Significant (p<0.05) variables from the univariate analysis were included in a multivariate analysis assessed by multiple linear regression analysis applied using forward data elimination. The level of significance was set at p<0.05. Data were analyzed using SPSS v. 17.0 for Windows (SPSS, Inc, Chicago, IL. USA).

Table 1: Baseline Clinical Characteristics, outcomes in Patients Grouped According to duration of hospitalization.

	A (n=177)	B(n=281)	P
Age(year)	58.6 ± 11.6	55.7 ± 14.7	0.037
Women(Y or N)	74	120	0.850
body mass(kg)	59.0 ± 11.7	59.6 ± 13.3	0.625
Hypertension(Y or N)	62	99	0.965
Diabetes mellitus(Y or N)	26	42	0.940
Preoperative albumin	35.3 ± 5.6	36.5 ± 5.2	0.020
Preoperative creatinine	97.2 ± 25.6	92.1 ± 20.2	0.017
CPB time(h)	2.4 ± 0.9	2.2 ± 1.9	0.222
Cross-clamping time(h)	1.4 ± 0.6	1.3 ± 0.6	0.038
Operation time(h)	5.7 ± 1.9	5.0 ± 1.7	0.000
Postoperative UO			
6 h(ml)	1099.8 ± 774.4	1404.0 ± 903.4	0.000
12 h(ml)	1744.1 ± 1042.2	2008.8 ± 1127.1	0.012
The first 24 h(ml)	3118.9 ± 1230.8	3428.6 ± 1381.9	0.015
The second 24 h(ml)	3148.1 ± 1060.0	3202.5 ± 1182.0	0.619
The third 24 h(ml)	3390.8 ± 1261.6	3488.9 ± 1384.7	0.446
Diuretic therapy			
Furosemide(Y or N)	168	231	0.000
Dopamine(Y or N)	97	79	0.000

A: Postoperative hospitalization time more than 21.7 days; B: Postoperative hospitalization less than 21.7 days; CPB: Cardiovascular Pulmonary Bypass; UO: Urine Output; h: Hour; Y: Yes; N: No; mean hospitalization time: 18.6 days

Results

Clinical characteristics and baseline correlations

A total of 458 patients undergoing cardiovascular surgery were eligible for the study. Of these, 77 patients (16.8%) presented with CABG, 231 (50.4%) with heart valve surgery, 16 (3.5%) with congenital heart surgery, 41 (9%) with thoracic aorta surgery, 61 (13.3%) with CABG and valve surgery, 13 with congenital heart disease and valve surgery (2.8%), and 19 (4.1%) with other types of heart surgery. The main cause of death in 13 patients was heart failure (four cases), bleeding (two cases) and cerebral infarction (five cases), pulmonary embolism (one case), and respiratory failure (one case). The overall mortality rate was 2.8%, mean postoperative hospitalization duration was 21.7 days, and mean ventilation duration was 30.6 h. The mean UO values at 6 h, 12 h, and the first, second, and third 24 h were 1286.5 mL, 1906.5 mL, 3308.9 mL, 3181.5 mL, and 3451.0 mL, respectively. The baseline characteristics of each subgroup are shown in Tables 1,2. After the first 24 h, furosemide was administered to 87.1% of patients, and small doses of dopamine in 38.4% patients. The ventilation and hospitalization durations were both correlated with reduced UO values at 6 h, 12 h, and the first 24 h (Tables 1,2). At 24 h after surgery, diuretics were used in some patients with oliguria. Ventilation and hospitalization durations were both correlated significantly with the use of low-dose dopamine. The use of furosemide was also correlated with ventilation and hospitalization durations (Tables 1,2).

Associations with early UO values of patients undergoing cardiovascular surgery

We further analyzed the factors predicting reduced UO at 6 h, 12 h, and the first 24 h. Patients were grouped according to the mean UO values at these times. Using univariate analysis, the possible factors

Table 2: Baseline Clinical Characteristics, outcomes in Patients Grouped According to duration of ventilation.

	A (n=84)	B(n=374)	P
Age(year)	59.9 ± 13.1	56.1 ± 15.0	0.030
Women(Y or N)	22	172	0.001
body mass(kg)	65.2 ± 13.5	58.0 ± 12.1	0.000
Hypertension(Y or N)	50	111	0.000
Diabetes mellitus(Y or N)	14	54	0.604
Preoperative albumin	32.9 ± 5.0	36.8 ± 5.2	0.000
Preoperative creatinine	102.8 ± 26.0	92.1 ± 21.3	0.000
CPB time(h)	2.9 ± 1.1	2.1 ± 1.6	0.000
Cross-clamping time(h)	1.8 ± 0.8	1.2 ± 0.5	0.000
Operation time(h)	6.5 ± 1.8	5.0 ± 1.7	0.000
Postoperative UO			
6 h(ml)	944.9 ± 593.3	1364.3 ± 901.6	0.000
12 h(ml)	1503.6 ± 785.2	1998.3 ± 1142.8	0.000
The first 24 h(ml)	2772.0 ± 1064.7	3431.3 ± 1358.4	0.000
The second 24 h(ml)	3108.9 ± 1245.4	3198.0 ± 1110.1	0.515
The third 24 h(ml)	3345.1 ± 1602.5	3475.2 ± 1271.3	0.419
Diuretic therapy			
Furosemide(Y or N)	84	315	0.000
Dopamine(Y or N)	54	112	0.000

A: Ventilation time more than 30.6 h; B: Ventilation time less than 30.6 h. mean ventilation time: 30.6 h; CPB: Cardiovascular Pulmonary Bypass; UO: Urine Output; h: Hour; Y: Yes; N: no

of age, gender, body mass, blood pressure, and presence of diabetes, preoperative levels of creatinine and albumin, the cross-clamping, cardiopulmonary bypass, and operation durations, and the use of diuretics were analyzed; then, significant risk factors were evaluated using multivariable analysis. Multiple linear regression analysis showed that preoperative albumin level and cross-clamping duration were both significant predictive factors for reduced UO values at 6 h, 12 h, and the first 24 h (Table 3).

Discussion

The heart, as the motor of blood delivery, can affect kidney malfunction manifested as hypourocrinia. Cardiac and renal dysfunction often co-exists, and this association is referred to as cardiorenal syndrome [10]. Thus, the reduced UO of patients following cardiotomy reflects impaired cardiac function and might correlate with patient status. Because of the small number of deaths associated with circulatory failure in this study, we did not analyze the relationship between early UO and in-hospital mortality. Patients were grouped according to mean values of hospitalization or ventilation durations. The UO values at 6 h, 12 h, and the first 24 h showed significant reductions correlated with hospitalization and ventilation durations. To further identify risk factors affecting impaired UO, patients were grouped again according to the mean UO values at 6 h, 12 h, and the first 24 h. The analysis showed that preoperative albumin levels and cross-clamping duration were both risk factors for impaired early UO.

According to univariate analysis, patients who were hospitalized and ventilated for longer than the mean durations had lower UO values at 6 h, 12 h, and the first 24 h than in the other groups. In this study, patients with oliguria received furosemide after 24 h, and

Table 3: Multiple linear regression analysis for risk factors of 6 h, 12 h and the first 24 h UO.

	P(6h)	P(12h)	P(No.1 24h)
Age	-	-	0.848
Women	-	-	-
body mass	-	-	0.000
Hypertension	-	-	-
Diabetes mellitus	0.559	0.319	-
Preoperative albumin	0.002	0.001	0.001
Preoperative creatinine	-	-	0.314
CPB time	-	0.404	-
Crossclamping time	0.000	0.001	0.003
Operation time	0.782	0.495	0.673

CPB: Cardiovascular Pulmonary Bypass; No.1 24 h = the first 24 hour

low-dose dopamine was used when the diuretic effect of furosemide was poor. These diuretic treatments might have affected UO after the first 24 h and may be the main reason why there was no statistical difference between the UO values for the second and third 24 h. Taken together, these data indicate that impaired UO values at 6 h, 12 h, and the first 24 h were well correlated with hospitalization and ventilation durations, and thus reflected the status of patients undergoing cardiovascular surgery.

Multiple linear regression analysis showed that preoperative albumin levels and cross-clamping time were risk factors for reduced UO values at 6 h, 12 h, and the first 24 h. Previous research has indicated that perioperative albumin levels were associated with poor prognosis following cardiac surgery [11,12], and hypoalbuminemia was associated with the incidence of postoperative kidney injury, which affected patient UO [13,14]. Our study showed similarly that the preoperative albumin level was related to poor postoperative UO and patient status. Factors contributing to poor postoperative UO were almost certainly multifactorial. Apart from the albumin level, the insult from the use of cardiopulmonary bypass for on-pump cardiac surgery might also have played an important role in this, and many studies have shown that the cardiopulmonary bypass process can cause damage to kidneys, and reduce the patient UO [15,16]. In this study, we analyzed the relationship between cross-clamping duration during pulmonary bypass and reduced postoperative UO. The cross-clamping time was a risk factor for poor postoperative UO, demonstrating that cardiopulmonary bypass can impair kidney function.

We assessed the correlation between different phases of UO with hospitalization and ventilation durations. In addition, preoperative albumin levels and cross-clamping times were independent risk factors for poor postoperative early UO. This finding helped us to screen other phases of UO to predict clinical outcomes, and implied that adequate attention should be paid during the nursing process to patients with early postoperative oliguria.

One limitation of this study was that we did not design it to compare or combine the amount of diuretic use with corresponding time points. We simply evaluated the use of diuretics at the second or third 24 h time phases. As vasopressin and aldosterone are closely related to urinary volume regulation [17], UO might be a useful indicator for assessing patient outcomes. Further study is warranted to evaluate the correlations between the levels of antidiuretic hormone and aldosterone, and the prognosis of patients undergoing cardiovascular surgery.

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Ethical Approval Information

All procedures were performed with the approval of the ethics committee of SunYat-sen Memorial Hospital, Sun Yat-sen University and following informed written consent by the patients.

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