Int J Clin Exp Med 2019;12(4):4193-4201
www.ijcem.com /ISSN:1940-5901/IJCEM0086379

Original Article

Predictors for prolonged stay in the intensive care unit after surgery for acute aortic dissection type A

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Received October 6, 2018; Accepted November 8, 2018; Epub April 15, 2019; Published April 30, 2019

Abstract: *Objective:* The goal of this study was to identify predictors of prolonged stay in the intensive care unit (ICU) in patients undergoing surgery for acute aortic dissection type A. *Methods:* A total of 202 patients who underwent surgery for acute aortic dissection type A in our hospital from May 2009 to May 2016 were divided into two groups based on their duration of stay in the ICU. Prolonged length of ICU stay was defined as 5 days or more in the ICU postoperatively. There were 167 patients with length of ICU stay less than 5 days, and 35 patients with length of ICU stay 5 days or more. Univariate and multivariate analysis (logistic regression) were used to identify the predictive risk factors. *Results:* The mean age of patients was (56.2±10.8) years, and there were 156 men (77.2%) and 46 women (22.8%). The lengths of ICU stay were (63.5±17.2) hours and (207.2±20.5) hours respectively. Overall in-hospital mortality rates were 2.4% and 14.3% respectively. Multivariate logistic analysis showed that CPB time, occurrence of postoperative stroke, acute renal failure, and acute respiratory failure were the independent predictors for prolonged ICU stay. *Conclusion:* The incidence of prolonged ICU stay is high after surgery for acute aortic dissection type A. Based on above factors, more active perioperative treatment strategies should be taken for patients with these risk factors to avoid more complications, and further to shorten the ICU stay time.

Keywords: Acute aortic dissection, risk factors, intensive care unit, cardiac surgery, aortic aneurysm

Introduction

Acute type A aortic dissection is a serious life-threatening cardiovascular disease that requires positive surgical treatment. Although the preoperative recognition, perioperative management and surgical techniques have been significantly improved, operations for acute type A aortic dissections are still associated with high mortality and high incidence of complications. Compared with other patients undergoing routine cardiac or aortic operation, these patients usually have prolonged stay in the intensive care unit (ICU). Prolonged ICU stay accounts for considerable expenditure of health care costs and excessive consumption of medical resources, and perioperative mortality and complication increased accordingly. Various predictive models for prolonged ICU stay after cardiac surgery have been developed during the last two decades, but we still know less about variables influencing the ICU length of stay in patients undergoing surgery for acute aortic dissection type A. Therefore, it is essential to investigate the risk factors of prolonged ICU stay after surgery for acute type A aortic dissection so as to implement reasonable and effective prevention and treatment. A retrospective study was conducted to identify potentially risk factors amenable to intervention for prolonged ICU stay in these patients in our institution, so as to improve the surgical treatment effect and reduce the perioperative mortality by early intervention and treatment.

Materials and methods

Clinical data

A total of 202 consecutive patients with acute type A aortic dissection diagnosed with enhanced computed tomography in our hospital from

Table 1. Univariate analysis of the preoperative characteristics of patients undergoing surgery for acute aortic dissection type A

Characteristics	ICU-LOS (days)		T/χ^2	*P* value
	≥5 (n=35)	<5 (n=167)		
Age (year, SD)	55.8±11.2	50.6±10.7	2.593	0.010
Gender (%)			0.763	0.382
Male	29 (82.9)	127 (76.0)		
Female	6 (17.1)	40 (24.0)		
Body mass index (Kg/m^2)	25.7±3.5	24.8±3.2	1.488	0.138
Chronic obstructive pulmonary disease (%)	3 (8.6)	11 (6.6)	0.177	0.674
Hypertension (%)	22 (62.9)	106 (63.5)	0.005	0.945
Cerebrovascular disease (%)	4 (11.4)	11 (6.6)	0.987	0.321
Diabetes mellitus (%)	5 (14.3)	12 (7.2)	1.893	0.169
New York Heart Association functional class III~IV (%)	11 (31.4)	37 (22.2)	1.373	0.241
Euroscore (SD)	8.9±2.9	7.5±2.6	2.838	0.005
Preoperative serum creatinine (μmol/L, SD)	96.8±24.3	94.5±22.6	0.540	0.590
Preoperative D-dimer (mg/L, SD)	8.9±2.1	7.5±1.9	3.057	0.003
LVEF (%, SD)	53.7±8.3	56.5±8.7	1.745	0.083
Emergency operation (%)	26 (74.3)	131 (78.4)	0.289	0.591

ICU, intensive care unit; LOS, length of stay; SD, Standard deviation; EuroSCORE, European system for cardiac operative risk evaluation; LVEF, left ventricular ejection fraction.

May 2009 to May 2016 were enrolled in this study. This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of our hospital (No.4), and written informed consent was obtained from all study participants. Prolonged stay in the ICU is defined as a stay of ≥5 days in the ICU after surgery [1]. The 202 patients were divided into two groups according to length of stay (<5 and ≥5 days). Among 202 patients, 35 patients had prolonged ICU stay. Exclusion criteria included intraoperative or early postoperative (within 5 days after surgery) death. Preoperative clinical characteristics of these two groups are listed in **Table 1.** Preoperative risk factors, operative data, and perioperative mortality and complications for all patients undergoing surgery for acute aortic dissection type A were systematically collected by two physicians. Clinical data were as follows: 1. Preoperative risk factors: age, sex, body mass index (BMI), chronic obstructive pulmonary disease (COPD), hypertension, cerebrovascular disease (CVD), diabetes mellitus, New York Heart Association functional class III~IV, Euroscore, preoperative serum creatinine, preoperative D-dimer, left ventricular ejection fraction (LVEF), emergency operation. 2. Intraoperative risk factors: with or without concomitant coronary artery bypass grafting (CABG), cardiopulmonary bypass (CPB) times, aortic cross-clamping times, deep hypothermic circulatory arrest (DHCA), lowest rectal temperature, blood transfusion volume, use of positive inotropic agents. 3. Postoperative risk factors: postoperative stroke, dialysis-dependent renal failure, respiratory failure, re-intubation, chest re-exploration.

Surgical procedures

All the patients with acute type A aortic dissection underwent surgical treatment by prosthetic graft replacement of ascending aorta and/or aortic arch. Operations were performed through a standard longitudinal median sternotomy. Cardiopulmonary bypass was established by cannulation of right atrium or separately the superior and inferior vena cava. Femoral or axillary arterial cannulation was established. Myocardial protection was provided by intermittent, antegrade, cold blood cardioplegic solution via coronary ostia. If an intimal tear was localized to the ascending aorta, the distal anastomosis was constructed proximal to the innominate artery. If the intimal tear originated in or extended into the arch, deep hypothermic circulatory arrest (DHCA) was instituted to extend the aortic replacement to include the intimal tear. Of the 202 patients, 65 cases underwent surgery with moderate hypothermic cardiopulmonary bypass. Cerebral protection was performed with DHCA and selective antegrade cerebral perfusion in 137 patients. Open distal repair was performed after finishing the proximal aortic root procedure with the rectal temperature 18°C around. Antegrade selective cerebral perfusion was applied during circulatory arrest, and the patients' heads were packed in ice bags. We simply replaced it when the intimal tear was located only in the ascending aorta. Aortic root replacement, Bentall procedure was performed for patients with dilation of aortic root. Partial or total arch replacement was performed when the entry site was present or extended into the aortic arch. Ascending aorta/hemiarch replacement was performed in 87 patients, the Bentall procedure in 68, the David procedure in 11, total arch replacement in 32, and aortoplasty in four. At the same time, 21 patients underwent CABG, and 65 patients underwent descending aorta stent implantation.

Definition

1. Criteria for discharge from the ICU: (1): Evidence of adequate neuropsychological function (patient alert and cooperative, and no seizure activity); (2): No need of mechanical respiratory assistance, self respiratory frequency is below 25 times/min, PaO_2 >80 mmHg, $PaCO_2$ <60 mmHg, SpO_2 >90% at an FiO_2 ≤0.5 by face mask; (3) Adequate cardiac stability with no hemodynamically significant arrhythmias, chest tube drainage <50 mL/h, urine output >0.5 mL/kg/h, no other intravenous inotropic or vasopressor agents in excess of dopamine 5 μg/kg/min [2]. 2. Positive inotropic agents: Infusion of intraoperative dopamine, dobutamine, epinephrine, norepinephrine, and isoproterenol more than 30 minutes. 3. Body mass index (BWI) is calculated by body weight (Kg)/height (m^2). 4. Emergency operation is defined as a surgical procedure within 24 hours after admission. 5. Renal failure is defined as postoperative acute renal failure with the necessity for continuous venovenous hemofiltration. 6. Respiratory failure is defined as the necessity for mechanical ventilation more than 48 hours postoperatively [3]. 7. Postoperative stroke is defined as having evidence of a new central neurologic deficit persisting for more than 72 hours during the postoperative period. Neurologic complications were diagnosed clinically and confirmed by cerebral computed tomography.

Statistical analysis

Statistical analysis was carried out by using SPSS Base 16.0 statistical software (SPSS Inc, Chicago, IL, USA). Continuous variables are expressed as mean ± standard deviation and analyzed with Student's t-text or t'-test. Categoric variables expressed as percentages were analyzed with the Chi-square test. After univariate analyses, variables found to be potentially predictive of the outcome variable from the univariate analyses (P<0.10) were included in the multivariate logistic regression models by using the method of maximum likelihood. Odds ratios (OR) were calculated with 95% confidence intervals (CI). A P value of less than 0.05 was considered statistically significant. The discriminatory ability of the risk model was assessed by using the area under the receiver operating characteristics curve (AUC), with an AUC of 100% equating to a predictive power of 100%. The Hosmer-Lemeshow goodness-of-fit test was performed to evaluate the calibration of the model. A small χ^2 value and a P greater than 0.05 would show an acceptable adaptation.

Results

Baseline clinical characteristics of the study population

There were 156 male cases and 46 female cases among 202 patients. Average age was 53.2±10.9 years (21-79 years). All the patients underwent surgical treatment within 7 days after admission, 157 (77.7%) within 24 hours. There were 35 patients (17.3%) with length of ICU stay 5 days or more, and the average time was (207.2±20.5) hours. The hospital stay was (33.2±11.2) days. Five out of the 35 patients died postoperatively accounting for an in-hospital mortality of 14.3% (5/35). There were 167 patients with length of ICU stay less than 5 days, and the average time was (63.5±17.2) hours. The hospital stay was (20.5±9.8) days, and the in-hospital mortality was 2.4% (4/167). The total in-hospital mortality was 4.5% (9/202). The differences in ICU stay, hospital stay, and in-hospital mortality between these two groups were statistically significant.

Table 2. Univariate analysis of the intra-operative and postoperative characteristics of patients undergoing surgery for acute aortic dissection type A

Characteristics	ICU-LOS (days)		T/χ^2	*P* value
	≥5 (n=35)	<5 (n=167)		
Concomitant CABG	6 (17.1%)	15 (9.0%)	2.069	0.150
CPB time (min, $\bar{x}$±s)	207.3±48.6	175.2±44.6	3.811	<0.001
Aortic cross-clamping times (min, $\bar{x}$±s)	93.6±27.2	88.4±26.5	1.051	0.295
DHCA	29 (82.9%)	108 (64.7%)	4.385	0.036
DHCA time (min, $\bar{x}$±s)	42.7±8.6	39.5±7.7	1.938	0.055
Lowest rectal temperature (°C, $\bar{x}$±s)	19.8±1.3	20.2±1.6	1.385	0.168
Blood transfusion in 24 hours postoperatively (U, $\bar{x}$±s)	9.2±3.5	8.5±3.2	1.158	0.248
Positive inotropic agents	29 (82.9%)	98 (58.7%)	7.244	0.007
Postoperative renal failure	8 (22.9%)	3 (1.8%)	24.926	<0.001
Postoperative respiratory failure	19 (54.3%)	26 (15.6%)	25.051	<0.001
Postoperative stroke	5 (14.3%)	3 (1.8%)	11.866	0.001
Reintubation	4 (11.4%)	6 (3.6%)	3.776	0.052
Chest re-exploration	5 (14.3%)	10 (6.0%)	2.898	0.089

ICU, intensive care unit; LOS, length of stay; SD, Standard deviation; CABG, coronary artery bypass grafting; CPB, Cardiopulmonary bypass; DHCA, Deep hypothermic circulatory arrest.

Table 3. Multivariate logistic regression analysis of prolonged stay in ICU in patients undergoing surgery for acute aortic dissection type A

Variable	Coefficient	Standard error	Ward value	Odds ratio	95% confidence interval		*P*
					Lower bound	Upper bound	
Age	0.037	0.030	1.526	1.038	0.979	1.100	0.217
Euroscore	0.204	0.220	0.866	1.227	0.798	1.887	0.352
Preoperative D-dimer	0.239	0.161	2.222	1.270	0.927	1.740	0.136
CPB time	0.038	0.012	9.587	1.039	1.014	1.064	0.002
DHCA	0.950	0.594	2.559	2.585	0.807	8.272	0.110
Positive inotropic agengts	0.983	0.768	1.635	2.671	0.592	12.043	0.201
Postoperative renal failure	1.627	0.809	4.046	5.087	1.043	24.824	0.044
Postoperative respiratory failure	1.778	0.590	9.077	5.917	1.861	18.810	0.003
Postoperative stroke	2.236	0.872	6.579	9.359	1.695	51.683	0.010
Constant	-16.553	3.592	21.235	<0.001	<0.001		

CPB, Cardiopulmonary bypass; DHCA, Deep hypothermic circulatory arrest.

Comparation of preoperative data

Patient characteristics, lab tests and surgical variables were summarized and compared. The details are listed in **Table 1**. Univariate analysis showed that there was no statistical significance between the two groups in gender, BMI, hypertension, diabetes, CVD history, COPD, cardiac function (NYHA Classification) Class III to IV, preoperative creatinine levels, preoperative LVEF and emergency operation (*P*>0.05). The mean age in the prolonged ICU stay group was significantly greater than that in non-prolonged ICU stay group (55.8±11.2 VS. 50.6±10.7, *P*<0.010), the preoperative D-dimer in prolonged ICU stay group was significantly higher than that in non-prolonged ICU stay group (8.9±2.1 VS. 7.5±1.9, *P*<0.003), and the Euroscore in the prolonged ICU stay group was significantly higher than that in non-prolonged ICU stay group (8.9±2.9 VS. 7.5±2.6, *P*<0.005).

Comparation of intra-operative and postoperative data

The intraoperative and postoperative characteristics of patients in the two groups are shown in **Table 2**. The CPB time in prolonged ICU stay

Table 4. AUC analysis of the prediction model

Test variable	AUC	Standard error	*P* value	95% confidence interval	
				Lower bound	Upper bound
CPB time	0.823	0.049	<0.001	0.727	0.919
Postoperative renal failure	0.647	0.059	0.007	0.532	0.762
Postoperative respiratory failure	0.708	0.054	<0.001	0.602	0.814
Postoperative stroke	0.579	0.058	0.145	0.465	0.693
New variable Pre	0.907	0.033	<0.001	0.842	0.971

AUC, area under the receiver operating characteristics curve; CPB, Cardiopulmonary bypass.

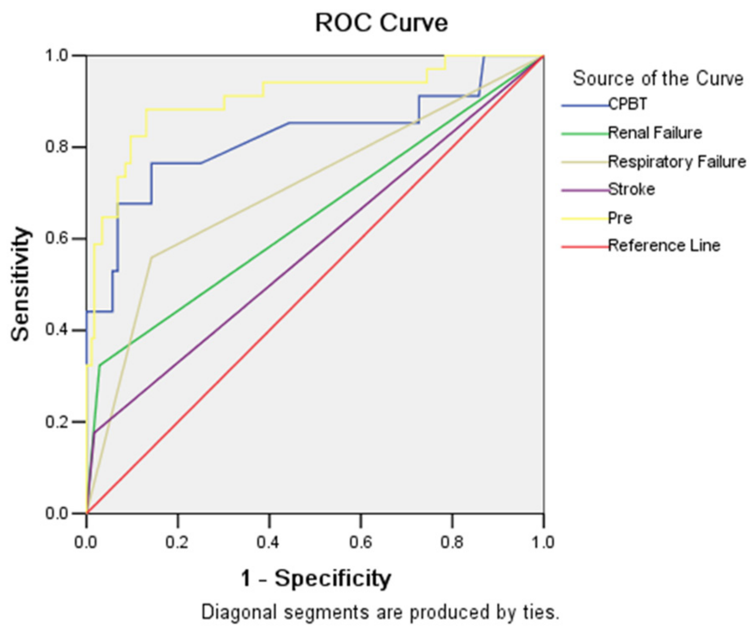

Figure 1. AUC of each test variable.

group was significantly longer than that in non-prolonged ICU group (207.3±48.6 VS. 175.2±44.6, *P*<0.001), the DHCA ratio in prolonged ICU stay group was significantly longer than that in non-prolonged ICU group (82.9% VS. 64.7%, *P*<0.036), the positive inotropic agents usage rate was significantly higher than that in non-prolonged ICU group (82.9% VS. 58.7%, *P*<0.007), and the incidence of postoperative stroke, postoperative renal failure and respiratory failure was significantly higher than that in non-prolonged ICU group (14.3% VS. 1.8%, *P*<0.001; 22.9% VS. 1.8%, *P*<0.001; 54.3% VS. 15.6%, *P*<0.001).

Multivariate analysis

Risk factors with a *P*-value <0.10 on univariate analyses were entered in the multivariate analyses to identify independent risk factors. Multivariate logistic regression analysis showed that CPB time (odds ratio [OR], 1.039; 95% confidence interval [CI], 1.014-1.064), postoperative stroke (OR, 9.359; 95% CI, 1.685-51.683), postoperative renal failure (OR, 5.087; 95% CI, 1.043-24.824) and respiratory failure (OR, 5.917; 95% CI, 1.861-18.810) were significant independent predictors for prolonged ICU stay in patients undergoing surgery for acute aortic dissection type A (*P*<0.05, **Table 3**).

Discrimination and calibration

We drew the probability prediction model of prolonged stay in the ICU after operation according to the result of logistic regression analysis (**Table 3**). A new variable Pre representing individual predictive value was produced in a SPSS worksheet. We drew the receiver operating characteristic (ROC) curve by taking the new variable Pre, CPB time, postoperative renal failure, postoperative respiratory failure and postoperative stroke as test variables and prolonged ICU stay as state variable. The corresponding AUC of each test variable were shown in **Table 4**: CPB time (*P*<0.001, AUC: 0.823; 95% CI, 0.727-0.919), Postoperative renal failure (*P*<0.007, AUC: 0.647; 95% CI, 0.532-0.762), Postoperative respiratory failure (*P*<0.001, AUC: 0.708; 95% CI, 0.602-0.814), Postoperative stroke (*P*<0.145, AUC: 0.579; 95% CI, 0.465-0.693). The AUC of the new variable Pre was higher than all the other test variables, the AUC of Pre was 0.907, *P*≤0.001, 95% confidence interval was 0.842 to 0.971, as shown in **Figure 1**. It indicated that the prediction model had a good discriminatory power. The sensitivity and specificity of the independent predictors and the new variable Pre are

Table 5. Sensitivity and specificity of the independent predictors and the new variable Pre

Variable	Sensitivity		Specificity	
	Value	95% CI	Value	95% CI
CPB time	0.510	0.368-0.650	0.950	0.900-0.976
Postoperative renal failure	0.688	0.415-0.879	0.881	0.825-0.922
Postoperative respiratory failure	0.524	0.366-0.677	0.929	0.876-0.961
Postoperative stroke	0.667	0.309-0.910	0.861	0.803-0.904
New variable Pre	0.625	0.473-0.757	0.975	0.934-0.992

CPB, Cardiopulmonary bypass; CI, confidence interval.

shown in **Table 5**. The details are as follows: CPB time (cutoff value, 193.5 min; sensitivity: 0.510, 95% CI: 0.368-0.650; specificity: 0.950, 95% CI: 0.900-0.976), postoperative renal failure (sensitivity: 0.688, 95% CI: 0.415-0.879; specificity: 0.881, 95% CI: 0.825-0.922), postoperative respiratory failure (sensitivity: 0.524, 95% CI: 0.366-0.677; specificity: 0.929, 95% CI: 0.876-0.961), postoperative stroke (sensitivity: 0.667, 95% CI: 0.309-0.910; specificity: 0.861, 95% CI: 0.803-0.904), and the new variable Pre (sensitivity: 0.625, 95% CI: 0.473-0.757; specificity: 0.975, 95% CI: 0.934-0.992). The Hosmer-Lemeshow goodness-of-fit test showed that $\chi^2<10.251$ and $P<0.248$. This indicated that this model was well-calibrated for prediction of prolonged ICU stay.

Discussion

Mortality rates following cardiac surgery have been steadily decreasing with improvements in preoperative diagnosis, surgical technique, and patient care. However, postoperative complications and prolonged ICU stay are still high with cardiac surgery increasingly utilized in older and having more advanced disease and greater co-morbidity patients. Prolonged ICU stay is associated with increased hospital costs and incremental use of medical resources, and it also leads to a shortage of ICU beds and results in operations being canceled [4]. Furthermore, these patients usually have poor quality of life and higher mortality after discharge [5]. The mortality rate is about 34% in one year after discharge, and even highly to about 60% in three years after discharge [6, 7]. Most patients undergoing surgery for acute aortic dissection type A have a more prolonged ICU stay in comparison to patients undergoing routine cardiac or aortic operation. In this study preoperative, intraoperative, and postoperative models were used to predict prolonged ICU stay. CPB time, postoperative renal failure, postoperative respiratory failure, and postoperative stroke are proved to be significant predictors for prolonged ICU stay after operation for acute aortic dissection type A. The model was well-calibrated and had good discriminatory power.

There are many reports about the risk factors related with the mortality after operation for acute aortic dissection type A. Many studies have pointed out that age, renal failure, preoperative hemodynamic instability, cardiopulmonary resuscitation, tamponade, prolonged DHCA, sustained injury to the nervous system, and respiratory insufficiency are the important risk factors related with in-hospital mortality after surgery [8-12]. But there are still few reports about the risk factors influencing ICU length of stay after operation for acute aortic dissection type A. Variables reported to determine ICU stay in routine cardiac operation are type of operation, emergency surgery, reoperation, age, higher preoperative serum creatinine, left ventricular function, CPB time, and volume of blood transfusions [13-16].

A substantial volume of work over the years has demonstrated that CPB time is predictor of immediate postoperative complications and mortality after cardiac surgery. It is related with prolonged mechanical ventilation time, postoperative renal dysfunction, gastrointestinal complications and prolonged ICU stay [17, 18]. Our study confirmed that CPB time was the independent risk factor for prolonged stay in the ICU after surgery for acute aortic dissection type A in accordance with above findings. Cardiopulmonary bypass can trigger significant inflammatory response during the cardiac surgery. Complements were activated, inflammatory cytokines release increased, oxidation products increased, and blood cells adhesion increased in endothelial cell with the extension of cardiopulmonary bypass time. All these inflammatory responses may result in multiple organ dysfunction (heart, brain, lung, liver and kidney etc) and blood coagulation mechanism disorder, thus extending the duration of mechanical ventilation and ICU stay time [18].

There is a relationship between CPB time and surgical skills and proficiency and complexity of the disease. The cardiopulmonary bypass time should be shortened as far as possible to reduce the multiple organ function damage and reduce postoperative ICU stay time.

Neurological complication is one of the major causes of in-hospital mortality and morbidity in patients undergoing operation for acute type A aortic dissection. Especially postoperative stroke is one of the catastrophic complications after great vessel operation, the mortality and disability rate are higher in these patients, and this seriously influences the prognosis and quality of life of these patients. This study confirmed that the postoperative stroke was an independent risk factor for prolonged stay in the ICU after surgery for acute aortic dissection type A. Therefore, the effective perioperative cerebral protection to reduce the incidence of postoperative stroke is one of the important measures to reduce the ICU stay length. The technique of DHCA associated with selective antegrade cerebral perfusion (ASCP) [19] is a more effective cerebral protection method in great vessel operation. In addition, taking effective monitoring measures such as the use of near infrared spectroscopy technology (NIRS) to monitor cerebral oxygen saturation continuously during DHCA is a reliable way to detect cerebral ischemia/hypoxemia timely. We can take effective treatment to prevent severe cerebral complications according the monitoring result [20].

Postoperative respiratory failure showed a significant influence on ICU stay length in patients with acute aortic dissection type A in our study. This is in accordance with much research on the risk factors related with prolonged ICU stay length in routine cardiac surgery [21, 22]. Respiratory failure is one of the serious postoperative complications in patients with acute aortic dissection type A, the incidence is about 13% in some studies [23]. These patients may fail to wean from the ventilator due to the respiratory failure, so they needed longer intubation or even tracheotomy. This resulted in prolonged ICU stay length. Therefore, effective perioperative measures should be taken to protect the lung function, and we should also take more measures timely and effectively to prevent and treat the postoperative respiratory failure, so this may shorten the ICU stay length in acute aortic dissection type A patients after operation. Some researchers have shown that prone positioning is a viable treatment option, improving pulmonary oxygenation significantly. Additionally, there was a tendency toward a shorter total time of mechanical ventilation and shorter ICU stay in the prone positioning subgroup in patients who underwent surgery for acute aortic dissection type A [23].

Acute renal failure is a frequent postoperative complication in patients after cardiac surgery with a reported incidence of between 1% and 31% [18]. It is related with increased postoperative mortality in patients undergoing cardiac surgery [22]. The results of this study showed that acute renal failure was an independent risk factor for prolonged stay in the ICU after surgery for acute aortic dissection type A.Many studies have demonstrated increased cardiopulmonary bypass time is associated with acute renal failure. Therefore, shortening the CPB time as far as possible can also reduce the incidence of postoperative acute renal failure after cardiac surgery, and so as to reduce the ICU stay length. For patients with postoperative acute renal failure, early initiation of continuous or intermittent renal replacement therapy can improve patients' outcomes [24], and so as to shorten ICU stay length.

In conclusion, this study demonstrates that CPB time, occurrence of postoperative stroke, acute renal failure, and acute respiratory failure are independent predictors for prolonged ICU stay after surgery for acute aortic dissection type A. These measures as follows may be useful in order to reduce the postoperative complications and shorten ICU stay length, promote effective protection of brain, kidney, and lung function in perioperative period, and in strengthening management of respiratory tract. This approach can be used to carefully and promptly treat respiratory failure postoperatively, thus ensuring sufficient renal blood supply during and after the operation. Furthermore, avoiding the application of nephrotoxic drugs, and timely and effective renal replacement therapy can be used to shorten he CPB time as far as possible during operation.

Limitation

Like all retrospective studies, this investigation also has several limitations. First, the patient population collected for investigation was relatively small and just in a single institution. Second, factors such as experience of the individual surgeon, and institutional philosophy influence the decision for method of treatment cannot be taken into account in this analysis. Third, long-term results are presently not obtained by the registry data. Finally, as this is a retrospective study, potential misclassification bias could not be completely excluded.

Acknowledgements

This work was supported by the project "Scientific research project" of Qingdao Municipal Bureau of health (No: 2014-WJZD030).

Disclosure of conflict of interest

None.

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