Original Article

Outcomes and risk factors of postoperative hepatic dysfunction in patients undergoing acute type A aortic dissection surgery

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Background: Postoperative hepatic dysfunction (HD) increases the morbidity and mortality risk after cardiac surgery; however, only a few studies have specifically focused on acute type A aortic dissection (AAAD) surgery. We explored the possible risk factors and outcomes of early postoperative HD in patients with AAAD undergoing surgery.

Methods: All patients who underwent AAAD surgery at our institution from April 2015 to April 2017 were retrospectively evaluated. Postoperative model for end-stage liver disease (MELD) score was used to define HD. Independent risk factors for HD were determined by multivariate logistic analysis.

Results: Two hundred fifteen patients with AAAD met the inclusion criteria. The incidence rate of early postoperative HD was 60.9%, and the rate of in-hospital mortality was 16.8%. Patients with a high postoperative MELD score had longer mechanical ventilation time, longer durations of intensive care unit (ICU) stay, and higher in-hospital mortality. During the postoperative period, patients with AAAD complicated by HD needed continuous renal replacement therapy (CRRT), reintubation, tracheostomy, and blood transfusion more frequently. Aortic cross clamp (ACC) time [per 10 min higher; odds ratio (OR): 1.216, 95% confidence interval (CI): 1.017–1.454, P=0.032], postoperative leucocytes (per 2×10^9/L higher; OR: 1.161, 95% CI: 1.018–1.324, P=0.026), postoperative respiratory dysfunction (OR: 3.176, 95% CI: 1.293–7.803, P=0.012), and postoperative low cardiac output syndrome (LCOS) (OR: 12.663, 95% CI: 1.432–111.998, P=0.022) were independent risk factors associated with HD in patients undergoing AAAD surgery.

Conclusions: Postoperative HD prolongs mechanical ventilation time and ICU stay, and is associated with increased in-hospital mortality among patients who undergo AAAD surgery. Several factors are associated with a high postoperative MELD score.

Keywords: Hepatic dysfunction (HD); acute type A aortic dissection (AAAD); model for end-stage liver disease score (MELD score); in-hospital mortality; multivariate analysis

Submitted Apr 06, 2019. Accepted for publication Aug 05, 2019.
doi: 10.21037/jtd.2019.08.72
View this article at: http://dx.doi.org/10.21037/jtd.2019.08.72

Introduction

Acute aortic dissection is the most common medical emergency involving the aorta. The mortality of acute type A aortic dissection (AAAD) ranges from 40% to 50% within 48 hours of onset. Surgery for AAAD remains a challenge for cardiovascular surgeons (1-3). Hepatic dysfunction (HD) has been suggested as an important postoperative risk factors for mortality and morbidity after cardiovascular surgery (4,5). Moreover, due to the complexity of surgery, long operation time, and substantial trauma, AAAD is easily complicated by renal insufficiency, HD, and bowel ischemia after surgery, which leads to increased mortality (1). Studies focusing on HD after AAAD surgery are rare, and little is known about postoperative HD outcomes and risk factors.

In the past 30 years, the principal indicator of HD has been the Child-Turcotte-Pugh (CTP) classification (6). However, as an important clinical method for estimating hepatic function, the model for end-stage liver disease (MELD) score has been reported to constitute a more useful assessment tool to predict postoperative mortality and morbidity than CTP classification in patients undergoing cardiac surgery (5,7). MELD scores have been verified as a measure of HD and are used as a tool to prioritize liver transplant candidates based on disease severity (8). Hence, we chose MELD scores as our tools to assess postoperative HD, based on the following clinical indices: (I) international normalized ratio (INR); (II) total serum bilirubin; (III) serum creatinine; and (IV) disease (bilious or alcoholic liver disease =0, all others =1). These score indicators are objective and easy to obtain (9). The aim of our study was to evaluate the risk factors of postoperative HD in patients with AAAD and its impact on clinical outcomes.

Methods

Patients

We retrospectively reviewed the medical records of patients who underwent surgery for AAAD at Changhai Hospital from April 2015 to April 2017. In most cases, enhanced computed tomography was used to diagnose AAAD and determine which vessels were affected by the dissection. This study was approved by the Committee on Ethics of Biomedicine Research, The Second Military Medical University, Shanghai (No. SMMUEC2018-012), with the need for individual patient consent waived.

Data collection

We collected data on patients' age, sex, body mass index, comorbidities (e.g., hypertension, diabetes, chronic obstructive pulmonary disease), history of smoking and alcohol consumption, preoperative MELD score and renal insufficiency, and laboratory test results [creatinine, leukocytes, hemoglobin, alanine transaminase (ALT), aspartate transaminase (AST), albumin, γ-glutamyl transferase, total bilirubin, K^+, Na^+, lactic acid, PaO_2, PaO_2/FiO_2 ratio].

We also collected data on time from symptom onset to surgery, preoperative shock, preoperative moderate/severe pericardial effusion, dissection involvement (celiac trunk, superior mesenteric artery, and renal artery), and intraoperative conditions [cardiopulmonary bypass (CPB) time, aortic cross clamp (ACC) time, deep hypothermic circulatory arrest, and surgical procedure]. Finally, we recorded the 24-h postoperative drainage volume, perioperative blood product transfusion, and postoperative laboratory test results including ALT, AST, albumin, white blood cells, and INR.

Postoperative complications, such as low cardiac output syndrome (LCOS); pneumonia; renal insufficiency; respiratory dysfunction; mechanical ventilation time; time in the intensive care unit (ICU); need for reintubation, continuous renal replacement therapy (CRRT), tracheostomy; sepsis; re-exploration for bleeding; and blood transfusion, including red blood cells, plasma, and cryoprecipitate, were also recorded.

Definitions and grouping

To calculate patients' MELD scores, we used the following formula:

$$\text{MELD} = 11.2 \text{ In (INR)} + 0.378 \text{ In (total bilirubin)} + 0.957 \text{ In (creatinine)} + 0.643 \ (\textit{cause})$$

where *cause* equaled 0 for bilious or alcoholic liver disease and 1 otherwise.

We used the results of laboratory tests within 7 days to calculate MELD score every day after surgery using the above formula, and the highest value of MELD was used to determine whether patients experienced early postoperative HD to avoid the influence of other factors such as infection. Considering that a few patients were taking warfarin during the study, which may have affected the INR and MELD scores, we collected the INR values of these patients before

they took their medicine. We grouped patients based on their postoperative score into high-MELD (MELD ≥14) and low-MELD (MELD <14) groups. Some previous studies set a cutoff point of 13 for patients with cirrhosis undergoing cardiac surgery (10,11), and recent research predicted postoperative mortality and morbidity after cardiac surgery based on a cutoff of 12 (5). Moreover, a recent study on outcomes of patients undergoing cardiac surgery after liver transplantation showed that the optimal cutoff point for predicting late mortality is 13.8 (12). In another study, the Youden index identified the optimal MELD score cutoff value of 13.5 for predicting surgical mortality of cardiac surgery in liver transplant recipients (13). Consequently, considering that AAAD surgery is more complicated than other cardiac surgeries, and based on the optimal cutoff values of MELD scores for risk of mortality in previous studies, we used 14 as our cutoff point.

Renal insufficiency was defined by an estimated glomerular filtration rate of <60 mL/min/1.73 m^2, and hyperbilirubinemia was defined by total bilirubin >3 mg/dL. Respiratory dysfunction was defined as inadequate oxygenation (PaO_2 <60 mmHg with a FiO_2 of 0.5 or PaO_2/FiO_2 ≤120) or ventilation (PCO_2 >50 mmHg) during mechanical ventilatory support (14). LCOS was diagnosed if the patient required two or more inotropic medications to maintain systolic blood pressure above 90 mmHg and a cardiac output greater than 2.2 L/min/m^2 postoperatively after adjusting the preload and correcting for all electrolyte or blood gas abnormalities (15). Transfusion threshold and policies were as follows: if the patient's hematocrit was lower than 25, we transfused packed red cell to increase the intravascular volume and maintain satisfactory tissue oxygenation; if the patient was bleeding in the early postoperative period, blood component therapy, selected based upon identification of specific coagulation abnormalities by point-of-care testing and treatment algorithms, plasma infusion, or cryoprecipitate were considered: fresh frozen plasma was usually given at 2–4 units for average adults, cryoprecipitate was given 1 unit at 1 unit/7–10 kg of body weight. Massive transfusion was defined as ≥10 units of blood transfused (16). Prolonged ICU stay was defined as >7 days (17).

Statistical analysis

Continuous variables are presented as means ± standard deviation or medians and interquartile range. Comparisons of continuous variables between the two groups were performed using the Student's *t*-test for variables with a normal distribution. The Wilcoxon rank-sum test was used for variables with a non-normal distribution. Categorical variables were analyzed using the Pearson's chi-squared or Fisher's exact test. Receiver operating characteristic (ROC) curve and the Youden index were used to determine the optimal cutoff value of MELD score for predicting the surgical risk of mortality.

Multivariate logistic regression analyses were performed to identify risk factors for a high MELD score. Significant variables (P<0.05) associated with a high MELD score in the univariate analysis and clinically relevant variables were included in the multivariate analysis. The multivariate regression analysis was performed using a forward stepwise (conditional) procedure to determine the independent significant prognostic factors. The multivariate regression analysis was performed to determine the effect of a postoperative high MELD score on mortality, prolonged ICU stay, and massive transfusion after adjusting for relevant confounding variables in the three models. All P-values were two-sided. Statistical significance was defined as P<0.05. All statistical analyses were performed using SPSS 24.0 (IBM Corp.).

Results

Of the 216 patients with AAAD who underwent surgery from April 2015 to April 2017, one patient was excluded due to persistent bleeding and death within 24 h after surgery; the remaining 215 patients were divided into high-MELD (MELD score ≥14; n=131) and low-MELD (MELD score <14; n=84) groups. Based on MELD scores, the incidence rate of early postoperative HD was 60.9%, with an in-hospital mortality rate of 16.8%.

Baseline and preoperative characteristics

Patients with high postoperative MELD scores tended to have high preoperative MELD scores and preoperative renal insufficiency. Laboratory examination showed that the high-MELD group had higher preoperative creatinine levels and leucocyte counts (*Table 1*).

Surgery and postoperative characteristics

Patients in the high-MELD group had longer CPB and ACC times than those in the low-MELD group and underwent higher number of total-arch replacements and

Table 1 Baseline characteristics of the 215 AAAD patients

Patients' characteristics	MELD <14 (N=84)	MELD ≥14 (N=131)	P value
Age (years)	47±12.4	48.8±12.4	0.302
Men	66 (78.6)	108 (82.4)	0.481
BMI	25.0±4.55	25.9±3.8	0.129
Hypertension	49 (58.3)	84 (64.1)	0.394
Diabetes	1 (1.2)	3 (2.3)	0.948
COPD	2 (2.4)	3 (2.3)	1.000
Ischemic heart disease	1 (1.2)	4 (3.1)	0.377
Smoking	39 (46.4)	58 (44.3)	0.757
Drinking	16 (19.0)	18 (13.7)	0.298
Preoperative hepatic dysfunction (MELD ≥ELD	1 (1.2)	13 (9.9)	0.011
Preoperative renal insufficiency	3 (3.6)	46 (35.1)	<0.001
Leucocytes ($10^9 \cdot L^{-1}$)	10.4 [8.1–14.0]	13.0 [10.4–16.4]	<0.001
Hemoglobin ($g \cdot L^{-1}$)	124±19	127±16	0.300
ALT (U/L)	24 [15.3–36.5]	29 [19.0–45.5]	0.053
AST (U/L)	27 [19–36]	29.5 [21–47]	0.134
Albumin (g/L)	38 [35–41]	39 [36–41]	0.364
γ-glutamyl transferase (U/L)	33 [21–83]	36 [22–72]	0.905
Preoperative hyperbilirubinemia	2 (2.4)	3 (2.3)	0.966
Na^+ (mmol/L)	138 [136–140]	138 [136–140]	0.733
K^+ (mmol/L)	3.6 [3.5–3.8]	3.7 [3.4–4.0]	0.234
Lactic acid (mmol/L)	1.3 [0.9–1.8]	1.4 [0.9–2.3]	0.254
PaO_2 (mmHg)	95 [76.5–140.0]	89 [73–133]	0.480
PaO_2/FiO_2 ratio	246 [205–311]	231 [192–305]	0.287
Onset to surgery time (h)	35 [20–165]	31 [21–60]	0.179
Moderate/severe pericardial effusion	22 (26.2)	44 (33.6)	0.251
Shock (systolic blood pressure <80 mmHg)	2 (2.4)	5 (3.8)	0.563
Involving the celiac trunk	15 (17.9)	32 (24.4)	0.255
Involving the superior mesenteric artery	8 (9.5)	18 (13.7)	0.355
Involving the renal artery	8 (9.5)	18 (13.7)	0.355

Data are presented as mean ± standard deviation, median [interquartile range], or number (%).AAAD, acute type A aortic dissection; MELD, end-stage liver disease; BMI, body mass index; COPD, chronic obstructive pulmonary disease; ALT, alanine transaminase; AST, aspartate transaminase; PaO_2, partial pressure of oxygen; FiO_2, fraction of inspired oxygen.

Table 2 Surgery and postoperative characteristics of the two groups

Patients' characteristics	MELD <14 (N=84)	MELD ≥14 (N=131)	P value
CPB time (min)	144.5 [122.8–170.0]	152 [138–172]	0.013
ACC time (min)	83.5±24.8	92.3±19.6	0.004
Deep hypothermic circulatory arrest (min)	24 [21–30]	25 [21–32]	0.366
Type of operation			
CABG	5 (6.0)	18 (13.7)	0.071
Ascending aorta replacement	79 (94.0)	127 (96.9)	0.300
Hemi-arch replacement	11 (13.1)	2 (1.5)	0.001
Total-arch replacement	67 (79.8)	125 (95.4)	0.000
Elephant trunk	65 (77.4)	121 (92.4)	0.002
24-h postoperative drainage volume (mL)	445 [302–660]	560 [370–870]	0.009
Leucocyte ($\times 10^9$/L)	17.7 [14.2–21.7]	22.5 [18.1–26.5]	<0.001
LCOS	1 (1.2)	18 (13.7)	0.016
Pneumonia	6 (7.1)	35 (26.7)	<0.001
Postoperative renal insufficiency	17 (20.2)	95 (72.5)	<0.001
Respiratory dysfunction	10 (11.9)	58 (44.3)	<0.001

Data are presented as mean ± standard deviation, median [interquartile range], or number (%). MELD, end-stage liver disease; CPB, cardiopulmonary bypass; ACC, aortic cross-clamp; CABG, coronary artery bypass graft; LCOS, low cardiac output syndrome.

elephant trunk surgical procedures. Postoperative renal insufficiency occurred more frequently in the high-MELD group (72.5% *vs.* 20.2%). LCOS, respiratory dysfunction, and pneumonia were associated with high MELD scores. Patients with high MELD scores had a higher leucocyte count postoperatively and higher 24-h postoperative drainage volume (*Table 2*).

In-hospital outcomes of patients with high MELD scores

Patients with a high MELD score after surgery had a longer mechanical ventilation time, longer ICU stay, and higher in-hospital mortality rate. Patients with AAAD and a high MELD score needed more CRRT, reintubation, and tracheostomy after surgery. In addition, this group had a greater need for blood transfusion (*Table 3*).

Logistic regression for high postoperative MELD score

ACC time, postoperative leucocyte counts, postoperative LCOS, and postoperative respiratory dysfunction were independent predictive factors of a high postoperative MELD score (*Table 4*). After adjusting for relevant confounding variables, a high postoperative MELD score was associated with mortality and prolonged ICU stay, but not with massive transfusion (*Tables 5,S1-S3*).

Discussion

The most important finding of our study was that a longer ACC time, higher postoperative leucocyte level, and postoperative LCOS and respiratory dysfunction were independent risk factors of postoperative HD in patients with AAAD.

Postoperative HD is a common serious complication in patients with AAAD. The MELD score has been used frequently in recent studies to evaluate hepatic function after cardiac surgery, but its use in AAAD surgery is relatively rare. Liu *et al*. reported that early postoperative HD incidence was 8.7% after AAAD surgery (18), while another study showed an HD incidence of 1.6% postoperatively among patients with AAAD, with a mortality rate of 38% (19). However, these studies relied on biochemical markers to evaluate hepatic function. In our study, we used the MELD score and found that the incidence of postoperative HD was as high as 60.9%, with an in-

Table 3 Outcomes

Variable	MELD <14 (N=84)	MELD ≥14 (N=131)	P value
In-hospital mortality	1 (1.2)	22 (16.8)	<0.001
Mechanical ventilation time (h)	37 [20–58.5]	67 [40–109.5]	<0.001
ICU stay (h)	99 [66.3–139]	158 [92–290.3]	<0.001
Reintubation	2 (2.4)	20 (15.3)	0.002
CRRT	2 (2.4)	18 (13.7)	0.005
Tracheostomy	2 (2.4)	14 (10.7)	0.024
Sepsis	0 (0)	6 (4.6)	0.118
Re-exploration for bleeding	1 (1.2)	6 (4.6)	0.331
Blood transfusion			
Erythrocytes (U)	6 [4–11.3]	10 [6–15]	<0.001
Plasma (U)	6.5 [3–10]	9 [5.5–15]	<0.001
Cryoprecipitate (U)	10 [10–10]	10 [10–20]	<0.001

Data are presented as median [interquartile range], or number (%). MELD, end-stage liver disease; ICU, intensive care unit; CRRT, continuous renal replacement therapy.

Table 4 Univariable and multivariate analysis of the risk factors for postoperative high MELD score

Variable	Univariable analysis			Multivariable analysis		
	OR	95% CI	P value	OR	95% CI	P value
Preoperative hepatic dysfunction (MELD ≥14)	9.144	1.173–71.261	0.035	–	–	–
Preoperative renal insufficiency	14.612	4.371–48.849	0.000	3.846	0.977–15.14	0.054
Preoperative leucocytes ($10^9 \cdot L^{-1}$)	1.232	1.074–1.413	0.003	–	–	–
Preoperative hyperbilirubinemia	0.961	0.157–5.875	0.966	–	–	–
Preoperative pericardial effusion	1.425	0.777–2.614	0.252	–	–	–
Preoperative shock (systolic blood pressure <80 mmHg)	1.627	0.308–8.585	0.566	–	–	–
CPB time (min) (per 10 min higher)	1.013	1.003–1.022	0.009	–	–	–
ACC time (min) (per 10 min higher)	1.198	1.052–1.363	0.006	1.216	1.017–1.454	0.032
Hemi-arch replacement	0.103	0.022–0.477	0.004	–	–	–
Total-arch replacement	5.286	1.99–14.041	0.001	3.040	0.885–10.44	0.077
Elephant trunk	3.537	1.553–8.054	0.003	–	–	–
24-h postoperative drainage volume (mL) (per 200 mL higher)	1.116	1.029–1.209	0.008	–	–	–
Postoperative leucocyte ($\times 10^9$/L) (per 2×10^9/L higher)	1.276	1.141–1.428	0.000	1.161	1.018–1.324	0.026
Postoperative LCOS	13.221	1.73–101.021	0.013	12.663	1.432–111.998	0.022
Postoperative pneumonia	4.740	1.896–11.847	0.001	–	–	–
Postoperative respiratory dysfunction	5.879	2.791–12.384	0.000	3.176	1.293–7.803	0.012

The final model for high MELD score had an area under receiver operating characteristic curve of 0.787, and the Hosmer-Lemeshow test with P>0.05. MELD, end-stage liver disease; CPB, cardiopulmonary bypass; ACC, aortic cross-clamp; LCOS, low cardiac output syndrome; OR, odds ratio; CI, confidence interval.

Table 5 Multivariate analysis for risk factors of mortality, prolonged ICU stay and massive transfusion

Variable	OR	95% CI	P value
Mortality			
Postoperative MELD ≥14	8.911	1.029–77.179	0.047
Prolonged ICU stay (>7 days)			
Postoperative MELD ≥14	2.465	1.121–5.420	0.025
Massive transfusion (≥10 units)			
Postoperative MELD ≥14	0.774	0.344–1.744	0.537

The multivariate regression analysis was performed after adjusting for relevant confounding variables in the three models. MELD, end-stage liver disease; ICU, intensive care unit; OR, odds ratio; CI, confidence interval.

hospital mortality rate of 16.8%. We also found that highly suspected risk factors (e.g., peritoneal artery involvement, onset to surgery time) were not independent risk factors for postoperative HD.

Almost all open thoracic AAAD surgeries are performed with extracorporeal circulation i.e. CPB. Since CPB is a non-physiological state, and liver perfusion would be significantly reduced, leading to liver function damage. Although there is distal perfusion during the ACC time, liver perfusion is significantly reduced (20). It has previously been reported that the blood volume in liver arteries decreases by 20% to 25% during CPB (21). Hence, a long ACC time can induce a critical reduction in perfusion, and significant hypoxemia in the abdominal organs is inevitable, thus overwhelming the protective mechanisms and causing hypoxic liver damage (22). Furthermore, a long ACC time is associated with serious clinical conditions and complicated procedures can also lead to an inflammatory response. The subsequent activation of a variety of inflammatory mediators, such as adhesion molecules, thrombin, cytokines, endothelin and macrophages weakens the immune response, and a combination of these factors causes multi-organ dysfunction (23-25).

Increased postoperative HD was associated with a higher postoperative leucocyte count in our study. The leucocyte count is an important index for inflammatory response, and an early postoperative increase is highly associated with an inflammatory response rather than infection. When AAAD occurs, it activates multiple responses in the circulatory system, which can cause severe systemic inflammatory response syndrome and coagulation disorders. The inflammatory response is closely linked to the development of AAAD (26); however, due to its critical nature, rapid progression, requirement of a complex surgery, high requirements for extracorporeal circulation, and longer turnaround time, AAAD is more likely to cause a systemic inflammatory response. This is consistent with our previous discussion about ACC. In addition, CPB induces a certain degree of hemolysis, which promotes the release of free hemoglobin, production of endogenous substances play an important role in aggravating body's inflammatory response (27), the risk of multi-organ failure increases, especially in the liver, kidney, lung, and other important organs.

As a common and serious complication in cardiac surgeries, postoperative respiratory dysfunction may prolong the ICU stay and increase in-hospital mortality (28,29). The incidence of postoperative hypoxemia is up to 51% after surgery for AAAD (30). In addition, prolonged respiratory dysfunction requires extended mechanical ventilation time, and the resulting hypoxia can damage vital organs, especially those that are more sensitive to hypoxia, such as the lung and liver. This damage causes other serious complications, such as sepsis and HD.

Pérez Vela *et al.* showed that patients who experienced LCOS after cardiac surgery had a poorer postoperative course, with a greater incidence of multi-organ failure and higher mortality (31). When LCOS develops, it directly causes insufficient hepatic perfusion pressure, leading to hepatic ischemia and hypoxia. In addition, inotropic agents used to improve patients' cardiac output were found to increase myocardial consumption and in-hospital mortality (32), leading to ischemia of other organs. The treatment goal of LCOS is to promote tissue DO_2 by providing appropriate hemodynamic support to avoid dysfunction and failure of critical organs (33), leading to a good clinical outcome.

This study has some limitations related to its retrospective design and the fact that all data was generated by a single center. The conclusions may be influenced by this center's practice standards; thus, multi-center studies should be carried out to obtain further insights. Moreover, the MELD score includes INR in the formula, and thus, warfarin administration may have an impact on the score; perhaps the MELD-XI score that excludes INR may be more appropriate for such analysis (34), and we hope that research on this aspect will be carried out in future. Finally, a strength of this study was the use of the MELD score to estimate liver function. We set a score of 14 as the cutoff point, which was higher than that used in previous

cardiac surgery studies. However, AAAD surgery is more complicated than other types of cardiac surgery, and we consider that a higher cutoff point is more reasonable in this setting. We look forward to further studies on the appropriate cutoff point for the MELD score to classify hepatic function in patients with AAAD.

Conclusions

Postoperative HD prolongs mechanical ventilation time and ICU stay, and it is associated with in-hospital mortality in patients with AAAD. A longer ACC time, higher postoperative leucocyte count, postoperative respiratory dysfunction, and postoperative LCOS are independent risk factors of HD in patients with AAAD undergoing surgery.

Acknowledgments

We want to thank the statistician of statistical guidance of this work: Weituo Zhang. PhD, worked in Clinical Research Center of Shanghai Jiao Tong University School of Medicine

Funding: This work was supported by the National Natural Science Foundation of China (No. 81873524) and a China Postdoctoral Science Foundation funded project (NO.2018M633709).

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: This study was approved by the Committee on Ethics of Biomedicine Research, The Second Military Medical University, Shanghai (No. SMMUEC2018-012), with the need for individual patient consent waived. The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Cite this article as: Zhou W, Wang G, Liu Y, Tao Y, Du Z, Tang Y, Qiao F, Liu Y, Xu Z. Outcomes and risk factors of postoperative hepatic dysfunction in patients undergoing acute type A aortic dissection surgery. J Thorac Dis 2019;11(8):3225-3233. doi: 10.21037/jtd.2019.08.72

Supplementary

Table S1 Multivariate analysis for evaluating predictors of mortality

Variable	OR	95% CI	P value
Postoperative MELD ≥14	8.911	1.029–77.179	0.047
Massive transfusion	6.622	1.606–27.307	0.009
Sepsis	5.350	0.698–40.986	0.106
Reintubation	3.911	1.193–12.819	0.024
Age	1.019	0.974–1.066	0.404
Re-exploration for bleeding	1.687	0.239–11.927	0.600
Postoperative leucocyte ($\times 10^9$/L) (per 2×10^9/L higher)	0.986	0.846–1.149	0.855
Preoperative renal insufficiency	0.817	0.257–2.599	0.733

MELD, end-stage liver disease; OR, odds ratio; CI, confidence interval.

Table S2 Multivariate analysis for evaluating predictors of prolonged ICU stay

Variable	OR	95% CI	P value
Postoperative MELD ≥14	2.465	1.121–5.42	0.025
Massive transfusion	9.938	4.564–21.639	0.000
24-h postoperative drainage volume (per 200 mL higher)	0.928	0.77–1.119	0.433
Re-exploration for bleeding	1.441	0.184–11.261	0.728
ACC time (min) (per 10 min higher)	1.024	0.867–1.209	0.780
LCOS	0.640	0.171–2.401	0.508
CRRT	10.110	1.969–51.907	0.006

MELD, end-stage liver disease; ICU, intensive care unit; ACC, aortic cross-clamp; LCOS, low cardiac output syndrome; CRRT, continuous renal replacement therapy; OR, odds ratio; CI, confidence interval.

Table S3 Multivariate analysis for evaluating predictors of massive transfusion

Variable	OR	95% CI	P value
Postoperative MELD ≥14	0.774	0.344–1.744	0.537
Sepsis	0.712	0.055–9.282	0.795
postoperative pneumonia	3.282	1.111–9.697	0.032
24-h postoperative drainage volume (per 200 mL higher)	1.547	1.239–1.931	0.000
CPB time (per 10 min higher)	1.202	0.912–1.584	0.191
Prolonged ICU stay	5.579	2.197–14.166	0.000
CRRT	2.772	0.604–12.722	0.190
Total-arch replacement	4.517	0.596–34.215	0.144
Preoperative MELD ≥14	1.245	0.243–6.372	0.793
Mechanical ventilation time (h)	1.001	0.994–1.009	0.703

MELD, end-stage liver disease; ICU, intensive care unit; CPB, cardiopulmonary bypass; CRRT, continuous renal replacement therapy; OR, odds ratio; CI, confidence interval.