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Article

Clinical Application of Three Antegrade Cerebral Perfusion Strategies in Acute DeBakey Type I Aortic Dissection

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Abstract

Objective: This study aimed to compare the efficacy of three antegrade cerebral perfusion (ACP) strategies in the surgical management of acute DeBakey type I aortic dissection. **Methods**: This retrospective comparative study included 207 patients with DeBakey type I aortic dissection who underwent surgical treatment at the Department of Cardiothoracic and Vascular Surgery, The First Affiliated Hospital of Hengyang Medical School, University of South China, between January 2020 and December 2024. Based on the ACP strategies utilized during surgery and the time periods of implementation, patients were divided into three groups: the unilateral antegrade cerebral perfusion (uACP) group (n = 28), the bilateral antegrade cerebral perfusion (bACP) group (n = 87), and the total antegrade cerebral perfusion (tACP) group (n = 92). Preoperative, intraoperative, and postoperative data were collected and analyzed to identify differences among the three groups. **Results**: There were no statistically significant differences in baseline clinical characteristics among the three groups, indicating good comparability. The tACP group demonstrated significantly shorter cardiopulmonary bypass times, postoperative awakening times, durations of tracheal intubation, and intensive care unit (ICU) stays compared to the other two groups ($p < 0.05$). Additionally, the tACP group exhibited a higher minimum nasopharyngeal temperature (approximately 24.8 °C, $p < 0.05$). The incidence of transient neurological dysfunction (TND) was highest in the uACP group (37.5%), intermediate in the bACP group (18.2%), and lowest in the tACP group (10.6%, $p < 0.05$). While the bACP group showed an advantage in lower body circulatory arrest time (approximately 28 minutes), the tACP group, despite requiring more meticulous cannulation techniques, provided superior overall neuroprotection. No statistically significant differences were observed among the three groups regarding other postoperative complications ($p > 0.05$). **Conclusion**: The tACP strategy demonstrated superior applicability during complex aortic arch reconstruction surgeries, significantly reducing the incidence of TND and accelerating postoperative recovery.

Keywords

acute DeBakey type I aortic dissection; antegrade cerebral perfusion strategies; cerebral protection

Introduction

DeBakey type I aortic dissection is a severe and highly fatal cardiovascular emergency primarily involving the ascending aorta, aortic arch, and descending aorta. Surgical intervention remains the gold standard for reducing acute-phase mortality, decreasing the hourly mortality rate from 0.5% to 0.09% within the first 48 hours post-treatment [1]. However, perioperative in-hospital mortality remains as high as 15.2% [2], with neurological complications being a significant contributing factor [3,4]. Against this backdrop, the choice of intraoperative cerebral protection strategies is critical. Current methods include deep hypothermic circulatory arrest (DHCA) and various cerebral perfusion strategies, classified as antegrade cerebral perfusion (ACP) and retrograde cerebral perfusion (RCP). Among these, ACP is widely adopted due to its closer alignment with physiological demands [5,6]. Common ACP strategies include unilateral antegrade cerebral perfusion (uACP) via the axillary artery, bilateral antegrade cerebral perfusion (bACP) via the brachiocephalic trunk and left common carotid artery, and total antegrade cerebral perfusion (tACP) through all three arch branches. uACP, a classical approach, necessitates an additional incision, while bACP is recommended for prolonged surgeries due to its comprehensive cerebral protection. The emerging tACP strategy aims to achieve superior intraoperative neuroprotection through global brain perfusion. Although previous studies have compared the safety and efficacy of these strategies, the optimal approach remains controversial [7–9]. This study retrospectively analyzes the three ACP strategies to provide clinical guidance for cerebral protection during aortic dissection surgery.

Materials and Methods

This retrospective cohort study included patients diagnosed with DeBakey type I aortic dissection via computed tomography angiography (CTA) and treated surgically at the Department of Cardiothoracic and Vascular Surgery, The First Affiliated Hospital of Hengyang Medical School, University of South China, between January 2020 and December 2024. All surgeries were performed by the same experienced cardiovascular surgical team to ensure procedural consistency.

We included 207 patients grouped according to the ACP strategy employed during surgery, illustrating the evolution of clinical practice over time: from January 2020 to December 2020, uACP (n = 28); from January 2021 to December 2022, bACP (n = 87); and from January 2023 to December 2024, tACP (n = 92). Male patients predominated in all groups, with mean ages of 49.96 ± 9.22, 53.41 ± 9.82, and 51.08 ± 11.47 years, respectively, reflecting a relatively young onset (Table 1).

Inclusion criteria: acute admission and a confirmed diagnosis of DeBakey type I aortic dissection. Completion of total aortic arch replacement with stented elephant trunk procedure. Age $\geq$18 years. Symptom onset to hospital admission $\leq$14 days.

Exclusion criteria: history of prior open cardiac surgery. Incomplete clinical data. Traumatic aortic dissection. Preoperative cerebral infarction or cerebral hemorrhage.

Patient data were extracted from the hospital's electronic medical record system, including demographic details (age, sex, smoking history, comorbidities such as hypertension, diabetes, coronary artery disease, pericardial tamponade, renal failure), intraoperative parameters (time to surgery, cardiopulmonary bypass time, aortic cross-clamp time, lower-body circulatory arrest time, selective cerebral perfusion time, minimum nasopharyngeal temperature), and postoperative outcomes (awakening time, intubation time, intensive care unit (ICU) stay, hospital stay, neurological deficits [permanent neurological dysfunction (PND), transient neurological dysfunction (TND)], paraplegia, re-thoracotomy, renal failure, wound infection, mortality). To ensure data accuracy, all information was independently verified by two radiologists and one senior cardiovascular surgeon.

In this study, the following definitions were applied: PND was defined as any persistent and irreversible neurological deficit, confirmed by clinical evaluation or imaging findings [10]. TND was characterized by newly developed neurological symptoms that were imaging-negative and resolved completely before discharge [11]. Paraplegia was defined as complete or severe loss of motor function in both lower extremities. Re-thoracotomy referred to a surgical intervention involving re-opening of the chest to control bleeding or manage other severe complications. Renal failure was diagnosed based on an increase in serum creatinine exceeding 0.3 mg/dL within 48 hours, a rise of $\geq$1.5 times the baseline, a urine output $\leq$0.5 mL/kg/h for $\geq$6 hours, or the need for renal replacement therapy [12]. Wound infection included superficial or deep surgical site infections, characterized by local redness, exudation, pain, or positive bacterial cultures. Mortality was defined as any death occurring within 30 days of surgery or during the same hospital stay, regardless of cause.

The study protocol was approved by the Ethics Committee of The First Affiliated Hospital of Hengyang Medical School, University of South China (Ethical Approval Code: 2024LL1226001). Written informed consent was obtained from all patients preoperatively. Patient data were anonymized to ensure confidentiality and protect privacy.

Surgical Technique

CTA was reviewed preoperatively to confirm aortic dissection details (Fig. 1A). Patients were positioned supine, and general anesthesia with endotracheal intubation was induced. After standard sterilization, a median sternotomy was performed (with axillary artery dissection for uACP cases). The pericardium was opened, and the brachiocephalic trunk, left common carotid artery, and left subclavian artery were dissected. Heparin sodium injection (Wangbang Biopharmaceutical, Jiangsu, China) was administered systemically at a dose of 3 mg/kg to achieve heparinization. Notably, a uniform perfusion circuit (cannulae and tubing) was used for all patients, with identical brands and specifications across the three strategies; the only differences were in cannulation sites and the number of cannulae, according to the ACP strategy. For cardiopulmonary bypass (CPB): uACP group: cannulation of the right axillary artery and right atrium (Fig. 1B). bACP group: cannulation of the brachiocephalic trunk (via end-to-end anastomosis with a vascular graft) and right atrium (Fig. 1C). tACP group: cannulation of the ascending aorta and right atrium (Fig. 1D). A left heart drainage tube was inserted via the right superior pulmonary vein. After inducing ventricular fibrillation and clamping the distal ascending aorta, the ascending aorta was incised longitudinally. Cardioplegia was administered through the coronary ostia, and the ascending aorta was resected. Depending on findings, Bentall/David procedures or proximal aortic repairs with graft anastomosis were performed. Once nasopharyngeal temperature reached 25 °C, the supra-aortic vessels were clamped: uACP: unilateral ACP through the right axillary artery. bACP: bilateral ACP via an additional cannula in the left common carotid artery. tACP: total ACP via additional cannulae in both the left common carotid and left subclavian arteries. Lower-body circulation was arrested, and the aortic arch was excised. A stented elephant trunk prosthesis (MicroPort CRONUS, Shanghai, China) was deployed proximally in the descending aorta, followed by distal anastomosis with a four-branch graft (W. L. Gore & Associates, Newark, DE, USA). Lower-body perfusion was restored, and proximal anastomosis was completed. After thorough de-airing, CPB was gradually weaned as rewarming continued to 36 °C. Sequential anastomoses of the left subclavian artery, left common carotid artery, and brachiocephalic trunk were performed (Fig. 1E). Hemostasis was achieved, drainage tubes were placed, and the chest was closed.

Statistical Analysis

All statistical analyses were performed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA). Continuous variables were tested for normality and homogeneity of variance. Normally distributed data were compared using one-way analysis of variance (ANOVA), with Welch's correction applied when variance was unequal. Non-normally distributed data were expressed as a median (interquartile range) and analyzed using the Kruskal–Wallis rank-sum test. For variables showing significant differences among the three groups ($p < 0.05$), pairwise comparisons were performed using the Mann–Whitney U test with Bonferroni correction. Categorical variables were compared using the chi-square test or Fisher's exact test as appropriate. In case of significant overall group differences, post hoc pairwise comparisons were also adjusted using the Bonferroni correction. A two-tailed p-value < 0.05 was considered statistically significant.

Results

Preoperative Baseline Characteristics

No statistically significant differences were observed among the three groups in terms of sex, age, smoking history, hypertension, diabetes mellitus, coronary artery disease, pericardial tamponade, or renal failure ($p > 0.05$), suggesting that the baseline characteristics were well-matched across groups (Table 1).

Intraoperative Data

In this study, significant differences were observed among the three cerebral perfusion strategies for surgery-related time intervals (Table 2). Specifically, the cardiopulmonary bypass time in the tACP group—224 (201–251) minutes—was significantly shorter than that in the bACP group—240 (220–275) minutes ($\chi^2 = 11.408$, $p = 0.003$). Lower-body circulatory arrest time was significantly shorter in the bACP group [28 (21–31.5) minutes] compared to the uACP [30.5 (27.5–33.5) minutes] and tACP [31 (27–34) minutes] groups ($\chi^2 = 11.937$, $p = 0.003$). Selective cerebral perfusion time was also significantly shorter in the bACP group—30 (23–33.5) minutes—than in the uACP [32.5 (29.5–35.5) minutes] or tACP [36 (31–38) minutes] groups ($\chi^2 = 24.593$, $p < 0.001$). In addition, the lowest nasopharyngeal temperature was significantly higher in the tACP group [24.8 (24.3–25.4) °C] than in the other two groups [uACP: 23.7 (23.4–24) °C, bACP: 24.05 (23.5–24.6) °C; $\chi^2 = 65.913$, $p < 0.001$]. No statistically significant differences were found among the three groups with respect to the surgical procedure ($\chi^2 = 0.657$, $p = 0.982$) or the time from symptom onset to surgery ($\chi^2 = 4.203$, $p = 0.122$).

Postoperative Data

Owing to the exclusion of patients who died intraoperatively or shortly after surgery, the number of patients included in the postoperative complication analysis was slightly lower than the total number in each group (Table 3). The postoperative awakening time was significantly shorter in the tACP group—185 (120–295) minutes—than in the uACP [380 (305–472.5) minutes] and bACP [257.5 (170–417.5) minutes] groups ($\chi^2 = 24.044$, $p < 0.001$). Tracheal intubation time was also significantly shorter in the tACP group—18 (14.7–42.5) minutes—than in the uACP [37.65 (24.25–58.9) minutes] or bACP [26.45 (19.45–52.6) minutes] groups ($\chi^2 = 19.168$, $p < 0.001$). The tACP group similarly showed a significantly shorter ICU stay [4.7 (3.8–6) days] compared to the uACP [7.10 (5.7–8) days] and bACP [6.30 (4.85–7.55) days] groups ($\chi^2 = 29.967$, $p < 0.001$). No significant difference was found among the three groups in overall postoperative hospitalization time ($\chi^2 = 5.375$, $p = 0.068$). Regarding neurological outcomes, the incidence of TND was highest in the uACP group [37.5% (9/24)], intermediate in the bACP group [18.2% (14/77)], and lowest in the tACP group [10.6% (9/85)], with a statistically significant difference among groups ($\chi^2 = 8.588$, $p = 0.014$). Further analysis revealed that the TND rate in the uACP group was significantly higher than in the other two groups. The incidence of permanent neurological dysfunction (PND) showed no statistically significant difference among the groups [uACP 12.5% (3/24); bACP 28.6% (22/77); tACP 17.7% (15/85); $\chi^2 = 4.180$, $p = 0.124$]. Additionally, there were no significant intergroup differences in paraplegia [uACP 12.5% (3/24); bACP 1.3% (1/77); tACP 4.7% (4/85), $\chi^2 = 5.157$, $p = 0.076$], rethoracotomy [uACP 4.2% (1/24); bACP 3.9% (3/77); tACP 4.7% (4/85), $\chi^2 = 0.066$, $p = 0.968$], renal failure [uACP 20.8% (5/24); bACP 5.2% (4/77); tACP 7.1% (6/85), $\chi^2 = 4.898$, $p = 0.086$], or wound infection [uACP 4.2% (1/24); bACP 10.4% (8/77); tACP 5.9% (5/85), $\chi^2 = 1.632$, $p = 0.442$]. The mortality rates among groups were also comparable [uACP 14.3% (4/28); bACP 11.5% (10/87); tACP 7.6% (7/92), $\chi^2 = 1.345$, $p = 0.510$].

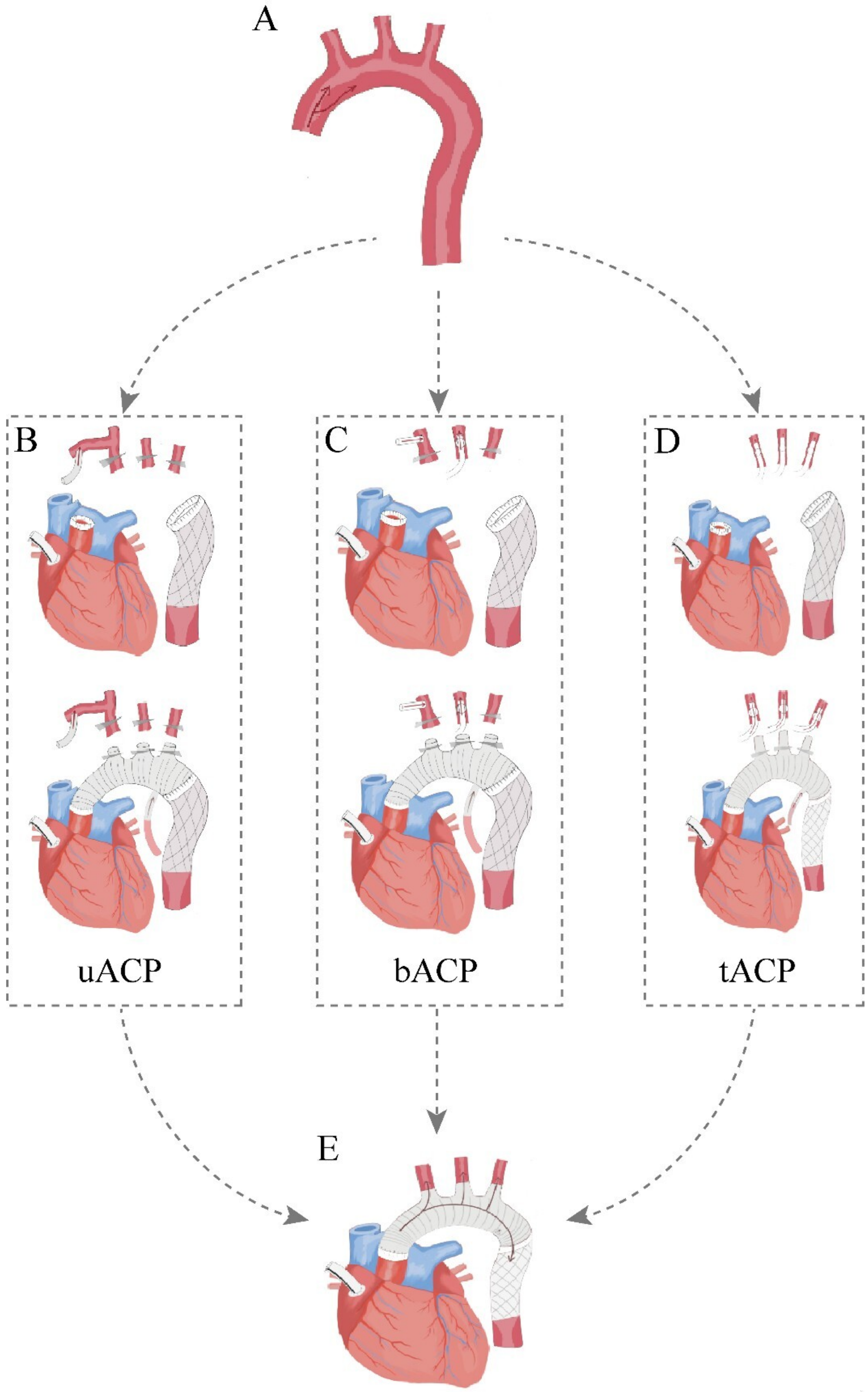

Fig. 1. Schematic diagram of the surgical procedure. (A) Acute DeBakey type I aortic dissection. (B) uACP: cerebral perfusion and arch reconstruction via the axillary artery alone. (C) bACP: cannulation of the brachiocephalic trunk and left common carotid artery to maintain bilateral cerebral perfusion and perform arch reconstruction. (D) tACP: cannulation of the brachiocephalic trunk, left common carotid artery, and left subclavian artery for cerebral perfusion and arch reconstruction. (E) Completion of ascending aorta replacement, total arch replacement, and stented graft implantation. uACP, unilateral antegrade cerebral perfusion; bACP, bilateral antegrade cerebral perfusion; tACP, total antegrade cerebral perfusion.

Table 1. Preoperative baseline characteristics.

Variable	Category	uACP Group (n = 28)	bACP Group (n = 87)	tACP Group (n = 92)	χ^2/F	p
Sex (n, %)	Female	4 (14.3%)	17 (19.5%)	13 (14.1%)	1.051	0.575
	Male	24 (85.7%)	70 (80.5%)	79 (85.9%)		
Age ($\bar{x} \pm$ S)	-	49.96 ± 9.22	53.41 ± 9.82	51.08 ± 11.47	1.657	0.193
Smoking (n, %)	No	17 (60.7%)	66 (75.9%)	60 (65.2%)	3.434	0.180
	Yes	11 (39.2%)	21 (24.1%)	32 (34.8%)		
Hypertension (n, %)	No	3 (10.7%)	19 (21.8%)	21 (22.8%)	2.017	0.365
	Yes	25 (89.3%)	68 (78.2%)	71 (77.2%)		
Diabetes (n, %)	No	25 (89.3%)	85 (97.7%)	89 (96.7%)	3.186	0.203
	Yes	3 (10.7%)	2 (2.3%)	3 (3.3%)		
Coronary artery disease (n, %)	No	27 (96.4%)	79 (90.8%)	79 (85.9%)	3.208	0.201
	Yes	1 (3.6%)	8 (9.2%)	13 (14.1%)		
Pericardial tamponade (n, %)	No	24 (85.7%)	79 (90.8%)	75 (81.5%)	3.280	0.194
	Yes	4 (14.3%)	8 (9.2%)	17 (18.5%)		
Renal failure (n, %)	No	27 (96.4%)	86 (98.9%)	86 (93.5%)	3.830	0.147
	Yes	1 (3.6%)	1 (1.2%)	6 (6.5%)		

Table 2. Intraoperative data.

Variable	Category	uACP Group	bACP Group	tACP Group	χ^2/H	p
Surgical approach (n, %)	Ascending Aorta + Sun's	22 (78.6%)	69 (79.3%)	70 (76.1%)	0.657	0.982
	Bentall + Sun's	5 (17.9%)	15 (17.2%)	19 (20.7%)		
	David + Sun's	1 (3.6%)	3 (3.5%)	3 (3.3%)		
Symptom onset to surgery (h)	-	37.50 (28–70.5)	32.50 (21–53)	28.00 (19–45)	4.203	0.122
CPB time (min)	-	230.00 (212.5–264)	240.00 (220–275)	224.00 (201–251)	11.408	0.003*
Aortic cross-clamp time (min)	-	145.00 (119.5–168.5)	142.50 (123.5–162)	142.00 (123–157)	0.749	0.688
Lower-body arrest time (min)	-	30.50 (27.5–33.5)	28.00 (21–31.5)	31.00 (27–34)	11.937	0.003*
Selective cerebral perfusion time (min)	-	32.50 (29.5–35.5)	30.00 (23–33.5)	36.00 (31–38)	24.593	<0.001*
Lowest nasopharyngeal temperature (°C)	-	23.70 (23.4–24)	24.05 (23.5–24.6)	24.80 (24.3–25.4)	65.913	<0.001*

Notes: The symbol (*) denotes statistical significance at the level of $p < 0.05$. CPB, cardiopulmonary bypass.

Pairwise Comparisons

Table 4 presents the results of post hoc pairwise comparisons among the three ACP groups for variables with significant overall differences. Compared with the bACP group, the tACP group was associated with a significantly shorter CPB time ($p = 0.002$) and lower-body circulatory arrest time ($p = 0.005$). The selective cerebral perfusion time was significantly shorter in the tACP group compared to the bACP group ($p < 0.001$). The tACP group also exhibited a significantly higher lowest nasopharyngeal temperature than both the uACP and bACP groups ($p < 0.001$ for both comparisons). Postoperative awakening time was significantly shorter in the tACP group compared to both the uACP ($p < 0.001$) and bACP ($p = 0.006$) groups. Similarly, the tACP group had a shorter tracheal intubation time and ICU stay than the bACP group ($p < 0.001$ for both comparisons). In terms of neurological outcomes, the incidence of TND was significantly lower in the tACP group compared to the uACP group ($p = 0.012$), while no significant difference was observed between the uACP and bACP groups ($p = 0.171$).

Discussion

With the continual advancement of surgical techniques, the mortality rate associated with acute DeBakey type I aortic dissection has been effectively controlled. Nonetheless, the overall incidence of perioperative complications remains high [13,14], particularly neurological complications, which markedly affect patients' quality of life [15]. Notably, TND and PND are regarded as pivotal metrics for assessing the efficacy of cerebral protection in aortic surgery [10,16]. By comparing uACP, bACP, and tACP in DeBakey I procedures, the present study demon-

Table 3. Postoperative outcomes.

Variable	Category	uACP Group	bACP Group	tACP Group	χ^2/H	*p*
Postoperative awakening time (min)	-	380.00 (305–472.5)	257.50 (170–417.5)	185.00 (120–295)	24.044	<0.001*
Tracheal intubation time (min)	-	37.65 (24.25–58.9)	26.45 (19.45–52.6)	18.00 (14.7–42.5)	19.168	<0.001*
ICU stay (days)	-	7.10 (5.7–8)	6.30 (4.85–7.55)	4.70 (3.8–6)	29.967	<0.001*
Total hospital stay (days)	-	26.65 (24.55–29)	26.20 (21.35–29.95)	22.60 (18.5–29.5)	5.375	0.068
PND (n, %)	No	21 (87.5%)	55 (71.4%)	70 (82.4%)	4.180	0.124
	Yes	3 (12.5%)	22 (28.6%)	15 (17.7%)		
TND (n, %)	No	15 (62.5%)	63 (81.8%)	76 (89.4%)	8.588	0.014*
	Yes	9 (37.5%)	14 (18.2%)	9 (10.6%)		
Paraplegia (n, %)	No	21 (87.5%)	79 (98.8%)	81 (95.3%)	5.157	0.076
	Yes	3 (12.5%)	1 (1.3%)	4 (4.71%)		
Re-thoracotomy (n, %)	No	23 (95.8%)	74 (96.1%)	81 (95.3%)	0.066	0.968
	Yes	1 (4.2%)	3 (3.9%)	4 (4.7%)		
Renal failure (n, %)	No	19 (79.2%)	73 (94.8%)	79 (92.9%)	4.898	0.086
	Yes	5 (20.8%)	4 (5.2%)	6 (7.1%)		
Wound infection (n, %)	No	23 (95.8%)	69 (89.6%)	80 (94.1%)	1.632	0.442
	Yes	1 (4.17%)	8 (10.4%)	5 (5.9%)		
Mortality (n, %)	No	24 (85.7%)	77 (88.5%)	85 (92.4%)	1.345	0.510
	Yes	4 (14.3%)	10 (11.5%)	7 (7.6%)		

Notes: The symbol (*) denotes statistical significance at the level of $p < 0.05$. ICU, intensive care unit; PND, permanent neurological dysfunction; TND, transient neurological dysfunction.

Table 4. Post hoc Pairwise Comparisons between ACP Groups.

Variable	uACP vs bACP	uACP vs tACP	bACP vs tACP
CPB time (min)	1.000	0.471	0.002*
Lower-body arrest time (min)	0.051	1.000	0.005*
Selective cerebral perfusion time (min)	0.051	0.538	<0.001*
Lowest nasopharyngeal temperature (°C)	0.043*	<0.001*	<0.001*
Postoperative awakening time (min)	0.042*	<0.001*	0.006*
Tracheal intubation time (hours)	0.737	0.005*	<0.001*
ICU stay (days)	0.180	<0.001*	<0.001*
TND	0.171	0.012*	0.550

Notes: * indicates a significant difference between the two groups. ACP, antegrade cerebral perfusion.

strated marked differences in intraoperative cerebral protection and perioperative complications. In particular, tACP achieved superior outcomes in terms of neuroprotection, awakening time, tracheal intubation duration, and ICU stay. Meanwhile, bACP showed intermediate performance regarding lower-body circulatory arrest time, TND incidence, and ICU stay; the TND rate in uACP exceeded that of the other two strategies. The following discussion interprets these findings from multiple perspectives.

Cerebral Perfusion Strategies and Neurological Protection

In the tACP group, the TND rate was 10.6%, which is significantly lower than the 37.5% observed with uACP ($p < 0.05$). This indicates that perfusing the entire brain can provide a more stable blood supply, thereby reducing transient cerebral ischemia caused by uneven perfusion or insufficient collateral circulation. In addition, the tACP group's higher minimum nasopharyngeal temperature (24.8 [24.3–25.4] °C) suggests that this strategy can maintain cerebral metabolic rates closer to physiological levels. By ensuring adequate blood flow to both hemispheres and the posterior circulation, tACP shortens the duration of deep hypothermic circulatory arrest [17], delivers more balanced cerebral perfusion, and reduces the risk of embolism and vasospasm, thus lowering postoperative complications. In contrast, the notably higher TND incidence in the uACP group underscores the limitations of unilateral perfusion when dealing with extensive arch disease that demands bilateral hemispheric and posterior circulation support. Contributing factors may include: (1) uneven blood-flow distribution—particularly in cases involving a broad surgical field, prolonged circulatory arrest, or congenital cerebrovascular abnormalities (e.g., incomplete Willis circle, insufficient vertebral artery flow) [18]; (2) high procedural complexity with heavy reliance on collateral circulation—because uACP typically involves cannulation via the right axillary artery, inadvertent cannula malposition or luminal stenosis can rapidly exacerbate local ischemia; (3) an inability to match metabolic demand with blood supply if the uACP flow is not promptly adjusted when operating times are extended. Accordingly, for patients with more extensive lesions or more complex procedures, unilateral perfusion may be less optimal for cerebral protection.

Operative Time and Circulatory Arrest Considerations

The bACP group had a shorter lower-body arrest time than the other two groups ($p < 0.05$), a finding that likely reflects variations in distal anastomosis difficulty or team coordination rather than a standardized difference in surgical protocol. Although tACP requires separate cannulation of the brachiocephalic trunk, left common carotid artery, and left subclavian artery—rendering it more complex than uACP or bACP—tACP still yielded superior results in awakening time, ICU stay, and TND incidence. This suggests that simultaneously prioritizing both cerebral and systemic circulation via three-vessel arch cannulation may confer more physiologically beneficial blood flow, which likely contributes to improved postoperative recovery. Moreover, tACP was associated with a relatively shorter cardiopulmonary bypass time, perhaps reflecting the team's increasing technical proficiency and enhanced collaboration. Overall, bACP and tACP each showed certain advantages in lower-body arrest duration, neurological protection, and complication rates; however, tACP appears promising for comprehensive neuroprotection and expedited recovery.

Impact of Perfusion Strategies on Complications

No significant differences emerged among the three groups in terms of PND, paraplegia, renal failure, rethoracotomy, wound infection, or mortality. Nonetheless, the uACP group exhibited rising trends in TND (37.5%) and renal failure (20.8%), possibly reflecting an incomplete Willis circle or less experienced teamwork. Of particular note, the tACP group achieved overall superior surgical outcomes, especially concerning neurological parameters, further corroborating the benefits of three-vessel perfusion in aligning with normal physiology [19]. Some studies report no clear differences between uACP and bACP in reducing perioperative complications [20], but when the arch lesion is extensive and severely involves supra-aortic vessels, even bilateral perfusion may be insufficient to meet perfusion demands for all cerebral regions. In such high-risk or prolonged circulatory arrest scenarios, tACP's comprehensive coverage offers a distinct advantage and is often recommended in clinical practice.

Clinical Applications and Strategy Selection

uACP remains a classic antegrade perfusion strategy when the three supra-aortic branches are relatively unaffected. By contrast, bACP expands the perfusion field and is thus more appropriate for scenarios involving prolonged circulatory arrest, extensive arch lesions, or cerebrovascular anomalies (e.g., an incomplete circle of Willis), thereby reducing the risk of localized ischemia to some extent. tACP requires separate cannulation of the brachiocephalic trunk, left common carotid artery, and left subclavian artery, delivering blood flow to the entire brain and covering posterior circulation and bilateral "blind spots". In this study, all three groups shared a target nasopharyngeal temperature of approximately 24 °C, and no deliberate temperature differentiation was applied across the various strategies. The slightly higher minimum temperature observed in the tACP group (24.8 °C) primarily resulted from minor fluctuations in cardiopulmonary bypass management—such as perfusion flow rate, rewarming speed, and monitoring location. The tACP group successfully underwent surgery at a relatively higher minimum nasopharyngeal temperature (24.8 [24.3–25.4] °C). Several investigations have explored the feasibility of continuous cerebral perfusion at higher temperatures [21–23], which may better reconcile neuroprotection with systemic organ perfusion and mitigate the inflammatory response, coagulopathy, and metabolic dysregulation associated with deep hypothermia. Overall, tACP affords more pronounced advantages in neuroprotection, perioperative recovery, and control of postoperative complications, but imposes higher demands on surgical expertise and intraoperative monitoring (including precise cannula placement, flow regulation, and cerebral oxygenation assessment). For high-risk patients, complex arch reconstructions, or anticipated prolonged circulatory arrest, tACP is indisputably more valuable and clinically applicable.

Limitations and Future Directions

This single-center retrospective analysis involved a relatively limited sample size, particularly in the uACP group (n = 28), which may introduce selection bias and affect the precision of estimated differences (potentially overestimating the observed TND disparity). Additionally, because each perfusion strategy was implemented in a different time period, there is an inherent risk of "time bias", as surgical technique and perioperative management could improve over the years. We mitigated this by using the same surgical team and standardized protocols throughout the study period, and by confirming that baseline characteristics were balanced; however, subtle temporal improvements cannot be entirely excluded. Further multicenter, large-scale prospective randomized trials are warranted to validate tACP's advantages and identify optimal patient candidates. Moreover, this study focused on perioperative outcomes and did not include long-term follow-up data on neurological function, survival, or quality of life—an important limitation. We have established a postoperative follow-up database and are actively collecting these long-term data, which will be reported in future studies to provide a more comprehensive evaluation of each ACP strategy's clinical value. Finally, we did not perform a multivariable analysis adjusting for confounders (such as year of surgery or patient risk factors) since perfusion strategy was the primary grouping factor and baseline data were comparable. Future research with larger cohorts should consider incorporating such analyses (for example, including the surgical era as a covariate or using propensity score matching) to confirm that the observed benefits of tACP are independent of other variables.

Conclusion

In conclusion, tACP yielded more prominent neuroprotective effects compared with other antegrade cerebral perfusion strategies in acute DeBakey type I aortic dissection. It not only reduced the incidence of TND but also shortened awakening and extubation times, as well as ICU stays. When the arch lesion is extensive or the procedure is more technically demanding, tACP appears to offer greater cerebral protection.

Availability of Data and Materials

The datasets used in this study are available from the corresponding author upon reasonable request.

Author Contributions

JZC conducted data collection, data analysis, result interpretation, and manuscript preparation. JL, YGF, JHX, and CEL contributed to the study's conception, design, and manuscript drafting. ZWL contributed to the overall conceptualization and design. All authors participated in revising the manuscript, approved the final version, and agreed to be accountable for all aspects of the work to ensure its accuracy and integrity.

Ethics Approval and Consent to Participate

This retrospective analysis was conducted in accordance with the ethical principles of the Declaration of Helsinki. The study protocol was approved by the Ethics Committee of The First Affiliated Hospital of Hengyang Medical School, University of South China (Ethical Approval Code: 2024LL1226001). Written informed consent was obtained from all patients preoperatively. Patient data were anonymized to ensure confidentiality and protect privacy.

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Conflict of Interest

The authors declare no conflict of interest.

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