Bilateral versus unilateral antegrade cerebral perfusion in total arch replacement for type A aortic dissection

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ABSTRACT

Background: Antegrade cerebral perfusion (ACP) is the most widely used cerebral protection strategy for complex aortic repair and includes unilateral (u-ACP) and bilateral (b-ACP) techniques. The superiority of b-ACP over u-ACP has been the subject of much debate. Focusing on type A aortic dissection requiring total arch replacement, we investigated the clinical effects of b-ACP versus u-ACP.

Methods: Between September 2006 and August 2014, 203 patients presenting with type A aortic dissection (median age, 51.0 ± 13 years; range, 17-72 years; 128 males) underwent total aortic arch replacement with hypothermic circulatory arrest. ACP was used in all patients, including u-ACP in 82 (40.3%) and b-ACP in 121 (59.7%).

Results: There was no significant difference between the u-ACP and b-ACP groups in terms of cardiopulmonary bypass (CPB) time, cross-clamp time, or circulatory arrest time. Overall 30-day mortality was comparable in the 2 groups (11.6% for b-ACP vs 20.7% for u-ACP; $P = .075$). The prevalence of postoperative permanent neurologic dysfunction (PND) was comparable as well (8.4% vs 16.9%; $P = .091$). Mean ventilation time was lower in the b-ACP group (95.5 ± 45.25 hours vs 147.0 ± 82 hours; $P < .001$). Mean lengths of stay in the intensive care unit and the hospital overall were comparable in the 2 groups (intensive care unit: 16 ± 17.75 days vs 17 ± 11.5 days, $P = .454$; hospital: 26.5 ± 20.6 days vs 24.8 ± 10.3 days, $P = .434$). The P values from logistic regression models indicated that in the 2 groups combined, CPB time and circulatory arrest time were independent risk factors for both mortality and PND.

Conclusions: In this, the first published study focusing on the efficacy of u-ACP and b-ACP in total arch replacement for type A aortic dissection, the b-ACP group did not demonstrate significantly lower 30-day mortality or PND rate compared with the u-ACP group. Future large-sample studies are warranted to thoroughly examine this critical issue. (*J Thorac Cardiovasc Surg* 2017;154:767-75)

Thirty-day mortality and PND in the u-ACP and b-ACP groups.

Central Message

In this study of unilateral antegrade cerebral perfusion (u-ACP) and bilateral antegrade cerebral perfusion (b-ACP) in total arch replacement for type A aortic dissection, clinical outcomes of u-ACP and b-ACP groups were compared.

Perspective

In this study comparing unilateral antegrade cerebral perfusion (u-ACP) and bilateral antegrade cerebral perfusion (b-ACP) in total arch replacement for type A aortic dissection, the b-ACP group did not exhibit significantly reduced mortality or permanent neurologic dysfunction. b-ACP did not prolong CPB, cardiac arrest, or circulatory arrest time. Future large-sample, randomized, multicenter studies are warranted to thoroughly compare b-ACP and u-ACP.

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Abbreviations and Acronyms

ACP	= antegrade cerebral perfusion
b-ACP	= bilateral antegrade cerebral perfusion
CABG	= coronary artery bypass grafting
COPD	= chronic obstructive pulmonary disease
CPB	= cardiopulmonary bypass
CT	= computed tomography
GERAADA	= German Registry for Acute Aortic Dissection Type A
IRAD	= International Registry of Aortic Dissection
MRI	= magnetic resonance imaging
PND	= permanent neurologic dysfunction
SET	= stented elephant trunk
TND	= temporary neurologic dysfunction
u-ACP	= unilateral antegrade cerebral perfusion

Scanning this QR code will take you to a procedural video.

Despite advances in surgical therapy, operative mortality for type A aortic dissection remains high.¹ Neurologic dysfunction is a common complication of open aortic arch reconstructive surgery, with a reported incidence ranging from 5.5% to 33.3%.² Hypothermia with adjunctive antegrade cerebral perfusion (ACP) has been shown to improve outcomes and reduce neurologic complications and being increasingly used in surgery to reconstruct the aortic arch.^{2,3} The superiority of unilateral ACP (u-ACP) over bilateral ACP (b-ACP) has been a subject of debate for years^{4,5}; however, to date only a few published studies have focused on the effects of different cerebral perfusion strategies in type A aortic dissection.^{5,6} Total arch replacement, the most radical repair strategy, is indicated in some patients with type A aortic dissection ranging from 5% to 53%, depending on differences in patient demographics and management strategies.⁷⁻⁹ Up to now, the use of u-ACP versus b-ACP has not been studied specifically in patients with type A aortic dissection requiring total arch replacement.

The aims of the present study were to report our clinical experience of selective cerebral perfusion for total arch replacement for type A aortic dissection, and to compare the protective effects of b-ACP and u-ACP in combination with hypothermic circulatory arrest.

PATIENTS AND METHODS

Between September 2006 and June 2014, a total of 203 patients with type A dissection underwent total arch replacement at Guangzhou General Military Hospital (Guangzhou, China) were enrolled into this study. Of all 351 patients with type A aortic dissection, total arch replacement was performed if 1 of the following was shown on computed tomography (CT) angiography: arch tear (primary or secondary tear), carotid dissection or occlusion, circumferential arch dissection, or aneurysmal arch. Ascending aorta or hemiarch replacement was performed when total arch replacement was not indicated.

Data were collected from a prospectively maintained database. The study protocol was approved by the Committee for the Protection of Human Subjects at the Guangzhou General Hospital of Guangzhou Military Command. Because this was a retrospective study, the requirement for informed consent was waived. All patients who underwent total arch replacement received ACP, including 82 (40.4%) in the u-ACP group and 121 (59.6%) in the b-ACP group. Further characteristic and preoperative data are summarized in [Table 1](#). The concomitant procedures in the 2 groups are compared in [Table 2](#).

Surgical Technique

Our surgical technique for type A aortic dissection included total cardiopulmonary bypass (CPB), moderate hypothermia, circulatory arrest, and u-ACP or b-ACP. Monitoring included central venous pressure, bilateral radial artery pressure, 5-lead electrocardiography, nasopharyngeal and rectal temperature, and intermittent arterial blood gas analysis. Cerebral saturation was monitored using near-infrared spectroscopy (NIRO 300; Hamamatsu Phototonics, Hamamatsu, Japan). Systolic arterial blood pressure was maintained around 70 to 80 mmHg intraoperatively. The nasopharyngeal temperature at the start of circulatory arrest was 24°C at the beginning of the study period and increased gradually to 26°C. The remaining strategies remained largely constant during the study period. Before September 2009, u-ACP combined with hypothermic circulatory arrest was used for cerebral protection. In September 2009, b-ACP combined with hypothermic circulatory arrest was initiated, and both techniques were used from that point until the end of the study period. Right axillary artery cannulation was performed for CPB.

In the b-ACP group, cerebral perfusion was performed through the right axillary artery and the left common carotid artery. After initiation of CPB and patient cooling, the left common carotid artery was cross-clamped and transected, and anastomosis to the 4-branched graft (Boston Scientific, Boston, Mass) was performed. The left hemisphere was perfused via the 4-branched graft connected to a branch of the arterial pump. When the temperature reached 30°C, the ascending aorta was cross-clamped, the proximal ascending aorta was opened longitudinally, and cold-blood cardioplegic solution was infused directly into the coronary ostia. When the nasopharyngeal temperature reached 24°C to 26°C, circulatory arrest was initiated by clamping the proximal innominate artery and the left subclavian artery. Flows used for ACP were 10 to 15 mL/kg/min, with perfusion pressures of 40 to 50 mm Hg. Stented elephant trunk (SET; MicroPort Medical Co Ltd, Shanghai, China), which has been shown to reduce the need for reintervention while adding little operative time,^{10,11} was routinely inserted into the proximal descending aorta. The distal end of the graft was firmly attached to the descending aorta, incorporating the SET. Systemic circulation was restarted via the perfusion limb of the 4-branch prosthetic graft. The indicated aortic root procedure was performed, followed by anastomosis of the aortic root to the prosthetic graft. Finally, anastomoses of the innominate artery and left subclavian artery to the 4-branched prosthetic graft were performed ([Video 1](#)).

In the u-ACP group, right axillary artery cannulation was performed for CPB and u-ACP. After cross-clamping of the ascending aorta, the indicated aortic root procedure was performed. When the nasopharyngeal temperature reached 24°C to 26°C, circulatory arrest was initiated by clamping the proximal innominate artery, the left common carotid artery, and the left

TABLE 1. Preoperative characteristics

Characteristic	Total (n = 203)	u-ACP (n = 82)	b-ACP (n = 121)	P value
Age (y), mean $\pm$ SD	51.0 $\pm$ 13	53 $\pm$ 14	47 $\pm$ 12.75	.205
Months to start of cohort, mean $\pm$ SD	43 $\pm$ 29	42 $\pm$ 32	44 $\pm$ 27.5	.208
Males, n (%)	128 (63.1)	55 (67.1)	73 (60.3)	.329
Females, n (%)	75 (36.9)	27 (32.9)	48 (39.7)	.436
Hypertension, n (%)	174 (85.7)	74 (90.2)	100 (82.6)	.129
Diabetes mellitus, n (%)	64 (31.5)	25 (30.5)	39 (32.2)	.793
Smoking, n (%)	109 (53.7)	44 (53.7)	65 (53.7)	.993
Previous CVA, n (%)	3 (1.5)	2 (2.4)	1 (0.8)	.350
Peripheral vascular disease, n (%)	14 (6.1)	7 (8.5)	7 (5.8)	.448
Renal dysfunction, n (%) [*]	25 (12.3)	10 (12.2)	15 (12.4)	.966
COPD, n (%)	3 (1.5)	2 (2.4)	1 (0.8)	.350
Marfan syndrome, n (%)	13 (6.4)	5 (6.1)	8 (6.6)	.883
Bicuspid aortic valve, n (%)	8 (3.9)	3 (3.7)	5 (4.1)	.865
Dissection <24 h, n (%)	135 (66.5)	54 (65.9)	81 (66.9)	.812
Dissection >24 h, n (%)	68 (33.5)	28 (34.1)	40 (33.1)	.945
Preoperative neurologic complications, n (%)	11 (5.4)	4 (4.9)	5 (5.8)	.779
Pericardial effusion/tamponade, n (%)	28 (13.8)	11 (13.4)	17 (14.0)	.898
Hemodynamic instability, n (%)	12 (5.9)	5 (6.1)	7 (5.8)	.926
Intubated on arrival, n (%)	16 (7.9)	7 (8.5)	9 (7.4)	.776

u-ACP, Unilateral antegrade cerebral perfusion; b-ACP, bilateral antegrade cerebral perfusion; SD, standard deviation; CVA, cerebrovascular accident; COPD, chronic obstructive pulmonary disease. ^{*}A serum creatinine level >2.0 mg/mL is considered to indicate renal dysfunction.

subclavian artery. The SET was inserted, and the sequence of anastomosis to the prosthetic graft was as follows: descending aorta, left common carotid artery, proximal aortic stump, innominate artery, and left subclavian artery.

Statistical Analysis

The outcome measures were 30-day mortality, permanent neurologic dysfunction (PND), temporary neurologic dysfunction (TND), renal failure, tracheostomy, and readmission to the operating room for bleeding and mediastinal infection. TND was defined as the presence of reversible postoperative confusion, agitation, transient delirium or motor deficit with normal findings on CT scan and resolution of all symptoms before discharge. PND was defined as the presence of new focal (stroke) or global (coma) permanent neurologic dysfunction and confirmed by CT or MRI. Pearson's χ^2 test was used for dichotomous variables. Normally distributed continuous variables were presented as mean $\pm$ standard deviation and compared with Student's *t* test. Non-normally distributed data was displayed as median $\pm$ interquartile range and compared using the Mann-Whitney *U* test. Blood product utilization was broken down to groups and compared with rank-sum test. The significance level was set at *P* < .05. Major perioperative characteristics and outcomes of those operated within 24 hours after onset of symptom were compared separately. To predict the probabilities of mortality, we performed bivariate logistic regressions using potential covariates of interest including age, female gender, renal dysfunctions, COPD, time at surgery to the start of cohort, acute type A dissection, pericardial effusion/tamponade, hemodynamic instability, CABG, type of cerebral perfusion, CPB time, cross-clamp time, and circulatory arrest time.^{5,12-16} For PND, potential covariates of

interest included age, acute type A dissection, hemodynamic instability, time to start of the cohort, type of cerebral perfusion, CPB time, cross-clamp time, and circulatory arrest time. Potential covariates of interest, including age, acute type A dissection, time to start of cohort, type of cerebral perfusion, preoperative renal dysfunction, CPB time, cross-clamp time, and circulatory arrest time, were used for predicting the probability of postoperative renal failure. In addition, multivariate logistic regression analysis was performed to further identify independent predictors of adverse outcomes. Variables with a *P* value < .10 in bivariate analysis were included in forward multivariate logistic regression models. Statistical analyses were performed using SPSS 22.0 (IBM, Armonk, NY).

RESULTS

Intraoperative Data

Table 2 presents concomitant procedures in the u-ACP and b-ACP groups. Rates of use of concomitant SET, Bentall operation, Valsalva sinus reconstruction, aortic valve resuspension, and coronary artery bypass grafting were not significantly different in the 2 groups.

As shown in Table 3, there were no significant differences in CPB time, cross-clamp time, circulatory arrest time, intensive care unit time, in-hospital time, packed red blood cell transfusion, serum transfusion, nasopharyngeal temperature, and rectal temperature between the u-ACP and

TABLE 2. Surgical strategies

Variable	Total (n = 203)	u-ACP (n = 82)	b-ACP (n = 121)	P value
SET, n (%)	199 (98.0)	80 (97.6)	119 (98.3)	1.000
Bentall operation, n (%)	39 (19.2)	19 (23)	20 (16.2)	.239
Valvasa sinus reconstruction, n (%)	40 (19.7)	17 (20.3)	23 (19.0)	.762
Aortic valve resuspension, n (%)	10 (4.9)	4 (4.9)	6 (5.0)	1.000
Coronary artery bypass grafting, n (%)	25 (12.3)	11 (13.4)	14 (11.6)	.695

u-ACP, Unilateral antegrade cerebral perfusion; b-ACP, bilateral antegrade cerebral perfusion; SET, stented elephant trunk.

VIDEO 1. Total arch replacement using bilateral ACP. Right axillary artery and right atrium cannulation were performed for CPB. After initiation of CPB and patient cooling, the left common carotid artery was cross-clamped and transected, and the anastomosis to the 4-branched graft was performed. The left hemisphere was perfused via the 4-branched graft connected to a branch of the arterial pump. When temperature reached 30°C, the ascending aorta was cross-clamped, the proximal ascending aorta was opened longitudinally, and cold-blood cardioplegic solution was infused directly into the coronary ostia. When the nasopharyngeal temperature reached 24°C to 26°C, circulatory arrest was initiated by clamping the proximal innominate artery and the left subclavian artery. Flows used for ACP were 10 to 15 mL/kg/min, with perfusion pressures of 40 to 50 mm Hg. The SET, which has been shown to reduce need for reintervention with little additional operating time, was inserted into the proximal descending aorta. The distal end of the graft was firmly attached to the descending aorta, incorporating the SET. Systemic circulation was restarted via the perfusion limb of the 4-branch prosthetic graft. The indicated aortic root procedure was performed, followed by anastomosis of the aortic root to the prosthetic graft. Finally, anastomoses of the innominate artery and left subclavian artery to the 4-branched prosthetic graft were performed. Video available at: [http://www.jtcvsonline.org/article/S0022-5223\(17\)30415-4/addons](http://www.jtcvsonline.org/article/S0022-5223(17)30415-4/addons).

b-ACP groups. As shown in Table 4, concomitant procedures and major intraoperative data in patients who underwent surgery within 24 hours of symptom onset were also comparable in the 2 groups.

Mortality

Overall 30-day mortality was 20.7% for the u-ACP group and 11.6% for the b-ACP group ($P = .075$) (Figure 1, Table 5). In the u-ACP group, causes of death were multiple organ failure in 8 patients, sepsis in 4 patients, and low cardiac output syndrome in 5 patients. In the b-ACP group, causes of death were multiple organ failure in 7 patients, low cardiac output syndrome in 5 patients, and sepsis in 2 patients. In the bivariate logistic regression model, age, female sex, preoperative renal dysfunction, acute type A dissection, pericardial effusion/tamponade, CPB time, cross-clamp time, and circulatory arrest time were predictive of mortality (Table 6). Furthermore, multivariable regression identified CPB time and circulatory arrest time as independent predictors of mortality. For patients undergoing surgery within 24 hours after symptom onset, the mortality rate was 22.2% in the u-ACP group and 11.1% in the b-ACP group ($P = .081$) (Table 4).

Morbidities

Postoperative neurologic dysfunction was divided into TND and PND. TND was observed in 6 of 65 surviving patients (9.2%) in the u-ACP group and in 5 of 107 (4.7%) in the b-ACP group ($P = .236$). PND was observed in 11 of 65 patients (16.9%) in the u-ACP group and in 9 of 107 (8.4%) in the b-ACP group ($P = .091$) (Figure 1). Tracheostomy was performed in 11 of 65 patients (16.9%) in the u-ACP group and in 4 of 107 (3.7%) in the b-ACP group ($P = .003$). Ventilation times were longer in the u-ACP group. In the univariate logistic regression model, age, acute type A dissection, CPB time, and circulatory arrest time were predictive of PND (Table 6). Furthermore, multivariate logistic regression identified CPB time and circulatory arrest time as independent predictors of PND (Table 7). The rates of postoperative renal failure were comparable in

TABLE 3. Perioperative data

Variable	Total (n = 203)	u-ACP (n = 82)	b-ACP (n = 121)	P value
CPB time (min), mean $\pm$ SD	198 $\pm$ 53	200.0 $\pm$ 53.75	204 $\pm$ 42.5	.197
Cross-clamp time (min), mean $\pm$ SD	101 $\pm$ 36	103.0 $\pm$ 30.25	105.0 $\pm$ 31.5	.545
Circulatory arrest time (min), mean $\pm$ SD	24 $\pm$ 8	23.0 $\pm$ 9.25	24.0 $\pm$ 8.0	.893
Nasopharyngeal temperature (°C), mean $\pm$ SD	23.6 $\pm$ 1.1	23.7 $\pm$ 1.1	23.6 $\pm$ 1.1	.504
Rectal temperature (°C), mean $\pm$ SD	25.9 $\pm$ 1.3	25.9 $\pm$ 1.4	26.0 $\pm$ 1.3	.463
Transfused RBC units, n				.391
≤ 10	56	21	35	
11-20	76	38	38	
21-30	66	22	44	
> 30	5	1	2	
Transfused serum units, n				.840
≤ 5	2	1	1	
6-10	109	43	66	
11-15	85	33	52	

u-ACP, Unilateral antegrade cerebral perfusion; b-ACP, bilateral antegrade cerebral perfusion; CPB, cardiopulmonary bypass; SD, standard deviation; ICU, intensive care unit; RBC, red blood cell.

TABLE 4. Major preoperative characteristic, perioperative data, and outcomes of acute (<24 h) type A aortic dissection

Variable	Total (n = 135)	u-ACP (n = 54)	b-ACP (n = 81)	P value
Age (y), mean $\pm$ SD	47 $\pm$ 15	45 $\pm$ 15	51 $\pm$ 14	.196
Months to start of cohort, mean $\pm$ SD	43 $\pm$ 29.25	42 $\pm$ 33	44.5 $\pm$ 27.75	.377
Male, n (%)	93 (66.9)	36 (66.7)	57 (70.4)	.649
Female, n (%)	42 (31.1)	18 (33.3)	24 (29.6)	.756
Hypertension, n (%)	112 (82.9)	47 (87.0)	65 (80.2)	.304
Preoperative neurologic complications, n (%)	6 (4.4)	3 (5.6)	3 (3.7)	.683
Pericardial effusion/tamponade, n (%)	17 (12.6)	7 (12.9)	10 (12.3)	.916
Hemodynamic instability, n (%)	7 (5.2)	3 (5.6)	4 (4.9)	1.000
Intubated on arrival, n (%)	10 (7.4)	4 (7.4)	6 (7.4)	1.000
SET, n (%)	133 (98.5)	53 (98.1)	80 (98.8)	1.000
Bentall operation, n (%)	27 (20.0)	10 (18.5)	17 (20.9)	.725
Valvula sinus reconstruction, n (%)	25 (18.5)	9 (16.7)	16 (19.8)	.651
Aortic valve resuspension, n (%)	7 (5.2)	2 (3.7)	5 (6.2)	.702
Coronary artery bypass grafting, n (%)	17 (12.6)	6 (11.1)	11 (13.6)	.672
CPB time (min), mean $\pm$ SD	208.5 $\pm$ 29.6	210.7 $\pm$ 28.9	206.8 $\pm$ 30.1	.259
Cross-clamp time (min), mean $\pm$ SD	102 $\pm$ 32	108.5 $\pm$ 31.75	95 $\pm$ 25.5	.593
Circulatory arrest time (min), mean $\pm$ SD	24 $\pm$ 8	25 $\pm$ 6	23 $\pm$ 6	.171
Ventilation time (h), mean $\pm$ SD	105 $\pm$ 71	160.5 $\pm$ 88.5	100 $\pm$ 36	.001
ICU time (d), mean $\pm$ SD	16 $\pm$ 15	15.5 $\pm$ 13.5	16 $\pm$ 16.5	.570
In-hospital time (d), mean $\pm$ SD	25 $\pm$ 11	21.5 $\pm$ 13.5	27 $\pm$ 10	.503
Nasopharyngeal temperature ($^{\circ}$ C), mean $\pm$ SD	24 $\pm$ 3	23 $\pm$ 3	23 $\pm$ 1	.181
Rectal temperature ($^{\circ}$ C), mean $\pm$ SD	26 $\pm$ 2	26 $\pm$ 2	26 $\pm$ 2.5	.655
Transfused RBC units, n				.739
$\leq$ 10	30	11	19	
11-20	57	23	34	
21-30	33	13	20	
>30	15	7	8	
Transfused serum units, n				.493
$\leq$ 5	4	1	3	
6-10	73	31	42	
11-15	44	19	25	
>15	14	3	11	
30-d mortality, n (%)	21 (15.6)	12 (22.2)	9 (11.1)	.081
Paraplegia, n (%)	3 (2.2)	2 (3.7)	1 (1.2)	.564
TND, n (%)	7 (5.2)	3 (5.6)	4 (4.9)	1.000
PND, n (%)	17 (12.6)	9 (16.7)	8 (9.9)	.244
Renal failure, n (%)	23 (17.0)	11 (20.4)	12 (14.8)	.400
Tracheostomy, n (%)	10 (7.4)	5 (9.3)	3 (3.7)	.266
Redo for bleeding, n (%)	3 (2.2)	2 (3.7)	1 (1.2)	.564
Mediastinal infection, n (%)	5 (3.7)	3 (5.6)	2 (2.5)	.389

u-ACP, Unilateral antegrade cerebral perfusion; b-ACP, bilateral antegrade cerebral perfusion; SD, standard deviation; SET, stented elephant trunk; CPB, cardiopulmonary bypass; ICU, intensive care unit; RBC, red blood cell; TND, temporary neurologic dysfunction; PND, permanent neurologic dysfunction.

the 2 groups (23.1% for u-ACP vs 18.0% for b-ACP; $P = .179$), Bivariate logistic analysis identified age, preoperative renal dysfunction, CPB time, cross-clamp time, and circulatory arrest time as predictors of postoperative renal failure. Multivariate regression identified age and preoperative renal dysfunction as independent predictors of postoperative renal failure (Table 8). The morbidities of redo for bleeding (4.6% vs 2.8%; $P = .64$), mediastinal infection (6.2% vs 3.7%; $P = .478$), and paraplegia (3.1% vs 2.8%; $P = 1.00$) were similar in the 2 groups. Major perioperative characteristics and outcomes of patients who

underwent surgery within 24 hours of symptom onset are presented in Table 4. In these patients, no significant between-group difference was observed for any parameter except ventilation time (160 $\pm$ 88.5 hours vs 100 $\pm$ 36 hours; $P < .001$), similar to the result for the whole cohort.

DISCUSSION

Aortic surgery centers have adopted different cerebral perfusion strategies to optimize operative results and minimize adverse outcomes.¹⁷⁻²⁰ Selective ACP has been shown

FIGURE 1. Thirty-day mortality and PND in the u-ACP and b-ACP group. PND, Permanent neurological defect; u-ACP, unilateral antegrade cerebral perfusion; b-ACP, bilateral antegrade cerebral perfusion.

not only to reduce perioperative adverse outcomes, but also to improve long-term outcomes and quality of life.^{6,21} Selective perfusion via the right or left carotid artery provides similarly effective and safe neuroprotection.²² The issue of u-ACP versus b-ACP has been examined in aortic arch surgery, but few reports have focused on type A aortic dissection. In the largest report comparing u-ACP and b-ACP in aortic surgery but not limited to dissection, enrolling 1002 patients who had undergone partial or total aortic arch repair, Zierer and colleagues²³ demonstrated that u-ACP offers as much brain and visceral organ protection as b-ACP and may be safer by avoiding manipulation of the arch vessels. In this report, patients with acute type A dissection (347 cases) accounted for 35% of the study population. In a meta-analysis, Malvindi and colleagues²⁴ analyzed 17 reports involving a total of 3548 patients, who underwent 2949 b-ACPs and 599 u-ACPs. They concluded that b-ACP allows for significantly longer ACP time, with increasing safety once ACP time exceeds 40 to 50 minutes.

In a report focusing on type A aortic dissection, Lu and colleagues²⁵ demonstrated that unilateral ACP via right

axillary artery offered brain and visceral protection not inferior to bilateral ACP. In that study, 82 of 263 patients underwent total arch replacement and the other 181 underwent subtotal arch replacement. In a study reported by Preventza and colleagues,¹⁵ among 157 consecutive patients with type A dissection, mortality and neurologic events were similar in the u-ACP and b-ACP groups. However, the total circulatory arrest time was higher in the b-ACP group, and total circulatory arrest time >30 minutes was identified as an independent predictor for stroke in multivariable regression analysis. In that study, the 157 patients included 11 who underwent total arch replacement and 146 who underwent hemiarch replacement.

Traditionally, total arch replacement has been performed in the following scenarios: complex tears for which proximal arch replacement is not sufficient for obliterating the false lumen channel, aneurismal arch, and arch tear.²⁶⁻²⁸ Concomitant carotid arterial dissection is commonly seen in type A aortic dissection. Cerebral malperfusion, most often secondary to this condition, plays a pivotal role in stroke development and is associated with poor outcomes.^{29,30} Trivedi and colleagues⁸ proposed aggressive replacement of the aortic arch for 4 indications, including arch tear, carotid dissection, circumferential arch dissection, and aneurysmal arch, and reported excellent outcomes. They also noted a higher rate of neurologic malperfusion in patients undergoing total arch replacement (19.7%) compared with those undergoing hemiarch replacement (12.6%; $P < .001$). Preoperative stroke also was more common in patients requiring total arch reconstruction (14.1% vs 6.0%; $P = .027$). In this study, an aggressive approach aimed to optimize bilateral carotid perfusion yielded optimal neurologic outcomes. Similar indications for total arch replacement were used in our protocol.

In the present study, we had a total arch replacement rate of 57.8%, which is significantly greater than the rates reported in most published series in North America and Europe but comparable to those in other reports from

TABLE 5. 30-day mortality and morbidity

Variable	Total (n = 203)	u-ACP (n = 82)	b-ACP (n = 121)	P value
Ventilation time (h), mean $\pm$ SD	101 $\pm$ 73	147.0 $\pm$ 82	95.5 $\pm$ 45.25	.000
ICU time (d), mean $\pm$ SD	17 $\pm$ 14	17 $\pm$ 11.5	16 $\pm$ 17.75	.454
In-hospital time (d), mean $\pm$ SD	24 $\pm$ 10	23 $\pm$ 8	25 $\pm$ 9	.321
30-d mortality, n (%)	31 (15.3)	17 (20.7)	14 (11.6)	.075
Paraplegia, n (%)	5 (2.9)	2 (3.1)	3 (2.8)	1.000
TND, n (%)	11 (6.4)	6 (9.2)	5 (4.7)	.236
PND, n (%)	20 (11.6)	11 (16.9)	9 (8.4)	.091
Renal failure, n (%)	31 (18.0)	15 (23.1)	16 (18.0)	.179
Tracheostomy, n (%)	15 (8.7)	11 (16.9)	4 (3.7)	.003
Redo for bleeding, n (%)	6 (3.5)	3 (4.6)	3 (2.8)	.64
Mediastinal infection, n (%)	8 (4.7)	4 (6.2)	4 (3.7)	.478

All outcomes except mortality are based on a total of 154 patients who survived surgery. u-ACP, Unilateral antegrade cerebral perfusion; b-ACP, bilateral antegrade cerebral perfusion; SD, standard deviation; ICU, intensive care unit; TND, temporary neurologic dysfunction; PND, permanent neurologic dysfunction.

TABLE 6. Risk factors for 30-day mortality

Risk factor	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P value	OR (95% CI)	P value
Age (y)	1.150 (1.084-1.220)	<.001		
Female sex	0.037 (0.013-0.107)	<.001		
Renal dysfunction	0.298 (0.102-0.873)	.027		
Acute type A dissection (<24 h)	0.181 (0.021-1.421)	.096		
COPD	0.085 (0.007-0.966)	.047		
Time to the start of cohort	1.003 (0.983-1.024)	.758		
Pericardial effusion/tamponade	0.279 (0.105-0.741)	.010		
Hemodynamic instability	0.103 (0.030-0.349)	<.001		
CABG	0.401 (0.151-1.061)	.066		
CPB time	1.048 (1.027-1.070)	<.001	0.945 (0.899-0.994)	.028
Cross-clamp time	1.099 (1.053-1.148)	<.001		
Circulatory arrest time	1.446 (1.242-1.68)	<.001	0.753 (0.595-0.954)	.019

OR, Odds ratio; CI, confidence interval; COPD, chronic obstructive pulmonary disease; CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass.

China.^{9,31} One rationale for the high total arch replacement rate is the relative young age of our patients (51.0 ± 13 years) in contrast to much older counterparts from the International Registry of Aortic Dissection³² and the German Registry for Acute Aortic Dissection Type A.⁷ Young age is associated with lower perioperative risk for total arch replacement,¹⁵ but a high risk of recurrence in the future,³³ which might be further exacerbated by poor hypertension control in the Chinese population.³⁴ Previous studies of similar total replacement rates have reported optimal short- and long-term outcomes with low reintervention rates.^{9,33} We believe that in patients with type A dissection in whom total arch replacement is indicated, an optimal intraoperative cerebral perfusion strategy is mandated to achieve optimal outcomes.

The mortality rate of 14.5% for our entire series is comparable with rates reported by others.^{20,25,35} Some surgeons are reluctant to use b-ACP because of its complexity. In the present study, we found no increase in cross-clamp time, CPB time, or surgery time in the b-ACP group. Another rationale for avoiding b-ACP cited by some surgeons is the risk of embolic injury by cannulating the left common carotid artery in an atheromatous aorta. In the present study, this risk was avoided by attaching the left common carotid

artery to the 4-branched prosthetic graft for left hemisphere perfusion.

In the present study, the rate of PND was similar in the u-ACP and b-ACP groups (16.9% vs 8.4%; $P = .091$). b-ACP was not associated with a lower incidence of TND; however, it was associated with shorter mean ventilation time (95.5 ± 45.25 vs 147.0 ± 82 hours; $P < .01$) and lower tracheostomy rate. In our institute, protocols to wean patients from ventilation were normally initiated as soon as consciousness was regained. There was no difference in the occurrence of renal failure between the u-ACP and b-ACP groups, consistent with previous reports.^{15,25}

In our entire series, bivariate logistic regression analysis identified age, female sex, preoperative renal dysfunction, acute type A dissection, pericardial effusion/tamponade, CPB time, cross-clamp time, and circulatory arrest time were predictive of mortality, whereas multivariate regression analysis identified CPB time and circulatory arrest time as independent predictors of mortality. Preventza and colleagues¹⁵ also identified age and circulatory arrest time, and Khaladj and colleagues³⁶ identified age, CPB time, and previous sternotomy, as independent risk factors for mortality. CPB time and circulatory arrest time have been identified as independent predictors of PND. Previous

TABLE 7. Risk factors for PND

Risk factor	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P value	OR (95% CI)	P value
Age (y)	1.125 (1.051-1.204)	.001		
Acute type A dissection (<24 h)	2.431 (0.874-8.293)	.053		
Hemodynamic instability	0.170 (0.027-1.090)	.062		
Type of cerebral perfusion	2.521 (0.956-6.644)	.062		
Time to the start of cohort	0.980 (0.954-1.006)	.125		
CPB time	1.039 (1.018-1.060)	<.001	0.957 (0.917-0.998)	.041
Cross-clamp time	1.049 (1.015-1.084)	.004		
Circulatory arrest time	1.480 (1.224-1.790)	<.001	0.427 (0.198-0.921)	.030

PND, Permanent neurologic dysfunction; OR, odds ratio; CI, confidence interval; CPB, cardiopulmonary bypass.

TABLE 8. Risk factors for renal failure

Risk factor	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P value	OR (95% CI)	P value
Age (y)	1.135 (1.068-1.206)	<.001	1.141 (1.037-1.255)	.007
Acute type A dissection (<24 h)	1.781 (0.841-3.541)	.251		
Type of cerebral perfusion	1.840 (0.832-4.071)	.132		
Renal dysfunction	0.082 (0.031-0.219)	<.001	0.030 (0.004-0.242)	.001
Time to the start of cohort	1.000 (0.980-1.021)	.987		
CPB time	1.040 (1.022-1.059)	<.001		
Cross-clamp time	1.068 (1.033-1.103)	<.001		
Circulatory arrest time	1.458 (1.238-1.718)	<.001		

OR, Odds ratio; CI, confidence interval; CPB, cardiopulmonary bypass.

studies suggested justified use of b-ACP for circulatory arrest times of >30 minutes¹⁵ or up to 40 to 50 minutes²⁴; however, the duration of circulatory arrest might be difficult to predict beforehand. In our b-ACP strategy, both cerebral perfusion routes were established before circulatory arrest.

Study Limitations

This study has some inevitable limitations. First, even though the data were extracted and analyzed from a prospectively maintained database, the study is a retrospective review, and the results may be affected by its nonrandomized design. Second, this study represents only a single-center experience and not a multicenter experience. There surely are some disparities among different centers and operators. Third, surgeries for the 2 groups were not performed entirely in the same era.

Although this is one of the largest single-center series to focus on the difference between u-ACP and b-ACP in total arch replacement for type A dissection, the patient population is still relatively small, and consequently conclusions can be challenging. Assuming u-ACP and b-ACP at a 1:1 ratio, a sample size of 506 is needed to demonstrate a mortality difference with 0.8 power at $\alpha = 0.05$, and at least 236 patients per group are required to demonstrate the PND difference. Finally, changes in cerebral monitoring, anesthetic management, and intensive care unit care may have had an impact on the 2 groups, given the extended duration of our study period.

CONCLUSIONS

In conclusion, our study, performed exclusively in patients who underwent total arch replacement for type A aortic dissection, showed that b-ACP was not associated with significantly lower 30-day mortality or PND compared with u-ACP. CPB time and circulatory arrest time were identified as independent risk factors for both mortality and PND. b-ACP did not increase CPB, cross-clamp, or circulatory arrest time. Future large sample size, randomized, multicenter studies are warranted to thoroughly compare b-ACP and u-ACP.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: antegrade cerebral perfusion, circulatory arrest, total arch replacement, type A aortic dissection