Combined Axillary-Femoral Artery Cannulation Versus Conventional Femoral Artery Single Cannulation: Cerebral Protection Benefits in Stanford Type A Aortic Dissection Repair Surgery

Ann. Ital. Chir., 2025 96, 12: 1641–1653
https://doi.org/10.62713/aic.4343

Hu Zhang[1], Zhu Wang[1], Yi Zhu[2], Yang Zhang[1], Yan Wang[2]

[1]Department of Cardiothoracic Surgery, The Affiliated Hospital of Xuzhou Medical University, 221000 Xuzhou, Jiangsu, China
[2]Department of Cardiothoracic Surgery, The Affiliated Huai'an Hospital of Xuzhou Medical University (The Second People's Hospital of Huai'an), 223002 Huai'an, Jiangsu, China

AIM: Conventional femoral artery cannulation with retrograde perfusion may increase the incidence of cerebral embolism in treating Stanford type A aortic dissection (STAAD). This study aimed to compare the neuroprotective effect of combined axillary-femoral artery cannulation utilizing an antegrade-retrograde perfusion strategy with femoral artery single cannulation in STAAD surgery.
METHODS: This was a two-center, retrospective cohort study including 120 patients who underwent STAAD surgery between January 2021 and January 2025. Among them, 63 patients received combined axillary-femoral artery cannulation (double arterial cannulation group, DAC group), while 57 patients underwent conventional femoral artery single cannulation (single arterial cannulation group, SAC group). Perioperative parameters, neurological outcomes, including incidences of permanent/transient neurological dysfunction (PND/TND), delirium and coma duration, modified Rankin Scale (mRS) score, and Montreal Cognitive Assessment (MoCA) score, were evaluated. Serum biomarkers of brain injury, including neuron-specific enolase (NSE) and S100 calcium-binding protein B (S100B) protein levels, as well as postoperative general complications, were also analyzed.
RESULTS: There was no significant difference in the key perioperative time parameters between the two groups ($p > 0.05$). Regarding neuroprotection, the DAC group exhibited superior outcomes, with significantly lower incidences of PND and TND, and shorter coma and delirium durations ($p < 0.05$). The DAC group also achieved better mRS and MoCA scores at 30 and 90 days postoperatively ($p < 0.001$). Peak postoperative levels of NSE and S100B were significantly lower in the DAC group ($p < 0.001$). Multivariate linear regression analyses revealed that the DAC strategy was an independent protective factor associated with improved neurological function (mRS), enhanced cognitive performance (MoCA), lower brain injury biomarker levels (NSE and S100B), and reduced coma and delirium durations ($p < 0.001$). There was no significant difference in the overall incidence of postoperative general complications between the two groups ($p > 0.05$). However, the incidence of postoperative limb ischemia was significantly lower in the DAC group ($p < 0.05$).
CONCLUSIONS: Compared with conventional femoral artery single cannulation, combined axillary-femoral artery cannulation provides superior and independent cerebral protection during STAAD surgery. This approach reduces permanent and transient neurological deficits, mitigates early brain injury, enhances neurological and cognitive recovery, and lowers the incidence of postoperative limb ischemia. It holds promise as a safe and effective cerebral protective perfusion strategy in STAAD surgical management.

Keywords: aortic dissection; arterial cannulation; femoral artery; axillary artery; neurological manifestations

Introduction

Stanford type A aortic dissection (STAAD) is one of the most life-threatening emergencies in cardiovascular surgery, with a persistently increasing incidence and an urgent need for prompt surgical aortic reconstruction [1,2]. For patients undergoing STAAD surgery, establishing an effective cardiopulmonary bypass (CPB) with rapid and safe arterial inflow while preventing malperfusion is critical [3]. Although anterograde and retrograde cerebral perfusion (ACP/RCP) techniques are widely applied, conventional arterial cannulation strategies have significant limitations. Femoral artery single cannulation depends on true-lumen flow and retrograde perfusion, which may induce cerebral embolism, uneven cerebral perfusion, and visceral organ ischemia. These complications elevate the risk of permanent neurological dysfunction (PND, equivalent to stroke) and transient neurological dysfunction (TND, such as delirium and disorientation), with TND incidence reported as high as 43.3%, and contribute to multi-organ complications, including acute kidney injury (8.5%) [4,5]. In contrast, axillary artery single cannulation, while improving anterograde cerebral perfusion, may prolong CPB duration due to low-flow conditions, thereby increasing the risk of hemorrhage and inflammatory responses [6].

Submitted: 7 September 2025 Revised: 27 October 2025 Accepted: 29 October 2025 Published: 10 December 2025
Correspondence to: Yan Wang, Department of Cardiothoracic Surgery, The Affiliated Huai'an Hospital of Xuzhou Medical University (The Second People's Hospital of Huai'an), 223002 Huai'an, Jiangsu, China (e-mail: haeywy333@163.com).

In recent years, a combined axillary-femoral artery cannulation strategy has been proposed to theoretically overcome these bottlenecks by enabling dual-pathway perfusion that simultaneously supports cerebral and lower-body circulation. Preliminary studies suggest this approach can reduce malperfusion, lower postoperative complication risks, and significantly decrease in-hospital mortality [3,7].

However, comprehensive evaluation of its cerebral protective efficacy remains limited. Most existing studies have predominantly focused on surgical mortality or single-organ outcomes, with insufficient analysis of cerebral protection benefits.

This study retrospectively analyzed 120 STAAD surgical cases from two hospitals, systematically evaluating, for the first time, the cerebral protective benefits of combined axillary-femoral artery cannulation versus conventional femoral artery single cannulation. The primary objectives were: (1) To quantify the impact of combined cannulation on the incidence and severity of PND and TND; (2) To analyze its effects on coma duration, neurological function scores, and neurobiomarker levels; and (3) To evaluate surgical safety through postoperative complication profiles. The findings aim to provide evidence-based guidance for optimizing cerebral perfusion strategies in STAAD surgery, thereby directly contributing to reduced postoperative disability rates and improved patient quality of life.

Methods

Study Population

This retrospective cohort study included 120 patients with STAAD who underwent surgical repair at the Affiliated Hospital of Xuzhou Medical University and the Second People's Hospital of Huai'an between January 2021 and January 2025. Among them, 63 patients received combined axillary-femoral artery cannulation (double arterial cannulation group, DAC group), and 57 patients underwent conventional femoral artery single cannulation (single arterial cannulation group, SAC group). The study protocol was approved by the Ethics Review Committee of the Affiliated Hospital of Xuzhou Medical University and the Second People's Hospital of Huai'an (XYFY2025-KL050-01; HEYLL202586). All procedures conformed to the ethical principles outlined in the Declaration of Helsinki, and all participants provided written informed consent prior to their inclusion.

Inclusion and Exclusion Criteria

Inclusion criteria: (1) Diagnosis of STAAD confirmed by preoperative aortic computed tomography angiography (CTA); (2) Time from symptom onset to surgery $\leq$14 days (acute phase); (3) Age $\geq$18 years; (4) Preoperative consciousness without severe neurological deficits (e.g., PND or coma).

Exclusion criteria: (1) Stanford Type B dissection, traumatic or iatrogenic dissection, chronic dissection (>14 days), Marfan syndrome, or aortic aneurysm; (2) Severe preoperative hepatic or renal dysfunction (eGFR <30 mL/min or Child-Pugh class C), malignancy, or active infection; (3) History of PND, traumatic brain injury, or intracranial hemorrhage; (4) Previous cardiac surgery or interventional procedure via the femoral artery approach; (5) Non-total arch replacement (e.g., partial arch replacement), non-deep hypothermic circulatory arrest strategy, or intraoperative cannulation site change; (6) Axillary artery diameter <6 mm (determined by ultrasound) or severe femoral artery calcification/stenosis (confirmed by CTA); (7) Dissection involving the axillary or femoral arteries, rendering them unsuitable for cannulation; (8) Incomplete or missing clinical data.

Surgical Methods

1. Group Allocation and Cannulation Strategies

DAC group: Patients were placed in the supine position and draped under aseptic conditions following povidone-iodine disinfection. Axillary artery cannulation: A 3–5 cm horizontal incision was made 1 cm below the right clavicle, followed by blunt dissection to expose the axillary artery (avoiding the brachial plexus). After systemic heparinization (400 IU/kg), the axillary artery was clamped proximally and distally. Two approaches were adopted: (a) Direct arteriotomy with insertion of an 18F–24F arterial cannula; or (b) End-to-side anastomosis of an 8 mm polyester graft, through which the cannula was introduced.

Direct arteriotomy was reserved for robust, disease-free arteries with a diameter $\geq$8 mm. In contrast, the side-graft technique was preferred for smaller or atherosclerotic vessels to mitigate the risks of dissection, malperfusion, and PND. Femoral artery cannulation: A 22F–24F arterial cannula was inserted via an inguinal incision. CPB initiation: Anterograde perfusion via the axillary artery combined with retrograde perfusion via the femoral artery was established.

SAC group: Only the femoral artery was cannulated (16F–20F cannula) to establish retrograde CPB.

2. Anesthesia and Monitoring

All patients received combined intravenous-inhalational anesthesia with endotracheal intubation. Continuous monitoring included invasive arterial pressure in upper and lower limbs and transesophageal echocardiography (TEE) to assess the extent of dissection and cardiac function.

3. Core Surgical Steps

Incision and exposure: In the DAC group, axillary artery cannulation preceded median sternotomy; in the SAC group, direct median sternotomy was performed. Proximal repair (based on root pathology): For root dilatation $\geq$45 mm or aortic regurgitation $\geq$Grade III, a Bentall or David procedure was performed. For intact root structures,

ascending aorta replacement with or without aortic valve replacement and coronary artery reimplantation, was performed.

Arch management: Indications for total arch replacement included any of the following: arch diameter ≥45 mm, intimal tear involving the arch, or false lumen thrombosis. Under deep hypothermic circulatory arrest (DHCA), the aortic arch was excised, and the distal end of a four-branch graft was anastomosed to a descending aortic stent (Frozen Elephant Trunk, FET).

4. Cerebral Perfusion and Temperature Management

DAC group: During DHCA, antegrade cerebral perfusion (ACP) was administered via the right axillary artery at a flow rate of 5–10 mL/kg/min.

SAC group: Retrograde cerebral perfusion (RCP) was used during DHCA. Temperature control: Systemic cooling continued until bladder core temperature of 18–22 °C. DHCA was initiated once the nasopharyngeal temperature reached 20–25 °C.

5. Rewarming and CPB Weaning

After reconstruction of the left common carotid artery, full CPB flow was restored. During rewarming, proximal ascending aortic anastomosis and reconstruction of arch branches (innominate and left subclavian arteries) were completed. Following cardiac resumption, CPB flow was gradually reduced by 20% every five minutes until complete cessation. Heparin was neutralized with protamine sulfate (1:1 ratio), and all cannulas were removed.

6. Hemostasis and Chest Closure

Meticulous hemostasis was confirmed before layered chest closure. The axillary incision was sutured in the DAC group, and groin incisions were closed in all patients.

7. Standardized Perioperative Management

All patients were managed under a uniform intraoperative hemodynamic protocol. Before CPB, mean arterial pressure (MAP) was maintained at 65–80 mmHg. During CPB, perfusion pressure was adjusted according to body temperature and maintained between 50 and 80 mmHg. The same anesthesiology team implemented this protocol consistently across both groups. Prophylactic neuroprotective agents (e.g., corticosteroids, mannitol) were not routinely administered in either group. They were reserved only for cases with evident neurological complications, as guided by established clinical guidelines.

Observation Indicators

(1) Baseline data

Recorded variables included age, sex, body mass index (BMI), history of hypertension, diabetes mellitus, smoking, alcohol use, coronary artery disease, maximum aortic diameter, true and false lumen areas, renal insufficiency (diagnosed based on clinical history, including preoperative serum creatinine >133 μmol/L or creatinine clearance rate <60 mL/min/1.73 m^2), chronic obstructive pulmonary disease (confirmed by clinical history and pulmonary function tests), cardiac tamponade, cerebral hypoperfusion (manifested as drowsiness, syncope, loss of consciousness, or CTA showing dissection involving the carotid artery), coronary malperfusion (electrocardiogram evidence of myocardial ischemia/infarction or CTA revealing dissection affecting coronary ostia), gastrointestinal hypoperfusion (symptoms such as intestinal necrosis, acute pancreatitis, melena, hematochezia, or CTA evidence demonstrating dissection involving the superior/inferior mesenteric arteries), and iliac artery hypoperfusion (signs include diminished/absent peripheral pulses in lower extremities, reduced skin temperature, sensory loss, or CTA showing dissection involving the iliac arteries).

(2) Surgical and recovery time parameters

Collected parameters included total operative time, CPB duration, mechanical ventilation time, the length of intensive care unit (ICU) stay, aortic cross-clamp (ACC) time, DHCA time, and postoperative awakening time (defined as the interval from cessation of intravenous anesthesia to the patient's ability to follow verbal commands).

(3) Neurological outcome metrics

Postoperative neurological outcomes were prospectively assessed by a multidisciplinary team of neurologists and cardiovascular intensivists, following standardized definitions to ensure consistency and diagnostic accuracy:

1. PND: Defined as a new-onset focal (e.g., hemiparesis, aphasia, visual field deficit) or global (e.g., persistent coma) neurological impairment that persisted until hospital discharge and was corroborated by corresponding new lesions on brain computed tomography (CT) or magnetic resonance imaging (MRI). To enhance specificity, corroborative imaging findings were strictly defined as newly developed cerebral infarcts (embolic or watershed), intracranial hemorrhages, or hypoxic-ischemic encephalopathy changes that were anatomically consistent with the clinical presentation [8].

2. Transient neurological dysfunction: Defined as a transient neurological dysfunction that resolved completely without residual deficit [8]. Diagnostic criteria included postoperative delirium (see detailed below for specific assessment), transient ischemic attacks (TIA; focal deficits lasting <24 hours), or reversible ischemic neurological deficits (RIND; focal deficits resolving within 72 hours to one week).

Time-to-recovery calculation: The 72-hour resolution threshold was measured from the initial documentation of symptom onset. In sedated patients, timing began after discontinuation of continuous sedative infusions and achievement of a Richmond Agitation-Sedation Scale (RASS) score of ≥–3.

Assessment method: Neurological function was evaluated at least twice daily through structured neurological examinations performed by the ICU team. Resolution of focal deficits was confirmed using the National Institutes of Health Stroke Scale (NIHSS), defined as patient returning to their preoperative baseline NIHSS score. Resolution of delirium was confirmed by two consecutive negative Confusion Assessment Method for the ICU (CAM-ICU) evaluations at least 4 hours apart.

Observation period: Patients were monitored for TND occurrence throughout their ICU stay. For patients with ICU stays exceeding 7 days, only deficits occurring within the first postoperative week were considered for the TND endpoint to ensure relevance to the perioperative period.

3. Duration of delirium and coma: During ICU hospitalization, each patient underwent two daily awakening screenings (morning and evening) using the RASS [9,10] and CAM-ICU [11]. The RASS scale was initially employed to evaluate the level of consciousness; coma was defined as a RASS score of –4 or –5. Patients with RASS scores $\geq$–3 subsequently underwent CAM-ICU evaluation. A positive CAM-ICU result, characterized by acute alterations/fluctuations in mental status, impaired attention, disorganized thinking, or altered level of consciousness, indicated the presence of delirium [12]. The duration of postoperative delirium or coma was calculated as the cumulative number of days during which either state was present throughout the ICU stay. Specifically, any day on which a patient exhibited a comatose state (RASS –4 or –5) or a positive CAM-ICU assessment was counted as a delirium/coma day. The total duration represented the cumulative number of such days from postoperative day 1 through the final assessment before ICU discharge.

(4) Comprehensive neurological scoring systems

Modified Rankin Scale (mRS): Preoperative, 30-day, and 90-day postoperative mRS scores were recorded. The mRS ranges from 0 to 6, where 0 indicates no symptoms; 1, no significant disability despite symptoms; 2, slight disability; 3, moderate disability requiring some help; 4, moderately severe disability requiring assistance with daily living; 5, severe disability (bedbound and incontinent); and 6, death. Lower scores indicate greater functional independence, while higher scores reflect increased disability or dependence in activities of daily living [13].

Montreal Cognitive Assessment (MoCA): Preoperative, 30-day, and 90-day postoperative MoCA scores were recorded. The MoCA evaluates global cognitive function across multiple domains, including attention, executive function, memory, language, conceptual thinking, calculation, visuospatial ability, and orientation. Scores range from 0 to 30, with higher scores representing better cognitive performance. Final scores were adjusted for education level (+1 point for individuals with $\leq$12 years of formal education) [14].

(5) Serum biomarkers of neurological injury

Peripheral venous blood samples were collected preoperatively, at 24–48 hours postoperatively, at 72 hours postoperatively, and on postoperative days 30 and 90. Samples were allowed to stand for 30 minutes at room temperature before centrifugation at 3000 rpm for 10 minutes to obtain serum. Serum was aliquoted and stored at –80 °C until batch analysis. Serum concentrations of S100 calcium-binding protein B (S100B) and neuron-specific enolase (NSE) were measured using enzyme-linked immunosorbent assay (ELISA). All procedures were strictly performed according to the manufacturer's instructions provided with the assay kits.

Measurement of S100B: Serum S100B levels were quantitatively determined in duplicate for each aliquot using an ELISA kit (SEA567Hu; Cloud-Clone Corp., Wuhan, China). The assay employed microtiter plates precoated with anti-S100B-specific antibodies. Standards or samples were added to designated wells, followed by incubation with biotinylated anti-S100B antibody and streptavidin-horseradish peroxidase (HRP). After sequential incubation and washing, a 3,3′,5,5′-tetramethylbenzidine (TMB) substrate solution was added. Only wells containing the specific S100B-antibody-enzyme complex exhibited color development. The enzymatic reaction was terminated by sulfuric acid solution, and optical density was measured at 450 nm using a Bio-Rad xMark microplate reader (Bio-Rad Laboratories, Hercules, CA, USA) in duplicate. Both intra- and inter-assay coefficients of variation were $<$6%. Mean values from replicate samples were used for analysis.

Measurement of NSE: Serum NSE concentrations were quantified using a commercial sandwich ELISA kit (DENL20; R&D Systems, Minneapolis, MN, USA), according to the manufacturer's instructions. Briefly, a 96-well plate precoated with anti-human NSE monoclonal antibodies was used. After blocking, 50 µL of standards, controls, or diluted serum samples were added to the respective wells. The plate was sealed and incubated for 2 hours at room temperature with gentle shaking. Wells were then washed thoroughly to remove unbound material, followed by incubation with HRP-conjugated polyclonal anti-NSE antibody for an additional 2 hours at room temperature. After washing, the TMB substrate solution was added and incubated for 30 minutes at room temperature in the dark. The enzymatic reaction was stopped by adding the stop solution, which caused the color to change from blue to yellow. Absorbance was measured at 450 nm with a reference at 570 nm (A450–A570). Concentrations were determined using a standard curve and expressed in ng/mL. The within- and between-assay coefficients of variation were both $<$10%, and mean values from replicate samples were used for statistical analysis.

(6) Postoperative general complications

Postoperative complications occurring within 6 months postoperatively were documented, including acute kidney injury, limb ischemia, axillary artery injury (e.g., brachial

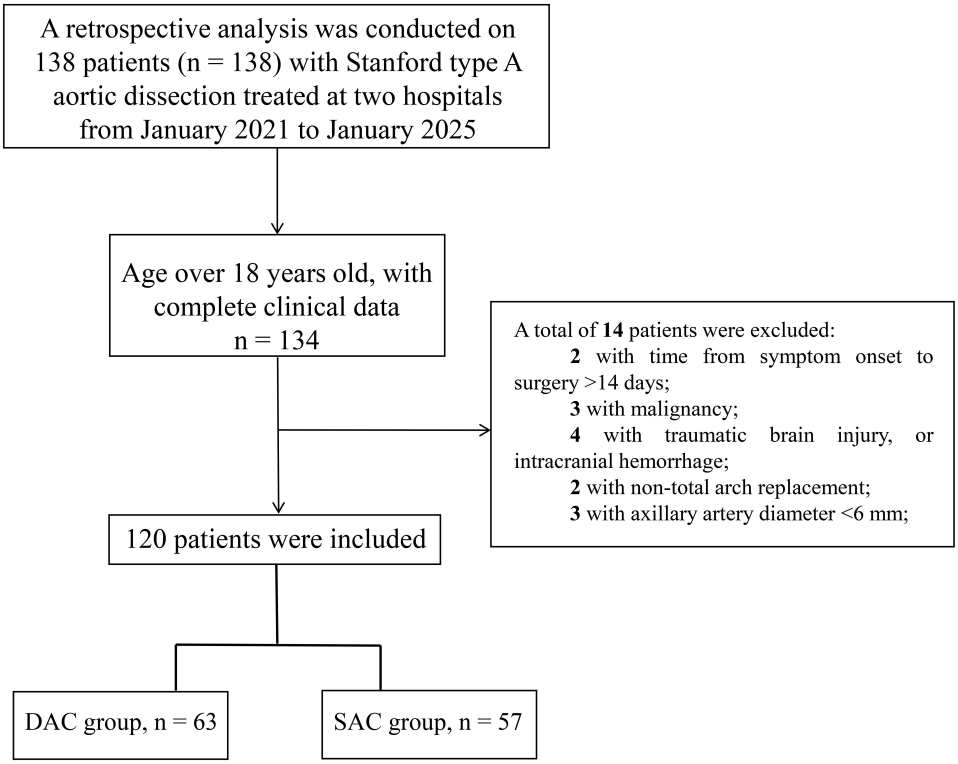

Fig. 1. Flow chart of patient selection for the study. DAC, double arterial cannulation; SAC, single arterial cannulation.

plexus injury, pseudoaneurysm formation, or acute thrombosis), pneumonia, and deep sternal wound infection.

Statistical Analysis

All data were analyzed using SPSS version 26.0 (IBM Corporation, Armonk, NY, USA). The Kolmogorov–Smirnov test was employed to assess the normality of continuous variables. Data conforming to a normal distribution were expressed as mean ± standard deviation ($\bar{x} \pm s$); between-group comparisons were conducted using the independent samples *t*-test, and within-group comparisons were assessed using the paired samples *t*-test. Non-normally distributed data were presented as median and interquartile range (Q1, Q3), with between-group comparisons performed using the Mann–Whitney U test and within-group comparisons evaluated using the Wilcoxon signed-rank test.

For repeated measurements obtained before and after surgery, repeated-measures analysis of variance (ANOVA) was applied to normally distributed data, followed by multiple comparisons using the least significant difference (LSD) *t*-test. For non-normally distributed continuous variables, generalized estimating equations (GEE) were applied. Categorical variables were summarized as frequencies and percentages [*n* (%)], and differences between groups were compared using the chi-square (χ^2) test: (1) The Pearson χ^2 test was applied when the sample size (n) was $\geq$40 and all theoretical frequencies were >5; (2) Yates' corrected χ^2 test was used when n was $\geq$40 and at least one theoretical frequency was between 1 and 5; and (3) Fisher's exact test was employed when n was <40 or any theoretical frequency was <1.

Multivariate linear regression analyses were performed to determine the independent effect of the arterial cannulation strategy on key neurological outcomes. The following postoperative continuous dependent variables were analyzed separately: mRS score at 90 days, MoCA score at 90 days, peak NSE level, peak S100B level, duration of delirium, and duration of coma. In each model, the independent variable of interest was the surgical strategy (DAC vs. SAC). The models were adjusted for pre-specified covariates known or suspected to influence neurological outcomes, including age, history of hypertension, preoperative pericardial tamponade, preoperative cerebral hypoperfusion, CPB time, and DHCA time. The results are presented as unstandardized regression coefficients (B) with corresponding 95% confidence intervals (CIs). All reported *p*-values were two-sided, and a p-value < 0.05 was considered statistically significant.

Results

Baseline Clinical Characteristics

As shown in Fig. 1, a total of 120 patients with STAAD were included in the study, based on the established inclusion and exclusion criteria. As shown in Table 1, no statistically significant differences were observed between the DAC and

Table 1. Comparison of preoperative characteristics between the DAC and SAC groups [$\bar{x} \pm$ s, *n* (%)].

Characteristic	DAC group (n = 63)	SAC group (n = 57)	t/χ^2-value	p-value
Gender (male)	40 (63.49)	39 (68.42)	0.323	0.570
Age (years)	56.29 ± 10.55	57.60 ± 9.86	0.701	0.485
BMI (kg/m^2)	24.86 ± 3.71	24.25 ± 3.64	0.906	0.367
Hypertension	46 (73.02)	44 (77.19)	0.278	0.598
Diabetes mellitus	3 (4.76)	2 (3.51)	<0.001 (Y)	1.000
Smoking	13 (20.63)	10 (17.54)	0.185	0.667
Alcohol consumption	10 (15.87)	7 (12.28)	0.318	0.573
Coronary heart disease	2 (3.17)	2 (3.51)	<0.001 (Y)	1.000
Maximum aortic diameter (mm)	51.36 ± 7.82	50.84 ± 7.55	0.370	0.712
True lumen area (cm^2)	2.12 ± 0.79	2.23 ± 0.72	0.794	0.429
False lumen area (cm^2)	10.24 ± 3.68	9.98 ± 3.47	0.397	0.692
Renal insufficiency	2 (3.17)	1 (1.75)	<0.001 (Y)	1.000
COPD	1 (1.59)	2 (3.51)	0.008 (Y)	0.930
Pericardial tamponade	3 (4.76)	2 (3.51)	<0.001 (Y)	1.000
Malperfusion				
Brain	4 (6.35)	5 (8.77)	0.024 (Y)	0.876
Coronary artery	4 (6.35)	4 (7.02)	<0.001 (Y)	1.000
Gastrointestinal tract	5 (7.94)	4 (7.02)	<0.001 (Y)	1.000
Iliac artery	7 (11.11)	7 (12.28)	0.040	0.842

Notes: DAC, double arterial cannulation; SAC, single arterial cannulation; BMI, body mass index; COPD, chronic obstructive pulmonary disease. (Y): Yates' corrected χ^2, applied to variables with sample sizes $\geq$40 but theoretical frequencies of $1 \leq t < 5$.

Table 2. Comparison of surgical and recovery parameters between the DAC and SAC groups [$\bar{x} \pm$ s].

Group	DAC group (n = 63)	SAC group (n = 57)	t-value	p-value
Operation duration (min)	408.25 ± 72.18	390.56 ± 66.43	1.392	0.166
CPB time (min)	255.47 ± 48.50	257.92 ± 42.52	0.293	0.770
Mechanical ventilation duration (h)	62.71 ± 13.47	63.52 ± 12.76	0.337	0.737
Postoperative ICU stay (d)	8.35 ± 2.46	8.51 ± 2.12	0.380	0.705
ACC time (min)	167.48 ± 45.39	164.26 ± 42.83	0.398	0.692
DHCA time (min)	29.71 ± 7.85	28.64 ± 8.23	0.725	0.470
Postoperative awakening time (h)	10.51 ± 3.01	11.33 ± 4.32	1.195	0.235

Notes: CPB, cardiopulmonary bypass; ACC, aortic cross-clamp; DHCA, deep hypothermic circulatory arrest; ICU, intensive care unit.

SAC groups in terms of gender, age, BMI, history of hypertension, diabetes mellitus, smoking, alcohol consumption, coronary artery disease, maximum aortic diameter, true lumen area, false lumen area, renal insufficiency, chronic obstructive pulmonary disease (COPD), pericardial tamponade, cerebral hypoperfusion, coronary artery malperfusion, gastrointestinal hypoperfusion, or iliac artery hypoperfusion ($p > 0.05$) (Table 1).

Surgical and Recovery Time Parameters

No statistically significant differences were observed between the two groups in operative time, CPB duration, mechanical ventilation time, ICU stay duration, ACC time, DHCA time, or postoperative awakening time ($p > 0.05$), as detailed in Table 2.

Neurological Outcomes

The incidence of postoperative PND and TND was significantly lower in the DAC group compared with the SAC group ($p < 0.05$). Additionally, the duration of coma and delirium was significantly shorter in the DAC group than in the SAC group ($p < 0.001$), as presented in Table 3.

Neurological Function Scores

There was no statistically significant difference in preoperative scores between the two groups ($p > 0.05$). At postoperative day 30, both groups exhibited significantly elevated mRS scores compared with baseline, indicating short-term neurological deterioration, with the SAC group showing markedly higher mRS scores than the DAC group ($p < 0.001$). By postoperative day 90, the DAC group demonstrated significantly lower mRS scores than the SAC group, reflecting superior neurological recovery ($p < 0.001$) (Table 4).

Table 3. Comparison of neurofunctional outcomes between the DAC and SAC groups [$\bar{x} \pm s$, *n* (%)].

Outcome	DAC group ($n = 63$)	SAC group ($n = 57$)	χ^2/t-value	p-value
PND	2 (3.17)	9 (15.79)	5.719	0.017
TND	4 (6.35)	11 (19.30)	4.588	0.032
Duration of coma (d)	1.60 ± 0.78	2.81 ± 1.17	6.543	<0.001
Duration of delirium (d)	3.28 ± 1.44	5.19 ± 2.11	5.709	<0.001

Notes: PND, permanent neurological dysfunction; TND, transient neurological dysfunction.

Table 4. Comparison of mRS scores between the DAC and SAC groups [median (Q1, Q3)].

Timepoint	DAC group ($n = 63$)	SAC group ($n = 57$)	Z-value	p-value
Before operation	0.00 (0.00, 0.00)	0.00 (0.00, 1.00)	1.555	0.120
30 days after operation	2.00 (1.00, 2.00) **	2.00 (2.00, 3.00) **	4.942	<0.001
90 days after operation	1.00 (1.00, 1.00) **,##	2.00 (1.00, 2.00) **,##	4.929	<0.001

Notes: mRS, modified Rankin Scale; Q1, quartile 1; Q3, quartile 3. **$p < 0.001$ vs. preoperative value within the same group; ##$p < 0.001$ vs. postoperative 30-day value within the same group.

Preoperative MoCA scores showed no significant difference between the groups ($p > 0.05$). At 30 days postoperatively, both groups experienced a significant decline in MoCA scores from their baseline values. However, the DAC group maintained significantly higher MoCA scores than the SAC group ($p < 0.001$). By 90 days postoperatively, MoCA scores had significantly increased from 30-day levels in both groups ($p < 0.001$), with the DAC group demonstrating considerably higher scores than the SAC group ($p < 0.001$) (Table 5).

As shown in Table 6, both groups demonstrated statistically significant time effects for mRS and MoCA scores ($p < 0.001$), indicating that these metrics varied significantly over time in both the DAC and SAC groups. Significant group effects were also observed for both mRS and MoCA scores ($p < 0.001$), suggesting distinct temporal trajectories between the two surgical interventions. Furthermore, statistically significant interaction effects were observed for both outcomes ($p < 0.001$), indicating that the influence of time on mRS and MoCA scores varied depending on the cannulation strategy employed.

Serum Biomarkers of Neurological Injury

As presented in Table 7, preoperative NSE levels did not differ significantly between the two groups ($p > 0.05$). At 24–48 hours postoperatively, NSE levels increased significantly from baseline in both groups ($p < 0.001$), with the DAC group showing significantly lower NSE levels than the SAC group ($p < 0.001$). At 30 and 90 days postoperatively, NSE levels decreased significantly from their peak values (24–48 hours post-surgery) in both groups, and the DAC group consistently maintained significantly lower NSE levels at both time points ($p < 0.001$).

As shown in Table 8, preoperative S100B levels were comparable between the two groups ($p > 0.05$). At 24 hours postoperatively, S100B levels rose significantly from baseline in both groups, with the DAC group exhibiting markedly lower levels than the SAC group ($p < 0.001$). By 72 hours and 90 days postoperatively, S100B levels declined considerably from their 24-hour values in both groups, with the DAC group retaining significantly lower levels at both time points ($p < 0.001$).

As demonstrated in Table 9, both groups exhibited statistically significant time effects for NSE and S100B levels ($p < 0.001$), indicating dynamic temporal changes in these biomarkers. Significant group effects were also observed for NSE and S100B concentrations ($p < 0.001$), reflecting distinct temporal trends between the two intervention groups. Moreover, statistically significant interaction effects were observed for both biomarkers ($p < 0.001$), demonstrating that the temporal changes in NSE and S100B levels were influenced by the cannulation strategy employed.

Multivariate Linear Regression Analyses

The results of the multivariate linear regression models, adjusted for age, hypertension, preoperative pericardial tamponade, cerebral hypoperfusion, CPB duration, and DHCA duration, are summarized in Table 10. The DAC strategy emerged as a statistically significant, independent protective factor for all six neurological outcomes investigated. Specifically, DAC was associated with significantly lower (better) mRS scores at postoperative day 90 (B = –0.524, 95% CI = –0.722~–0.326, $p < 0.001$) and higher (better) MoCA scores at postoperative day 90 (B = 2.396, 95% CI = 1.845~2.947, $p < 0.001$). In terms of serum biomarkers of brain injury, the DAC strategy was independently associated with significantly reduced postoperative peak levels of both NSE (B = –11.450, 95% CI = –14.936~–7.964, $p < 0.001$) and S100B (B = –0.129, 95% CI = –0.165~–0.093, $p < 0.001$). Furthermore, DAC independently predicted shorter durations of postoperative coma (B = –1.233, 95% CI = –1.596~–0.871, $p < 0.001$) and postoperative delirium (B = –1.942, 95% CI = –2.596~–1.288, $p < 0.001$).

Table 5. Comparison of MoCA scores between the DAC and SAC groups [median (Q1, Q3)].

Timepoint	DAC group (n = 63)	SAC group (n = 57)	Z-value	p-value
Before operation	28.00 (28.00, 28.00)	28.00 (27.00, 29.00)	1.868	0.062
30 days after operation	25.00 (24.00, 26.00) **	22.00 (21.00, 24.00) **	6.825	<0.001
90 days after operation	27.00 (26.00, 27.00) **,##	24.00 (23.00, 25.00) **,##	6.919	<0.001

Notes: MoCA, Montreal Cognitive Assessment. **$p < 0.001$ vs. preoperative value within the same group; ##$p < 0.001$ vs. postoperative 30-day value within the same group.

Table 6. Repeated measures analysis of variance for mRS and MoCA scores before and after surgery.

Variable	Time effect		Intergroup effect		Interaction effect	
	Wald χ^2	p-value	Wald χ^2	p-value	Wald χ^2	p-value
mRS score	826.774	<0.001	56.789	<0.001	18.635	<0.001
MoCA score	688.202	<0.001	141.145	<0.001	57.216	<0.001

Postoperative General Complications

The SAC group exhibited a significantly higher incidence of postoperative limb ischemia compared with the DAC group ($p < 0.05$). No statistically significant differences were observed between the groups in other postoperative complications, including acute kidney injury, axillary artery injury, pneumonia, or deep sternal wound infection ($p > 0.05$) (Table 11).

Discussion

This two-center retrospective study compared the efficacy of axillary-femoral dual-arterial cannulation versus conventional femoral artery single cannulation in STAAD repair surgery. The findings revealed that, compared with the SAC group, patients in the DAC group exhibited significantly lower incidences of PND and TND, and experienced markedly shorter durations of coma and delirium. Regarding neurological function, the DAC group demonstrated significantly superior neurological recovery at 30 and 90 days postoperatively, as reflected by lower mRS scores and higher MoCA scores. Additionally, serum biomarker analysis revealed that the DAC group had significantly lower postoperative peak levels of NSE and S100B, with these reductions persisting through 90 days after surgery. Collectively, these findings suggest that the combined cannulation strategy not only mitigates acute-phase cerebral injury but also promotes long-term neurological recovery.

Notably, the observed neuroprotective advantages of DAC were achieved despite comparable baseline surgical parameters, including total operative time, CPB duration, and mechanical ventilation time, between the two groups. This indicates that the neuroprotective mechanism of DAC is largely independent of routine surgical factors and is directly related to optimized perfusion dynamics. Notably, no cases of postoperative limb ischemia occurred in the DAC group, whereas the SAC group demonstrated an incidence rate of 10.53%. Furthermore, compared to conventional femoral artery single cannulation, the combined axillary-femoral arterial approach significantly reduces the occurrence of postoperative PND and the duration of postoperative delirium.

The neuroprotective advantages of axillary-femoral arterial combined cannulation can be attributed primarily to its adaptability to variations in cerebrovascular anatomy. In unilateral cerebral perfusion, contralateral hypoperfusion is a frequent concern, particularly in patients lacking an intact Circle of Willis [15]. In this study, the DAC group exhibited significantly lower incidences of postoperative PND and TND, along with shorter coma/impaired consciousness, supporting the hypothesis that dual-artery perfusion ensures more balanced cerebral oxygen delivery.

We observed that the incidence of TND in the SAC group aligned with outcomes reported for isolated femoral artery cannulation in another comparative study evaluating axillary versus femoral artery cannulation techniques in STAAD. Notably, that same study reported no statistically significant difference in postoperative neurological outcomes between its isolated axillary cannulation cohort (18.8% TND rate) and the isolated femoral cannulation cohort [16]. Taken together, these findings suggest that the axillary-femoral dual arterial cannulation more effectively maintains intraoperative cerebral blood and reduces the risk of ischemic brain injury.

Mechanistically, the DAC approach provides robust circulatory support, simultaneously delivering antegrade and retrograde flow to achieve optimal systemic perfusion while ensuring homogeneous cerebral blood distribution [17]. Perfusion through the right axillary artery sustains flow within the right carotid system, whereas femoral artery cannulation, upon restoration of lower-body circulation, facilitates global perfusion of the aortic arch branches through true lumen reconstruction [18]. This synergistic dual-perfusion pattern enhances collateral circulation within the basilar arterial system, preserving compensatory capacity during DHCA [3].

When neurological dysfunction occurs, a series of neurobiological markers, such as S100B and NSE, can be detected in the blood, showing significant fluctuations in their concentrations. S100B, a calcium-binding protein predom-

Table 7. Comparison of NSE levels between the DAC and SAC groups [$\bar{x} \pm s$].

Timepoint	DAC group (n = 63)	SAC group (n = 57)	t-value	p-value
Before operation	10.30 ± 2.40	10.60 ± 2.49	0.671	0.504
24–48 h after operation	30.30 ± 8.49**	41.70 ± 10.60**	6.528	<0.001
30 days after operation	15.51 ± 3.40**,##	21.60 ± 4.70**,##	8.060	<0.001
90 days after operation	11.70 ± 2.50*,##	16.80 ± 3.79**,##	8.608	<0.001

Notes: NSE, neuron-specific enolase. Compared with the *$p < 0.05$ vs. preoperative value within the same group; compared with the **$p < 0.001$ vs. preoperative value within the same group; compared with the ##$p < 0.001$ vs. postoperative 24–48 h within the same group.

Table 8. Comparison of S100B levels between the DAC and SAC groups [$\bar{x} \pm s$].

Timepoint	DAC group (n = 63)	SAC group (n = 57)	t-value	p-value
Before operation	0.07 ± 0.02	0.08 ± 0.04	1.512	0.134
24 h after operation	0.26 ± 0.07**	0.39 ± 0.12**	7.163	<0.001
72 h after operation	0.14 ± 0.05**,##	0.24 ± 0.07**,##	8.967	<0.001
90 days after operation	0.09 ± 0.03**,##	0.15 ± 0.06**,##	7.042	<0.001

Notes: S100B, S100 calcium-binding protein B. Compared with the **$p < 0.001$ vs. preoperative value within the same group; compared with the ##$p < 0.001$ vs. postoperative 24 h within the same group.

Table 9. Repeated measures analysis of variance for NSE and S100B levels before and after surgery.

Variable	Time effect		Intergroup effect		Interaction effect	
	F-value	p-value	F-value	p-value	F-value	p-value
NSE level	404.328	<0.001	130.080	<0.001	36.346	<0.001
S100B level	306.071	<0.001	174.300	<0.001	29.694	<0.001

Table 10. Multivariate linear regression analyses of key neurological outcomes.

Item	B	95% CI	p-value
Postoperative 90-day mRS score	–0.524	–0.722~–0.326	<0.001
Postoperative 90-day MoCA score	2.396	1.845~2.947	<0.001
Postoperative peak NSE level	–11.450	–14.936~–7.964	<0.001
Postoperative peak S100B level	–0.129	–0.165~–0.093	<0.001
Postoperative coma duration	–1.233	–1.596~–0.871	<0.001
Postoperative delirium duration	–1.942	–2.596~–1.288	<0.001

Notes: B, unstandardized regression coefficients.

Table 11. Comparison of postoperative complications between the DAC and SAC groups [*n* (%)].

Group	DAC group (n = 63)	SAC group (n = 57)	χ^2	p-value
Acute kidney injury	9 (14.29)	9 (15.79)	0.053	0.818
Limb ischemia	0 (0.00)	6 (10.53)	4.940 (Y)	0.026
Axillary artery injury[a]	1 (1.59)	0 (0.00)	Fisher	1.000
Pneumonia	6 (9.52)	5 (8.77)	0.020	0.887
Deep sternal wound infection	2 (3.17)	2 (3.51)	<0.001 (Y)	1.000
Total	18 (28.57)	22 (38.60)	1.353	0.245

Notes: [a] One of the complications categorized under axillary artery injury includes brachial plexus injury. (Y), Yates' corrected χ^2 test, applied when the sample size ≥40 and expected frequency $1 \leq t < 5$. Fisher, Fisher's exact test, used when the sample size was <40 or any expected cell count <1.

inantly expressed in astrocytes, serves as a biomarker of acute brain injury [19]. A randomized clinical trial demonstrated that, in patients with brain injury, serum S100B levels increase during CPB, peak at the termination of CPB, and gradually decline over the 24 hours following CPB [20]. In this study, compared with DAC patients, who had a lower incidence of PND, the SAC group, which showed higher PND rates, exhibited significantly elevated serum S100B levels within 24–72 hours postoperatively, followed by a gradual decrease. This pattern aligns with previous

research findings [20,21]. NSE, an intracellular enzyme abundant in neurons, is a critical predictor of adverse neurological outcomes and injury severity [22]. At 24–48 hours postoperatively, both groups showed significantly elevated NSE levels compared with the preoperative baseline values. However, the DAC group maintained significantly lower NSE levels than the SAC group. Even at 30 and 90 days after surgery, although NSE levels declined significantly in both groups, the DAC group continued to exhibit lower NSE levels, indicating more severe neural injury in the SAC group.

This study employed two complementary assessment tools, the mRS and the MoCA, to comprehensively evaluate the short- and mid-term effects of two arterial cannulation strategies on postoperative neurological function in patients with acute STAAD, addressing both functional disability and cognitive performance. The results demonstrated strong internal consistency and provided compelling evidence supporting the superiority of axillary-femoral combined cannulation for cerebral protection. First, in terms of overall neurological recovery, mRS scores revealed significant advantages of the DAC strategy. Preoperative mRS scores were comparable between groups, ensuring baseline equivalence. By postoperative day 30, both cohorts showed significantly higher mRS scores than preoperative baselines, objectively reflecting the profound neurological burden imposed by aortic dissection surgery and DHCA; virtually all patients experienced some degree of functional impairment [23]. However, the SAC group exhibited significantly greater disability at this stage, suggesting less severe global neurological impairment or faster early recovery in the DAC group. This advantage became even more evident by postoperative day 90, when the DAC group demonstrated significantly greater improvement in mRS compared with the SAC group. The trajectory of mRS changes clearly illustrates superior neurological recovery among DAC patients, with meaningful clinical implications, including earlier achievement of self-care independence, quicker return to normal activities, and reduced familial and societal care demands [24].

Second, in the more nuanced domain of cognitive function, MoCA scores revealed a complex yet informative pattern. At postoperative day 30, both groups displayed substantial declines in MoCA scores compared to preoperative levels. This early deterioration likely resulted from potent transient confounders such as systemic inflammatory response syndrome, residual anesthetic effects, sleep deprivation, and ICU-related environmental stressors, resulting in universal and comparable postoperative cognitive dysfunction across all patients [25,26]. By postoperative day 90, however, a distinct divergence emerged. As these nonspecific factors resolved, the underlying impact of perfusion discrepancies and differential neural repair capacities became evident. The DAC group achieved significantly higher MoCA scores than the SAC group, suggesting better cognitive recovery. These findings suggest that while all patients experienced postoperative cognitive decline, those in the SAC group likely sustained more profound and potentially irreversible neural injury. Remarkably, these observations align perfectly with the biochemical profiles, as lower peak levels and faster decline rates of NSE and S100B in the DAC group provide molecular-level confirmation of reduced parenchymal brain injury, thereby offering objective biological validation for the observed functional improvements.

The most compelling evidence supporting this interpretation comes from the multivariate linear regression analyses. While retrospective designs are inherently susceptible to confounding, the present study rigorously controlled for a comprehensive set of baseline and procedural variables, including age, comorbidities (hypertension), markers of preoperative acuity (tamponade, cerebral hypoperfusion), and key intraoperative factors (CPB time and DHCA time) that are strongly associated with neurological injury [27,28]. Notably, the DAC strategy emerged as a robust, independent, and consistent protective factor across multiple outcome domains, spanning objective serum biomarkers (NSE, S100B), clinical states (coma, delirium), and long-term functional and cognitive indices (mRS, MoCA). This cross-domain consistency significantly strengthens the causal inference that the perfusion strategy itself constitutes the primary driver of the observed neurological benefit.

The convergence of these findings across biochemical, clinical and cognitive domains of neurological injury is remarkable. The reduction in biomarker levels indicates decreased intraoperative cellular damage; the shortened durations of coma and delirium suggest a more rapid and orderly neurological recovery; and the superior mRS and MoCA outcomes reflect meaningful, long-term improvements in functional independence and cognitive integrity. The multivariate results further confirm that these benefits are not simply due to shorter ischemic times or favorable baseline characteristics, but are inherent to the antegrade-retrograde perfusion paradigm unique to the DAC strategy. This paradigm likely minimizes cerebral embolic load by avoiding retrograde perfusion through a diseased descending aorta while ensuring more stable and physiologically uniform cerebral perfusion during critical operative stages [7].

This study compared the effects of different arterial cannulation strategies on postoperative general complications in STAAD surgery. The findings demonstrated that the DAC approach significantly reduced the incidence of postoperative limb ischemia compared with the SAC approach, while no significant differences were observed in other complications between the two groups. Postoperative limb ischemia represents a severe complication closely associated with the chosen cannulation strategy. In this cohort, the SAC group exhibited markedly higher rates of limb ischemia compared with the DAC group, a difference attributed to the distinct perfusion pathways involved. When using retro-

grade femoral access, preexisting dissection extending into the iliac or femoral arteries may lead to catheter malposition within the false lumen or compression of the true lumen, thereby exacerbating lower-extremity ischemia. In contrast, DAC employs combined femoral-axillary artery cannulation to establish hybrid antegrade-retrograde perfusion. Even when femoral flow is compromised, antegrade circulation through the axillary artery sustains effective distal perfusion via collaterals or direct routes, substantially mitigating the risk of limb ischemia [3].

In terms of acute kidney injury, comparable incidence rates between groups are consistent with previous evidence, suggesting that while dual-artery cannulation improves limb perfusion, it does not confer additional renal protection compared with single-artery access [7]. Similarly, no statistically significant differences were observed in pneumonia or deep sternal wound infection rates, indicating that the greater technical complexity of DAC does not elevate infectious risks. Notably, one instance of axillary artery injury occurred in the DAC group. Although this difference lacked statistical significance, such vascular injuries remain clinically consequential. Literature reports indicate an incidence of 1–1.5% for arterial complications associated with axillary cannulation [29]. However, in experienced cardiac surgery centers that utilize meticulous surgical techniques, right axillary access remains a safe and viable option for aortic arch procedures [30]. The low incidence of axillary artery damage observed in this study reflects the proficiency of the surgical team in vascular anastomosis, effectively keeping this potential complication within acceptable clinical limits.

Despite these valuable findings, this study has several limitations. First, the retrospective, non-randomized controlled design introduces inherent selection bias and the potential influence of unmeasured confounders, despite the inclusion of cases from two centers to enhance demographic and procedural diversity. For instance, the specific technical approach to axillary artery cannulation (direct cannulation versus indirect cannulation) was determined intraoperatively based on the surgeon's subjective assessment of vascular conditions, a practice that reflects real-world clinical judgment but lacks systematic documentation of procedural duration or local complication differences. Consequently, causal inferences must be drawn cautiously.

Second, regarding laboratory parameters, although standardized sample processing protocols and stringent exclusion criteria were followed, the absence of systematic hemolysis index testing and correction for stored serum samples raises the possibility that minor hemolysis may have subtly influenced NSE and S100B measurements. Third, surgical strategy selection was primarily driven by surgeon experience and preference rather than standardized objective criteria, potentially introducing indication bias. Furthermore, despite the dual-center design, the limited sample size constrained robust subgroup analyses among high-risk populations, such as elderly patients or those with preoperative hypoperfusion, thereby limiting the generalizability of conclusions to these cohorts.

Finally, the relatively short postoperative follow-up period precluded evaluation of medium- to long-term outcomes. Extended longitudinal observation is required to fully characterize the sustained effects of interventional strategies. Moving forward, we plan to conduct a multicenter, prospective, randomized controlled trial that builds upon these findings. The forthcoming study will implement standardized operating procedures and refined inclusion and exclusion criteria while extending follow-up durations to 3, 5, and 10 years postoperatively. This aims to substantially strengthen the evidence base and enhance the translational impact of this research.

Conclusions

This two-center retrospective cohort study demonstrates that, in STAAD repair surgery, the axillary-femoral arterial combined cannulation strategy may offer superior and independent cerebral protection compared with isolated femoral artery cannulation. This conclusion is supported by consistent evidence across multiple outcome parameters. First, regarding clinical endpoints, the DAC group exhibited significantly lower incidences of PND and TND, along with shorter durations of impaired consciousness, suggesting better short-term neurological outcomes. Second, in neurofunctional assessments, although all patients experienced postoperative declines in neurological and cognitive function, the DAC group demonstrated faster and more complete neurological recovery, along with better preservation of mid- to long-term cognitive performance. Third, in terms of serum biomarkers, the DAC group showed significantly lower peak levels of NSE and S100B proteins postoperatively, with faster normalization, providing objective biochemical evidence of reduced perioperative parenchymal brain injury. After adjusting for key patient- and surgery-related covariates, the DAC strategy remained independently associated with improved neurological and cognitive function, reduced biochemical evidence of brain injury, and shorter periods of postoperative consciousness impairment. These findings strongly support the adoption of combined axillary-femoral artery cannulation as a safe and effective perfusion strategy for enhanced cerebral protection during this high-risk procedure. Furthermore, the DAC group exhibited lower rates of limb ischemic complications compared with the SAC group.

In summary, by simultaneously establishing antegrade and retrograde perfusion, axillary-femoral combined cannulation likely provides more physiological, stable, and reliable cerebral perfusion while facilitating surgical procedures. These findings suggest that DAC, as a perfusion strategy, holds the potential to improve postoperative neurological outcomes in patients with STAAD. However, its definitive

efficacy warrants further validation through well-designed prospective studies.

Availability of Data and Materials

The data analyzed are available from the corresponding author upon reasonable request.

Author Contributions

HZ and YW designed the research study and wrote the first draft. ZW and YZhu performed the research. HZ and YZhang analyzed the data. All authors have been involved in revising the manuscript critically for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

The study protocol was approved by the Ethics Review Committee of the Affiliated Hospital of Xuzhou Medical University and the Second People's Hospital of Huai'an (XYFY2025-KL050-01; HEYLL202586). All procedures conformed to the ethical principles outlined in the Declaration of Helsinki, and all participants provided written informed consent prior to their inclusion.

Acknowledgment

Not applicable.

Funding

This study is supported by Construction Project of High Level Hospital Construction Project of Jiangsu Province (GSPJS202404).

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Fu Z, Xu Q, Zhang C, Bai H, Chen X, Zhang Y, *et al*. Admission Systolic Blood Pressure Predicts Post-Operative Delirium of Acute Aortic Dissection Patients in the Intensive Care Unit. International Journal of General Medicine. 2021; 14: 5939–5948. https://doi.org/10.2147/IJGM.S329689.

[2] Kesieme EB, Iruolagbe CO, Ngaage DL. Recognition and initial management of acute aortic dissection. British Journal of Hospital Medicine. 2024; 85: 1–12. https://doi.org/10.12968/hmed.2024.0004.

[3] Lin CY, Tseng CN, Lee HA, Ho HT, Tsai FC. Double arterial cannulation strategy for acute type A aortic dissection repair: A 10-year single-institution experience. PLoS ONE. 2019; 14: e0211900. https://doi.org/10.1371/journal.pone.0211900.

[4] Wang X, Liu N, Wang H, Liu Y, Sun L, Zhu J, *et al*. Femoral artery cannulation increases the risk of postoperative stroke in patients with acute DeBakey I aortic dissection. The Journal of Thoracic and Cardiovascular Surgery. 2023; 166: 1023–1031.e15. https://doi.org/10.1016/j.jtcvs.2021.12.049.

[5] Hussain A, Uzzaman M, Mohamed S, Khan F, Butt S, Khan H. Femoral versus axillary cannulation in acute type A aortic dissections: A meta-analysis. Journal of Cardiac Surgery. 2021; 36: 3761–3769. https://doi.org/10.1111/jocs.15810.

[6] Chang Y, Lin H, Qian X, Guo H, Yu C, Sun X, *et al*. Comparison of Single Axillary vs. Dual Arterial Cannulation for Acute Type a Aortic Dissection: A Propensity Score Matching Analysis. Frontiers in Cardiovascular Medicine. 2022; 9: 809493. https://doi.org/10.3389/fcvm.2022.809493.

[7] Tang Z, Yuan C, Liu H, Ding Y, Gu J, Li M, *et al*. Comparison of clinical outcomes between double arterial cannulation and single arterial cannulation in type A aortic dissection. Scientific Reports. 2025; 15: 136. https://doi.org/10.1038/s41598-024-83945-9.

[8] Ikeno Y, Sasaki K, Matsueda T, Inoue T, Tanaka H, Sugimoto K, *et al*. Impact of white matter changes on neurologic outcomes of total arch replacement using antegrade cerebral perfusion. The Journal of Thoracic and Cardiovascular Surgery. 2019; 157: 1350–1357.e1. https://doi.org/10.1016/j.jtcvs.2018.10.150.

[9] Sessler CN, Gosnell MS, Grap MJ, Brophy GM, O'Neal PV, Keane KA, *et al*. The Richmond Agitation-Sedation Scale: validity and reliability in adult intensive care unit patients. American Journal of Respiratory and Critical Care Medicine. 2002; 166: 1338–1344. https://doi.org/10.1164/rccm.2107138.

[10] Wang S, Sigua NL, Manchanda S, Gradney S, Khan SH, Perkins A, *et al*. Preoperative STOP-BANG Scores and Postoperative Delirium and Coma in Thoracic Surgery Patients. The Annals of Thoracic Surgery. 2018; 106: 966–972. https://doi.org/10.1016/j.athoracsur.2018.05.089.

[11] Ely EW, Margolin R, Francis J, May L, Truman B, Dittus R, *et al*. Evaluation of delirium in critically ill patients: validation of the Confusion Assessment Method for the Intensive Care Unit (CAM-ICU). Critical Care Medicine. 2001; 29: 1370–1379. https://doi.org/10.1097/00003246-200107000-00012.

[12] Liu GY, Su X, Meng ZT, Cui F, Li HL, Zhu SN, *et al*. Handover of anesthesia care is associated with an increased risk of delirium in elderly after major noncardiac surgery: results of a secondary analysis. Journal of Anesthesia. 2019; 33: 295–303. https://doi.org/10.1007/s00540-019-02627-3.

[13] Minhas JS, Wang X, Lavados PM, Moullaali TJ, Arima H, Billot L, *et al*. Blood pressure variability and outcome in acute ischemic and hemorrhagic stroke: a post hoc analysis of the HeadPoST study. Journal of Human Hypertension. 2019; 33: 411–418. https://doi.org/10.1038/s41371-019-0193-z.

[14] Bernstein IH, Lacritz L, Barlow CE, Weiner MF, DeFina LF. Psychometric evaluation of the Montreal Cognitive Assessment (MoCA) in three diverse samples. The Clinical Neuropsychologist. 2011; 25: 119–126. https://doi.org/10.1080/13854046.2010.533196.

[15] Bergeron EJ, Mosca MS, Aftab M, Justison G, Reece TB. Neuroprotection Strategies in Aortic Surgery. Cardiology Clinics. 2017; 35: 453–465. https://doi.org/10.1016/j.ccl.2017.03.011.

[16] Wang Z, Yu Y, Xie X, Wan L, Wang L, Yin J. Comparison of outcomes between axillary and femoral artery cannulation for type A aortic dissection surgery. Journal of Cardiothoracic Surgery. 2025; 20: 236. https://doi.org/10.1186/s13019-025-03465-z.

[17] Zhang H, Xie W, Lu Y, Pan T, Zhou Q, Xue Y, *et al*. Double arterial cannulation versus right axillary artery cannulation for acute type A aortic dissection: a retrospective study. Journal of Cardiothoracic Surgery. 2021; 16: 326. https://doi.org/10.1186/s13019-021-01714-5.

[18] Jin N, Pang X, Song S, Zheng J, Liu Z, Gu T, *et al*. A comparative study of femoral artery and combined femoral and axillary artery cannulation in veno-arterial extracorporeal membrane oxygenation patients. Frontiers in Cardiovascular Medicine. 2024; 11: 1388577. https://doi.org/10.3389/fcvm.2024.1388577.

[19] Langeh U, Singh S. Targeting S100B Protein as a Surrogate Biomarker and its Role in Various Neurological Disorders. Current Neuropharmacology. 2021; 19: 265–277. https://doi.org/10.2174/1570159X18666200729100427.

[20] Ziabakhsh Tabary S, Ziabakhsh Tabary P, Sanei Motlagh A. Neuroprotective effect of memantine on serum S100-B levels after on-pump coronary artery bypass graft surgery: A randomized clinical trial. Caspian Journal of Internal Medicine. 2022; 13: 412–417. https://doi.org/10.22088/cjim.13.2.412.

[21] Cañizo Vázquez D, Hadley SM, Pérez Ordóñez M, Lopez-Abad M, Valls A, Viñals ML, *et al*. Oxidative Stress and Indicators of Brain Damage Following Pediatric Heart Surgery. Antioxidants (Basel, Switzerland). 2022; 11: 489. https://doi.org/10.3390/antiox11030489.

[22] Kimura F, Kadohama T, Kitahara H, Ise H, Nakanishi S, Akasaka N, *et al*. Serum Neuron-Specific Enolase Level as Predictor of Neurologic Outcome after Aortic Surgery. The Thoracic and Cardiovascular Surgeon. 2020; 68: 282–290. https://doi.org/10.1055/s-0038-1677511.

[23] Rajaram A, Milej D, Suwalski M, Yip LCM, Guo LR, Chu MWA, *et al*. Optical monitoring of cerebral perfusion and metabolism in adults during cardiac surgery with cardiopulmonary bypass. Biomedical Optics Express. 2020; 11: 5967–5981. https://doi.org/10.1364/BOE.404101.

[24] Kanchayawong P, Aramvanitch K, Yuksen C, Trakulsrichai S, Sricharoen P, Suwatcharangkoon S, *et al*. Real-Time Telemedical Oversight Improves Prehospital Stroke Metrics: A Five-Year Cohort Study. Archives of Academic Emergency Medicine. 2025; 13: e57. https://doi.org/10.22037/aaemj.v13i1.2693.

[25] Zhou Y, Li X, Chen H, Zhong X, Ren H. Efficacy and safety of sivelestat sodium for the treatment of inflammatory response in acute Stanford type A aortic dissection: a retrospective cohort study. Journal of Thoracic Disease. 2022; 14: 3975–3982. https://doi.org/10.21037/jtd-22-1220.

[26] Bhushan S, Li Y, Huang X, Cheng H, Gao K, Xiao Z. Progress of research in postoperative cognitive dysfunction in cardiac surgery patients: A review article. International Journal of Surgery. 2021; 95: 106163. https://doi.org/10.1016/j.ijsu.2021.106163.

[27] Goebel N, Holder SA, Huether F, Maw E, Ayala R, Anguelov Y, *et al*. Long-Term Results and Quality of Life after Surgery for Acute Aortic Dissection Type A: Contemporary Single-Centre Experience. Journal of Clinical Medicine. 2024; 13: 5645. https://doi.org/10.3390/jcm13185645.

[28] Lin XF, Xie LF, He J, Xie YL, Zhang ZF, Chen LW, *et al*. A nomogram-based model to predict postoperative transient neurological dysfunctions in patients receiving acute type A aortic dissection surgery. Journal of Clinical Hypertension. 2023; 25: 1193–1201. https://doi.org/10.1111/jch.14744.

[29] Lee HK, Kim GJ, Cho JY, Lee JT, Park I, Lee YO. Comparison of the Outcomes between Axillary and Femoral Artery Cannulation for Acute Type A Aortic Dissection. The Korean Journal of Thoracic and Cardiovascular Surgery. 2012; 45: 85–90. https://doi.org/10.5090/kjtcs.2012.45.2.85.

[30] Guo J, Wang Y, Zhu J, Cao J, Chen Z, Li Z, *et al*. Right axillary and femoral artery perfusion with mild hypothermia for aortic arch replacement. Journal of Cardiothoracic Surgery. 2014; 9: 94. https://doi.org/10.1186/1749-8090-9-94.