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Association Between Cardiopulmonary Bypass Weaning Time and Adverse Outcomes in Patients with Aortic Dissection Who Underwent Total Arch Replacement Combined With Stented Elephant Trunk Implantation

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Abstract

Background:

Postoperative complications in patients with acute type A aortic dissection (ATAAD) significantly affect their prognosis. This study investigates the association between cardiopulmonary bypass(CPB) weaning time and postoperative adverse outcomes in patients with aortic dissection who underwent total arch replacement combined with stented elephant trunk implantation.

Methods:

Patients diagnosed with ATAAD who underwent surgical repair between June 1, 2015, and June 1, 2024, were retrospectively enrolled. CPB weaning time was recorded for each patient. Univariate and multivariate logistic regression analyses were performed to evaluate the association between CPB weaning time and postoperative adverse outcomes, including death, stroke, and other adverse outcomes. Subgroup analyses were also conducted. Receiver operating characteristic (ROC) curve analysis was used to determine the optimal cutoff value of CPB weaning time. Kaplan–Meier survival analysis and log-rank tests were subsequently applied to compare survival between groups stratified by the cutoff value.

Results:

A total of 475 patients were included in the analysis. Prolonged CPB weaning time was significantly associated with increased postoperative in-hospital death (Odds Ratio[OR]: 1.05; 95% Confidence Interval[CI]: 1.02–1.07; P < 0.001) and stroke (OR: 1.02; 95% CI: 1.00–1.03; P = 0.016), but not with other outcomes. The association between CPB weaning time and postoperative in-hospital death remained consistent across subgroups, whereas its association with stroke was influenced by sex, history of coronary heart disease, coronary artery bypass grafting (CABG), axillary artery cannulation, and femoral artery cannulation. The area under the curve (AUC) values of CPB weaning time for predicting postoperative in-hospital death and stroke were 0.844 (95% CI: 0.790–0.899) and 0.670 (95% CI: 0.606–0.734), respectively, with an optimal cutoff value of 90 minutes. When patients were stratified by this cutoff, a statistically significant difference in short-term survival was observed between the two groups, whereas no significant difference was found in mid-term survival.

Conclusions:

CPB weaning time is associated with postoperative death and stroke in patients with ATAAD undergoing total arch replacement combined with stented elephant trunk implantation. It is also associated with poor short-term survival but not with mid-term survival, and serve as a predictor of early postoperative risk of mortality in this population.

Keywords:

cardiopulmonary bypass; aortic dissection; death; stroke

Introduction

Acute type A aortic dissection (ATAAD) represents one of the most fatal aortic pathologies, with mortality increasing by 1–2% per hour without intervention (1). Although surgical repair significantly improves survival, the process of circulatory arrest and prolonged cardiopulmonary bypass (CPB) time often predisposes patients to adverse outcomes such as death, renal failure, and stroke (2). Therefore, identifying risk factors for poor postoperative outcomes and recognizing high-risk patients early are of paramount importance.

In previous studies, difficulty in CPB weaning has been regarded as an intraoperative adverse event and has been associated with increased postoperative complications (3). However, its somewhat ambiguous definition limits its value in postoperative risk stratification. Variations in preoperative cardiac function, vasoplegic syndrome, and other intraoperative factors lead to differences in the time required for CPB weaning; patients with poorer intraoperative status may require a longer duration to achieve stable separation from CPB (4).We therefore hypothesized that CPB weaning time itself is associated with adverse postoperative outcomes in patients with ATAAD.

The aim of this study was to investigate the association between CPB weaning time and adverse postoperative outcomes in patients undergoing surgical repair for acute type A aortic dissection.

Materials and Methods

Study Population and Data Collection

We retrospectively reviewed 641 consecutive ATAAD patients who underwent total arch replacement combined with stented elephant trunk implantation between June 1, 2015, and June 1, 2024. Patients who required Extracorporeal Membrane Oxygenation (ECMO) or intra-aortic balloon pump support (n=6), those with preoperative renal failure (n=2), preoperative malperfusion (n=16), preoperative coma or new-onset stroke (n=15), and those with incomplete data (n=127) were excluded. A total of 475 patients were included in the final analysis (Figure 1). Among patients with missing data, 77.2% (n = 98) had missing clinical data and 22.8% (n = 29) had missing follow-up data. Missing clinical data primarily involved intraoperative variables obtained from the anesthesia system, including key parameters such as CPB time, as well as partial baseline information. For survival analysis, patients with missing follow-up data were excluded rather than censored. The CPB weaning time was defined as the interval from the release of the aortic cross-clamp to the complete discontinuation of the CPB circuit.

Baseline and outcome data were extracted from the electronic medical record system, and intraoperative information was obtained from the electronic anesthesia records. Variables collected for analysis included demographics, medical history, laboratory findings, and intraoperative parameters.All study procedures were conducted in accordance with the Declaration of Helsinki (revised in 2013). This single-center retrospective study was approved by the institutional ethics committee, which waived the requirement for written informed consent due to the retrospective nature of the research.

Outcome Definitions

The primary outcome was postoperative in-hospital death. Secondary outcomes included stroke, renal failure, prolonged mechanical ventilation, and delayed awakening. Death was defined as death from any cause during the hospital stay after surgery. stroke was defined as a new postoperative neurological deficit confirmed by computed tomography (CT) or magnetic resonance imaging (MRI). In cases where imaging did not reveal a clear lesion but a neurologist-confirmed diagnosis was made, the event was still classified as stroke.Renal failure was defined as a threefold increase in serum creatinine from baseline, serum creatinine ≥4 mg/dL, or the need for postoperative renal replacement therapy (5).Prolonged mechanical ventilation was defined as ventilation duration >24 hours (6), and delayed awakening was defined as failure to regain consciousness within 6 hours after discontinuation of anesthesia (7).

Imaging

All imaging examinations were performed using a Siemens Somatom Definition dual-source computed tomography (DSCT) system. Patients underwent aortic computed tomography angiography (CTA) with the following scanning parameters: tube voltage 120 kV, tube current 100 mA, pitch 1.25, slice thickness 5 mm, and slice interval 5 mm. Patients were positioned supine with both arms elevated. Iopamidol contrast agent (Shanghai Bracco Sine Pharmaceutical Co., Ltd.) was administered via an antecubital vein using a high-pressure injector at a dose of 100 mL and a flow rate of 5 mL/s, with a post-injection delay of approximately 25–30 s. Acquired images were transferred to a dedicated workstation for post-processing.

surgical procedures

After induction of anesthesia, a median sternotomy was performed, and the aortic arch and its three supra-arch branches were exposed. Following systemic heparinization, CPB was established once the activated clotting time (ACT) exceeded 500 s. When nasopharyngeal temperature decreased to 33° C, the ascending aorta was cross-clamped and proximal repair was initiated. At a nasopharyngeal temperature of 25° C, circulatory arrest and cerebral perfusion were instituted.An intraoperative stent graft was deployed into the distal descending aorta via the left subclavian artery. A four-branched prosthetic graft was anastomosed to the proximal end of the descending aortic stent. After clamping the proximal end of the four-branched graft, circulatory arrest was terminated. The proximal anastomosis between the graft and the ascending aorta was then completed, followed sequentially by reconstruction of the left common carotid artery(LCCA), innominate artery(IA), and left subclavian artery(LSA). Once heart rate and blood pressure stabilized, CPB flow was gradually reduced and discontinued, cannulas were removed, and heparin was neutralized. Hemostasis was achieved, temporary epicardial pacing wires were placed, pericardial and mediastinal drains were inserted, and the chest was closed.

Myocardial protection was achieved using antegrade del Nido cardioplegia; if cardiac arrest exceeded 1.5 hours, repeated antegrade cardioplegia was administered. Arterial cannulation was typically performed via the femoral artery, with venous cannulation of the superior and inferior vena cava. Axillary artery cannulation was adopted when severe involvement of the innominate artery or true lumen compression threatened cerebral or myocardial perfusion during retrograde perfusion. In cases of severe true lumen stenosis or excessive body weight causing difficulties in temperature management, combined femoral and axillary artery cannulation was used. No patients in this cohort underwent innominate artery cannulation.Bilateral cerebral oxygen saturation was continuously monitored intraoperatively. Unilateral cerebral perfusion was routinely employed, using pre-arrest cerebral oxygen saturation as baseline. Bilateral cerebral perfusion was initiated if left-sided cerebral oxygen saturation decreased by more than 15% or if the absolute value fell below 45%.

Statistical Analysis

Categorical variables are presented as frequencies and percentages; continuous variables are expressed as mean ± standard deviation (SD) when normally distributed, or as median (interquartile range,IQR) when not normally distributed. Comparisons between survivors and non-survivors were made using the chi-square test for categorical variables, the independent-samples t-test for normally distributed continuous variables, and the Mann–Whitney U test for non-normally distributed data.Univariate and multivariate logistic regression analyses were performed to assess the association between CPB weaning time and outcomes. To explore the potential modifying effects of factors such as sex and age, subgroup analyses were further conducted for outcomes that reached statistical significance. To minimize the potential impact of multicollinearity, variance inflation factor (VIF) were calculated to assess correlations among variables; a VIF < 10 was considered indicative of no significant multicollinearity.For clinical interpretability, the optimal cutoff value for CPB weaning time was determined using the Youden index, and Kaplan–Meier survival curves with log-rank tests were used to compare survival between groups. For survival analysis, a landmark analysis with a cutoff at 1 month was performed to evaluate short-term and mid-term differences in mortality. All statistical analyses were conducted using R software version 4.4.2. A two-sided P value < 0.05 was considered statistically significant.

Results

Baseline and Intraoperative Characteristics

At our center, approximately 87.6% of patients with type A aortic dissection undergo total arch replacement combined with stented elephant trunk implantation. Among all included patients, 58 (12.2%) experienced postoperative in-hospital death. Baseline characteristics, preoperative laboratory findings, and intraoperative data of patients with and without postoperative in-hospital death are presented in Tables 1 and 2. Patients who experienced postoperative in-hospital death had a higher prevalence of coronary heart disease (CHD，4.6% vs 15.5%, P = 0.003). Preoperative laboratory values were significantly higher in the death group, including white blood cell count (11.02 vs 13.75, P < 0.001), neutrophil count (9.67 vs 12.30, P < 0.001), creatinine (82.00 vs 95.00, P = 0.005), uric acid (341.00 vs 404.50, P < 0.001), creatine kinase (89.00 vs 101.50, P = 0.018), and CK-MB (15.00 vs 21.50, P < 0.001). Intraoperatively, patients with postoperative in-hospital death were more likely to undergo coronary artery bypass grafting (CABG) (2.6% vs 17.2%, P < 0.001), had a lower rate of sinus repair (24.5% vs 5.2%, P = 0.002), and a higher rate of aortic valve replacement or repair (1.7% vs 8.6%, P = 0.007). They also had longer operative time (346.00 vs 448.50, P < 0.001), CPB time (161.60 vs 207.50, P < 0.001), CPB weaning time (64.00 vs 91.00, P < 0.001), greater intraoperative blood loss (1300.00 vs 1520.00, P < 0.001), and a higher proportion of femoral artery cannulation (79.4% vs 94.1%, P = 0.046).

Logistic Regression and Subgroup Analyses

The analyses confirmed that no multicollinearity was present among the variables included in the models, and the detailed results are provided in Supplementary Table 1.In univariable logistic regression, CPB weaning time was significantly associated with postoperative in-hospital death (Odds Ratio [OR]: 1.06; 95% Confidence Interval [CI]: 1.05 – 1.08; P < 0.001), renal failure (OR: 1.02; 95% CI: 1.01 – 1.03; P < 0.001), and stroke (OR: 1.02; 95% CI: 1.01 – 1.03; P < 0.001). However, in multivariable analysis, CPB weaning time remained independently associated only with postoperative in-hospital death (OR: 1.05; 95% CI: 1.02 – 1.07; P < 0.001) and stroke (OR: 1.02; 95% CI: 1.00 – 1.04; P = 0.016) (Table 3). In subgroup analyses, no significant differences were observed in the association between CPB weaning time and in-hospital death across subgroups. Similarly, no subgroup differences were identified in the association between CPB weaning time and stroke when stratified by age or cerebral perfusion strategy. However, the association between CPB weaning time and the risk of stroke varied across subgroups defined by sex, history of coronary heart disease, CABG, axillary artery cannulation, and femoral artery cannulation, suggesting the potential influence of these factors. These findings require further validation (Figure 2).

ROC Curve and Survival Analyses

The AUC of CPB weaning time for predicting postoperative in-hospital death and stroke was 0.844 (95% CI: 0.790–0.899) and 0.670 (95% CI: 0.606–0.734), respectively. The optimal cutoff value calculated using the Youden index was 90 minutes for both outcomes (Figure 3). Patients with CPB weaning time > 90 minutes had a significantly increased risk of postoperative in-hospital death (OR: 7.35; 95% CI: 2.46–21.94; P < 0.001), whereas the association with postoperative stroke was not statistically significant (Table 4). The mean follow-up duration was 46.44 months, and patients with incomplete follow-up were excluded. Landmark analysis using a 1-month cutoff demonstrated significantly lower short-term survival in patients with CPB weaning time > 90 minutes compared with those ≤ 90 minutes, while no statistically significant difference in mid-term survival was observed (P = 0.24) (Figure 4).

Discussion

This retrospective study found that longer CPB weaning time was associated with an increased risk of postoperative in-hospital death and postoperative stroke in patients with aortic dissection, and was also associated with reduced short-term survival, but not with mid-term survival. Subgroup analyses showed that age, sex, history of CHD, and cannulation strategy might not be potential modifiers of the association between CPB weaning time and postoperative in-hospital death; age and cerebral perfusion strategy might not be potential modifiers of the association between CPB weaning time and stroke. In contrast, sex, history of CHD, performance of CABG, axillary artery cannulation, and femoral artery cannulation might be potential modifiers of the association between CPB weaning time and stroke.

In previous studies, difficulty in CPB weaning has been regarded as an intraoperative adverse event and has been shown to predict poor postoperative outcomes. Denault et al. identified difficult CPB weaning as an independent risk factor for postoperative death and adverse outcomes following cardiac surgery (3), while Gellings et al. Also demonstrated a significant association between difficult CPB weaning and postoperative death (8). However, there is currently no universally accepted definition of difficult CPB weaning. Some studies define it as requiring more than two inotropic agents, multiple weaning attempts, or the need for intra-aortic balloon pump support (9), while others incorporate hemodynamic parameters such as blood pressure to refine the definition (10). These inconsistencies have led to widely variable reported incidences—ranging from rare to as high as 35.8% (3,11,12)—making it difficult to stratify high-risk patients based on CPB weaning difficulty alone.

Despite these limitations, the concept underscores the clinical significance of the CPB weaning process itself as a marker of postoperative risk. During CPB weaning, mechanical support is gradually reduced under continuous monitoring of hemodynamic parameters such as blood pressure. Myocardial injury and vasoplegic syndrome may lead to hemodynamic instability, thereby prolonging the weaning process. These same factors are well-known contributors to adverse postoperative outcomes (4,13). Based on this pathophysiological rationale, we hypothesized that CPB weaning time may be directly associated with adverse outcomes—an association confirmed by our findings.

In our study, CPB weaning time was associated with in-hospital death following surgery. CPB weaning time is influenced by preoperative cardiac function, the degree of myocardial injury, and vasoplegic syndrome, as well as by myocardial protection strategies and coronary artery status. Previous studies have demonstrated that preoperative cardiac function, myocardial injury, and vasoplegic syndrome are all associated with adverse postoperative outcomes (14)(15)(16), which may help explain the observed association between CPB weaning time and postoperative death. In our cohort, the use of standardized myocardial protection strategies and a uniform choice of cardioplegia minimized the impact of variability in myocardial protection on study outcomes. Moreover, subgroup analyses stratified by history of CHD and the performance of CABG suggested that coronary status may have a limited impact on the association between CPB weaning time and death.

Although CPB weaning time was associated with postoperative death, this association appeared to be confined to a reduction in short-term survival, with no significant effect on mid-term survival. Previous studies have shown that mid-term survival in patients with ATAAD is primarily determined by preexisting comorbidities and anatomical factors (17,18), whereas short-term survival is also influenced by perioperative conditions (19). As an indicator reflecting perioperative status, CPB weaning time may therefore not adequately capture the risk of mid-term death. Notably, although the AUC for the association between CPB weaning time and postoperative death was relatively high, the OR was modest. A higher AUC reflects the ability of CPB weaning time to discriminate patients at higher risk of death, while the lower OR indicates that each incremental minute of weaning confers only a limited increase in risk. Thus, the application of a cutoff value may represent a more practical approach in clinical decision-making.

Apart from death, CPB weaning time was associated only with postoperative stroke, and this association appeared unstable. During CPB weaning, mechanical support is gradually reduced under close monitoring of hemodynamic parameters such as blood pressure. This process inevitably induces systemic blood pressure fluctuations that may transiently impair organ perfusion (20).

Given the brain's low tolerance to hypoxia, prolonged weaning may predispose patients to cerebral ischemia, explaining its relationship with postoperative stroke. However, in patients with ATAAD, cerebral protection strategies and anatomical factors play a more dominant role than transient hemodynamic fluctuations during weaning, thereby attenuating the impact of CPB weaning time and leading to an inconsistent association with postoperative stroke. Subgroup analyses further supported this finding: CPB weaning time was associated with postoperative stroke only in male patients and in those without axillary artery cannulation or with femoral artery cannulation. Female patients with aortic dissection are generally older and have more extensive dissection involvement (21,22), factors that affect intraoperative cerebral perfusion and protection strategies. Moreover, axillary artery cannulation provides antegrade arterial flow, which helps avoid false lumen expansion and malperfusion caused by retrograde perfusion, thereby reducing postoperative stroke incidence (23,24). The effects of these more influential factors may potentially compromise the robustness of the association between CPB weaning time and postoperative stroke.

Beyond death and stroke, no association was observed between CPB weaning time and other postoperative outcomes. Postoperative renal failure in ATAAD patients is primarily influenced by anatomical factors and preoperative renal function, and the kidneys exhibit greater ischemic tolerance than the brain (25), rendering them less susceptible to variations in CPB weaning time. Prolonged mechanical ventilation is generally associated with cardiovascular function, transfusion requirements, body mass index (BMI), and chronic obstructive pulmonary disease (COPD) (26); hence, CPB weaning time alone may be insufficient to predict its risk. Similarly, postoperative awakening time is affected by anesthetic use, organ perfusion, surgical approach, and cerebral perfusion (27,28), suggesting that CPB weaning time is unlikely to be a major determinant.

As an indicator reflecting patient condition, prolonged CPB weaning time is associated with preoperative status and the degree of myocardial injury. Although the emergent nature of ATAAD surgery limits optimization of preoperative conditions, more comprehensive preoperative planning may help reduce CPB weaning time. Previous studies have reported worse postoperative outcomes in patients undergoing rescue CABG compared with planned CABG during ATAAD surgery; improved preoperative coronary assessment and planning may reduce myocardial injury (29, 30), thereby potentially shortening CPB weaning time. Although reducing CPB weaning time may be challenging, it remains a clinically valuable marker for identifying patients at high postoperative risk. Notably, all patients included in this study received antegrade del Nido cardioplegia for myocardial protection. Although the use of del Nido cardioplegia has not yet become a standard practice in aortic surgery, its safety and efficacy have been demonstrated in previous studies. Some reports have shown no significant differences between del Nido cardioplegia and other cardioplegic solutions with respect to outcomes such as postoperative death and stroke (31). Other studies suggest that del Nido cardioplegia may reduce myocardial injury and postoperative atrial fibrillation (32,33). Although whether del Nido cardioplegia is superior to other cardioplegic strategies remains controversial, its use in aortic surgery is considered a feasible option.

This study has several limitations. First, as a single-center retrospective study, the relatively small sample size and potential biases during data collection may have resulted in deviations in the study findings. In addition, the exclusion of patients with missing follow-up data may have introduced further selection bias. Second, although other risk factors were balanced in the analysis, the cumulative extent of the dissection and the involvement of branch vessels are also important contributors to adverse postoperative outcomes. The lack of complete preoperative imaging data prevented us from adequately adjusting for these factors. In addition, owing to the absence of detailed information on causes of death and the use of inotropic agents, the potential impact of these factors remains unclear. Moreover, because the hemostatic process overlaps with myocardial recovery and attempts at weaning from CPB, it was not feasible to reasonably exclude this component. However, the primary aim of this study was to explore whether CPB weaning time could serve as a novel indicator for identifying postoperative high-risk patients. Severe bleeding and difficulty in achieving hemostasis, together with the extent of myocardial injury and the patients' preoperative condition, may all be considered determinants of CPB weaning time; therefore, this issue may not materially compromise the reliability of our conclusions. Finally, this study was limited to patients with type A aortic dissection who required circulatory arrest during surgery, and whether the findings are applicable to patients undergoing other CPB procedures warrants further investigation.

Conclusions

CPB weaning time is associated with postoperative in-hospital death and stroke in patients with aortic dissection undergoing total arch replacement combined with stented elephant trunk implantation. It is also associated with short-term survival but not with mid-term survival, and represents a risk factor for early postoperative adverse events.

Declarations

Abbreviations

The following abbreviations are used in this manuscript

abbreviations	Full name
ATAAD	Acute type A aortic dissection
CPB	cardiopulmonary bypass
ECMO	Extracorporeal Membrane Oxygenation
CT	computed tomography
MRI	magnetic resonance imaging
CHD	Coronary heart disease
WBC	White Blood Cell
RBC	Red Blood Cell
HB	Hemoglobin
Plt	Platelet
CK	Creatine Kinase
CK-MB	Creatine Kinase- Myocardial Band
IA	Innominate Artery
LCCA	Left Common Carotid Artery
LSA	Left Subclavian Artery
CABG	coronary artery bypass grafting
UO	urine output during cardiopulmonary bypass
AUC	area under the curve
ROC	Receiver operating characteristic
SD	standard deviation
IQR	interquartile range
OR	Odds Ratio
CI	Confidence Interval

Ethics approval and consent to participate

All procedures involving participants in this study complied with the Declaration of Helsinki (2013 revision).

This study was a single-center, retrospective study and has been approved by the Ethics Committee (approval No. 2025KY-020-01,Date:2025-05-21).

Ethics Committee Full Name: Ethics Review Committee of Tianjin Chest Hospital

Affiliated Institution: Tianjin Chest Hospital

Consent for publication

Not Applicable

Availability of data and materials:

The data can be obtained from the author upon reasonable request. Please contact the first author Peiquan Li at this email address (lipeiqvan0207@163.com); or contact the corresponding author Qingliang Chen at this email address (qingliang1971@126.com) for the data.

Competing Interests

The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results

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Authors' contributions

(I) Conception and design: Peiquan Li, Shaopeng Zhang; (II) Administrative support: Yunpeng Bai, Qingliang Chen, Nan Jiang; (III) Provision of study materials or patients: Yunpeng Bai, Qingliang Chen, Nan Jiang; (IV) Collection and assembly of data: Peiquan Li, Chenyu Zhang; (V) Data analysis and interpretation: Peiquan Li, Shaopeng Zhang; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Acknowledgements

Not Applicable

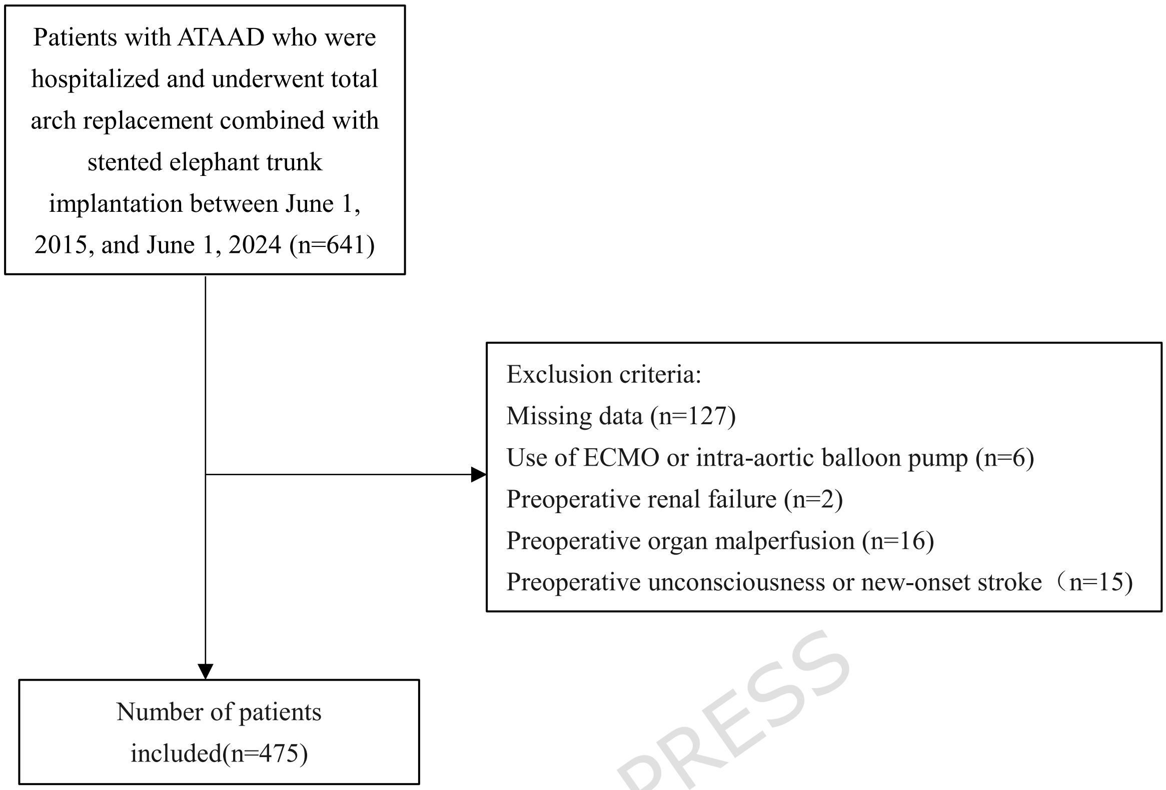


Figure 1. Flowchart of patient inclusion and exclusion criteria ; ATAAD: acute type A aortic dissection; ECMO: Extracorporeal Membrane Oxygenation

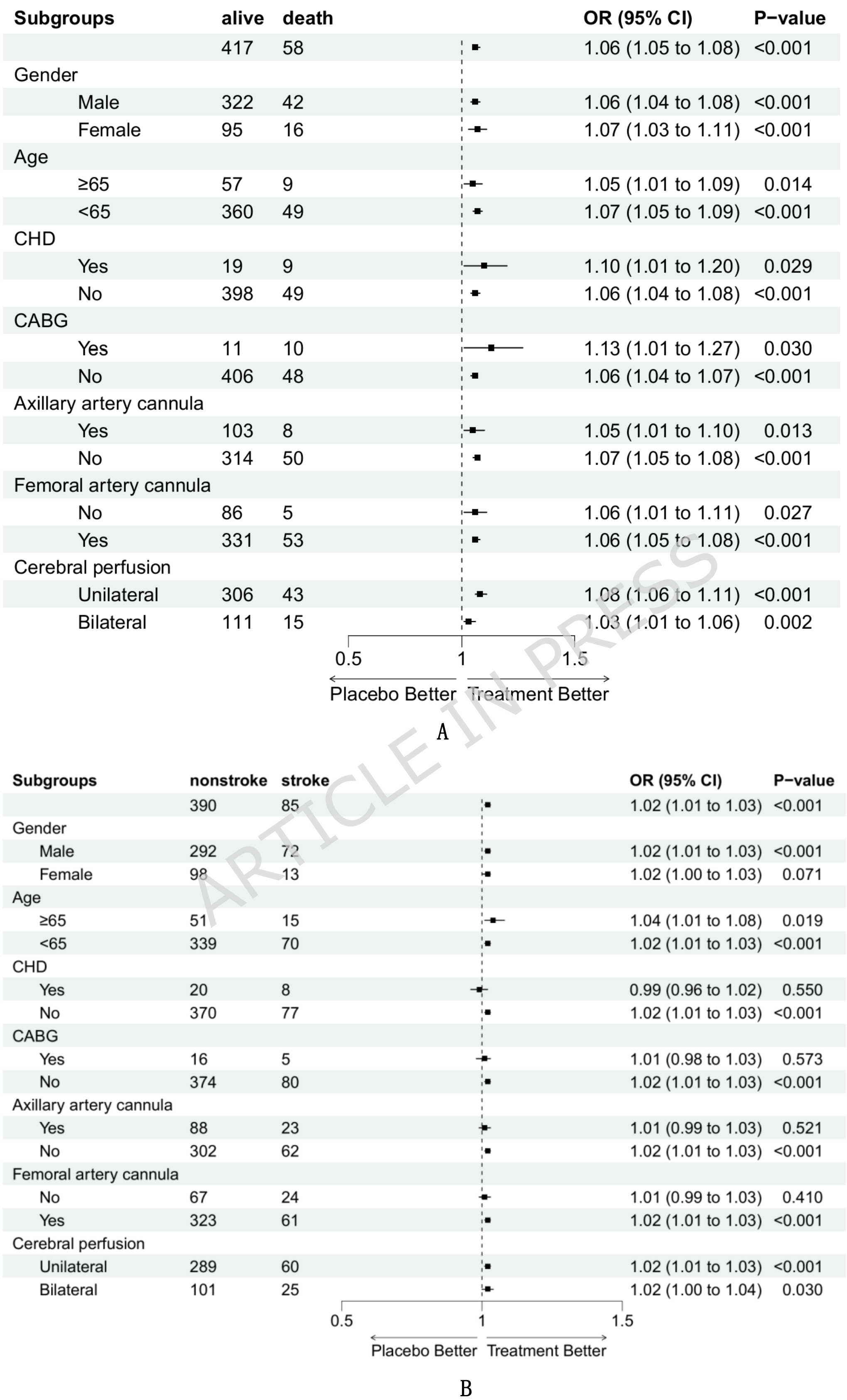
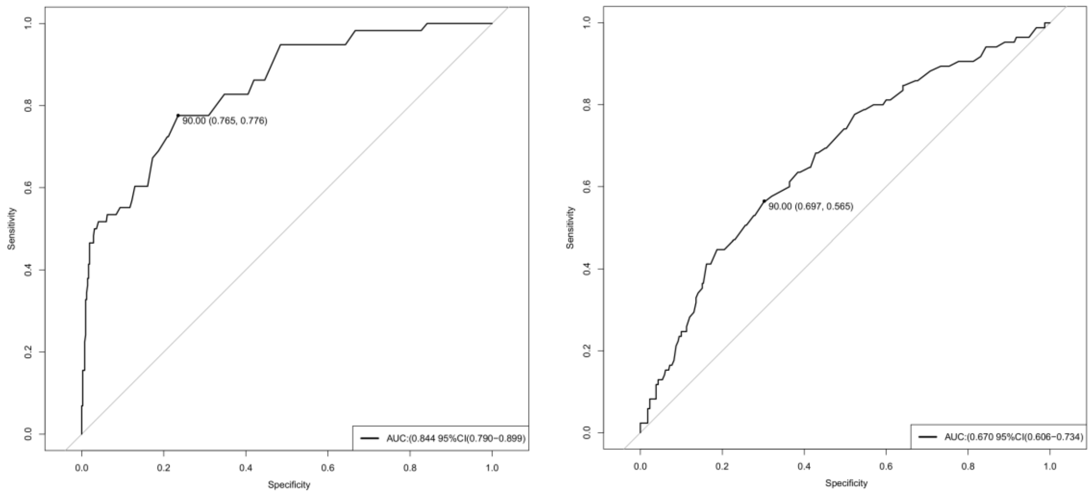


Figure 2. Subgroup analyses ; A: Subgroup analysis for death outcomes ; B: Subgroup analysis for stroke outcomes ; CHD: Coronary heart disease ; CABG: Coronary Artery Bypass Grafting.



A B

Figure 3. Receiver operating characteristic (ROC) curves illustrating the relationship between cardiopulmonary bypass weaning time and postoperative complications:(A) Death;(B) Stroke.

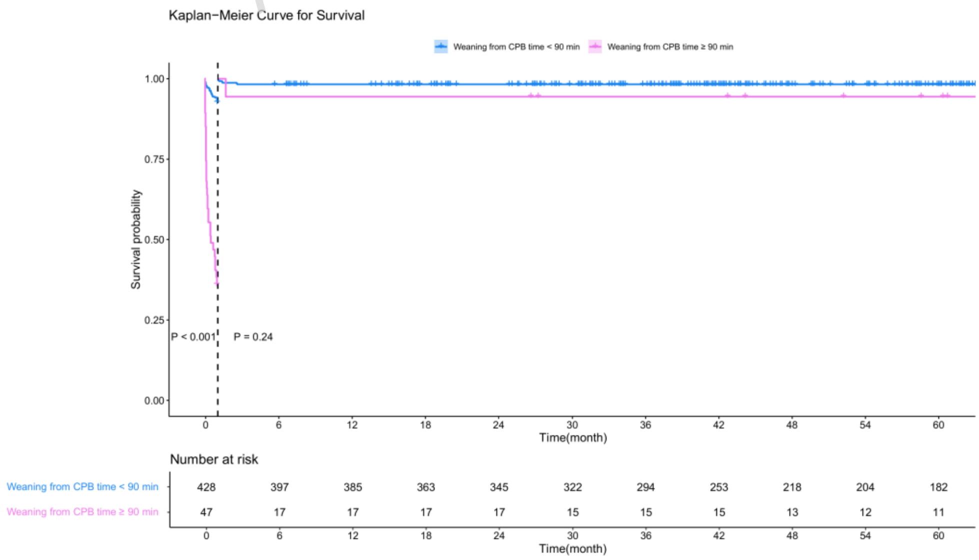


Figure 4. Landmark survival curve analysis between groups stratified by the cutoff value

Variables	Total（n=475）	Alive（n=417）	Death（n=58）	P-value
Sex,(Femalen,%)	111 (23.4)	95 (22.8)	16 (27.6)	0.519
Age（year）	52.00 [42.00, 60.00]	51.00 [41.00, 60.00]	52.00 [43.00, 59.50]	0.628
Height（cm）	172.00 [167.00, 176.00]	172.00 [168.00, 176.00]	170.00 [165.25, 175.00]	0.198
Weight（kg）	80.00 [70.00, 90.00]	80.00 [70.00, 90.00]	80.00 [70.00, 90.00]	0.704
Hypertension（n,%）	336 (70.7)	290 (69.5)	46 (79.3)	0.168
Stroke（n,%）	25 (5.3)	22 (5.3)	3 (5.2)	1.000
CHD（n,,%）	28 (5.9)	19 (4.6)	9 (15.5)	0.003
Smoke（n,%）	231 (48.6)	208 (49.9)	23 (39.7)	0.187
Alcohol abuse（n,%）	85 (17.9)	79 (18.9)	6 (10.3)	0.156
WBC（10^9/L）	11.23 [8.94, 14.00]	11.02 [8.82, 13.50]	13.75 [10.25, 15.92]	<0.001
Neutrophil（10^9/L）	9.86 [7.52, 12.86]	9.67 [7.42, 12.07]	12.30 [9.05, 14.86]	<0.001
Lymphocyte（10^9/L）	0.91 [0.64, 1.33]	0.91 [0.64, 1.32]	0.92 [0.65, 1.32]	0.940
RBC（10^12/L）	4.28 [3.84, 4.68]	4.28 [3.81, 4.67]	4.32 [4.12, 4.70]	0.134
Hb（g/L）	131.00 [117.00, 143.00]	131.00 [115.00, 143.00]	135.50 [126.25, 142.00]	0.088
Plt（10^9/L）	175.00 [140.00, 212.50]	174.00 [140.00, 211.00]	180.00 [142.00, 226.75]	0.566
Creatinine（umol/L）	85.00 [69.00, 110.00]	82.00 [69.00, 109.00]	95.00 [77.25, 128.25]	0.005
Uric acid（umol/L）	351.00 [273.00, 434.00]	341.00 [270.00, 429.00]	404.50 [342.50, 458.00]	<0.001
C-reactive protein（mg/L）	11.97 [3.88, 39.72]	12.20 [3.89, 43.00]	11.60 [3.50, 25.73]	0.548
CK（U/L）	91.00 [61.00, 146.00]	89.00 [59.00, 142.00]	101.50 [77.00, 202.00]	0.018
CK- MB（U/L）	16.00 [12.00, 21.00]	15.00 [11.00, 20.00]	21.50 [15.00, 27.50]	<0.001
Deritis Ratio	1.08 [0.82, 1.50]	1.08 [0.79, 1.49]	1.13 [0.91, 1.83]	0.081
IA Involvement（n,%）	150 (31.6)	134 (32.1)	16 (27.6)	0.584
LCCA Involvement（n,%）	100 (21.1)	83 (19.9)	17 (29.3)	0.140
LSA Involvement（n,%）	125 (26.3)	108 (25.9)	17 (29.3)	0.694

Table 1. Baseline characteristics, preoperative laboratory findings, and anatomical features of the patients; CHD: Coronary heart disease, WBC: White Blood Cell, RBC: Red Blood Cell, HB: Hemoglobin, Plt: Platelet, CK: Creatine Kinase, CK-MB: Creatine Kinase-MB, IA：Innominate Artery，LCCA：Left Common Carotid Artery，LSA: Left Subclavian Artery

Variables	Total（n=475）	Alive（n=417）	Death（n=58）	P-value
CABG（n,%）	21 (4.4)	11 (2.6)	10 (17.2)	<0.001
Aortic Sinus Repair（n,%）	105 (22.1)	102 (24.5)	3 (5.2)	0.002
Aortic Valve Replacement or Repair（n,%）	12 (2.5)	7 (1.7)	5 (8.6)	0.007
Surgical time（min）	351.00 [308.50, 401.50]	346.00 [306.00, 390.00]	448.50 [376.25, 542.25]	<0.001
CPB time（min）	165.00 [145.00, 185.00]	161.60 [144.00, 181.00]	207.50 [170.00, 257.50]	<0.001
Circulatory arrest time（min）	16.00 [10.00, 20.00]	15.00 [9.00, 20.00]	16.00 [15.00, 19.00]	0.074
Aortic cross-clamp time（min）	97.00 [84.95, 113.00]	97.00 [84.90, 111.00]	110.50 [85.25, 141.50]	0.001
Weaning from CPB time（min）	65.00 [56.00, 75.00]	64.00 [55.00, 73.00]	91.00 [74.00, 116.75]	<0.001
Intraoperative blood loss（ml）	1300.00 [1000.00, 1658.50]	1300.00 [1000.00, 1600.00]	1520.00 [1300.00, 2495.00]	<0.001
Ultrafiltration volume（ml）	2500.00 [1850.00, 3400.00]	2500.00 [1800.00, 3300.00]	2500.00 [2000.00, 3475.00]	0.269
UO（ml）	600.00 [400.00, 1000.00]	600.00 [400.00, 1000.00]	600.00 [300.00, 1475.00]	0.924
Axillary artery cannula（n,%）	111 (23.4)	103 (24.7)	8 (13.8)	0.094
Femoral artery cannula（n,%）	384 (80.8)	331 (79.4)	53 (91.4)	0.046
Cerebral perfusion				1.000
Unilateral（n,%）	349(73.5)	306(73.4)	43(74.1)	
Bilateral（n,%）	126 (26.5)	111 (26.6)	15 (25.9)	

Table 2. Intraoperative data of the patients; CABG：Coronary Artery Bypass Grafting ; UO: urine output during cardiopulmonary bypass ； CPB：cardiopulmonary bypass

Variables (CPB weaning time)	Univariate analysis Odd ratios (95%CI , P-Value)	Multivariate analysis Odd ratios (95%CI , P-Value)
Death	1.06 (1.05-1.08, p<0.001)	1.05 (1.02-1.07, p<0.001)
Renal Failure	1.02 (1.01-1.03, p<0.001)	1.01 (0.99-1.03, p=0.230)
Stroke	1.02 (1.01-1.03, p<0.001)	1.02 (1.00-1.04, p=0.016)
Prolonged mechanical ventilation	1.00 (1.00-1.01, p=0.346)	-
Delayed awakening	1.01 (1.00-1.02, p=0.053)	-

Table 3. Univariable and multivariable logistic regression analyses of CPB weaning time for different outcomes.The full univariable and multivariable logistic regression tables for each outcome are presented in Supplementary Tables 2－6； CPB：cardiopulmonary bypass

Variables (CPB weaning time≥90min)	Univariate analysis Odd ratios (95%CI , P-Value)	Multivariate analysis Odd ratios (95%CI , P-Value)
Death	25.21 (12.42-51.16, p<0.001)	7.35 (2.46-21.94, p<0.001)
Stroke	2.40 (1.23-4.66, p=0.010)	1.30 (0.50-3.38, p=0.593)

Table 4. Univariable and multivariable logistic regression analyses of CPB weaning time cutoff values for different outcomes.The complete univariable and multivariable logistic regression tables for cutoff values and various outcomes are provided in Supplementary Tables 7 and 8； CPB：cardiopulmonary bypass

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