Effect of different types of cerebral perfusion for acute type A aortic dissection, unilateral versus bilateral

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Abstract

Background

Antegrade cerebral perfusion (ACP), including unilateral and bilateral, is most commonly used way for cerebral protection in aortic surgery. There is still no consensus on the superiority of the two methods. Our research was aimed to investigate the clinical effects between u-ACP and b-ACP.

Methods

321 patients with type A aortic dissection were studied retrospectively. 124 patients (38.6%) received u-ACP and 197 patients(61.4%) received b-ACP. We compared the incidence of postoperative neurological complications and other collected data between two groups. We also analyzed perioperative variables in order to find the potential associated factors for neurolocial dysfunction (ND).

Results

For u-ACP group, 54 patients (43.5%) had postoperative neurological complications including 22 patients (17.7%) with permanent neurologic dysfunction (PND) and 32 patients (25.8%) with temporary neurologic dysfunction (TND). For b-ACP group, 47 patients (23.8%) experienced postoperative neurological complications including 16 patients (8.1%) of PND and 31 patients (15.7%) of TND. The incidence of PND and TND were significantly different between two groups along with shorter CPB time ($p = 0.016$), higher nasopharyngeal temperature ($p \leqq 0.000$), shorter awakening time ($p = 0.030$) and lower incidence of hypoxia ($p = 0.022$). Furthermore, multivariate stepwise logistic regression analysis confirmed that preoperative neurological dysfunction (OR = 1.20, P = 0.028), CPB duration (OR = 3.21, P = 0.002) and type of cerebral perfusion (OR = 1.48, P = 0.017) were strongly associated with postoperative ND.

Conclusions

In our study, we found that b-ACP procedure had many advantages compared to u-ACP and we inferred that b-ACP may be more suitable for patients with type A AD undergoing total arch replacement.

Background

AORTIC DISSECTION (AD) is one of the most serious cardiac emergencies due to its associated high mortality rates, especially Stanford type A [1, 2]. Presently, surgery is the primary treatment method. The frozen elephant trunk technique is increasingly being used to repair dissections extending over the entire aortic arch. Despite immense improvements in surgical techniques, the operative mortality and complications of type A aortic dissection(AD) remain considerably high [3]. Neurological dysfunction

(ND) is a common complication, with a reported rate ranging from 5.5–33.3% of cases [4]. Consequently, it is crucial to implement appropriate measures to prevent cerebral injury.

In recent decades, various kinds of protocols to avoid cerebral damage have been utilized. Advances in these protocols have subsequently improved neurological outcomes for type A AD. Currently, antegrade cerebral perfusion (ACP) has become the standard method of cerebral support. However, there is still a controversy regarding the superiority of either the unilateral ACP (u-ACP) or bilateral ACP (b-ACP) as the most effective perfusion approach [5, 6].

As is well-known, the feasibility of u-ACP for keeping the brain perfused during the circulatory arrest period is based on the integrity of the circle of Willis. Nevertheless, there are several anatomical variations of the circle. The b-ACP approach is a way of providing cerebral perfusion through both sides simultaneously which mimics the physiological conditions. Therefore, we postulated that b-ACP may be more advantageous for cerebral support or other aspects relating to mortality, neurological outcome, and other systemic complications, compared to u-ACP.

We also retrospectively gathered potential variables, according to the Society of Thoracic Surgeons (STS) National Database, aiming at identifying risk factors for postoperative neurological dysfunction in patients with type A AD undergoing total aortic arch replacement.

Methods

Study Populations

We retroactively studied 321 patients with type A AD who were admitted to our cardiac surgical intensive care unit after total aortic arch replacement from January 1, 2014 to December 31, 2018, of whom 124 underwent a u-ACP (38.6%) and 197 underwent a b-ACP (61.4%). The experimental protocol and informed consent were approved by the Institutional Review Board of our hospital, and all subjects gave informed consent. Among the 321 patients, there were 224 males and 97 females. The mean age was 51.98 ± 9.78 years. All the cases were diagnosed using preoperative computed tomography angiography (CTA) and therapy was conducted within 2 weeks of onset. The indications for total aortic arch replacement included one of the following manifestations shown on CTA: arch tear, carotid dissection or occlusion, or the presence of an aneurismal arch. Preoperative echocardiography was also necessary to evaluate the cardiac function, the exact position of intima rupture, and to assess the condition of the aortic and mitral valves. Every patient underwent total arch replacements. The concomitant procedures included Bentall procedure, coronary artery bypass grafting (CABG) and Bentall + CABG. The relevant demographic data and surgical strategies were illustrated in Table 1. Preoperative neurological complications were defined as acute neurological dysfunctions from dissection, which included one patient with coma, three with somnolence, one with hemiplegia, and four with monoplegia.

The anesthetic regimen was kept standard. Intravenous (IV) injections of 2.5–5 mg midazolam, 0.2–0.6 mg/kg etomidate, 0.1-5ug/kg sufentanil, and 0.6 mg/kg rocuronium were performed as the standard anesthetic induction in these patients. Subsequently, tracheal intubations were executed. Anesthesia was maintained by continuous inhalation of sevoflurane, IV injections of dexmedetomidine and rocuronium, combined with theadditional administration of midazolam and sufentanil when necessary.

Operative Technique

All operations were conducted by the same surgical staff. Our operative techniques comprised of cardiopulmonary bypass (CPB), moderate hypothermia (24–28℃), circulatory arrest, and ACP. Monitoring data included left radial and dorsalis pedis arterial pressures, main arterial pressure (MAP), central venous pressure (CVP), electrocardiography (ECG), blood oxygen saturation (SaO_2), and arterial blood gas (ABG) analysis. Cerebral saturation was monitored with near-infrared spectroscope (NIRS). Prior to December 2015, u-ACP with moderate hypothermia circulatory arrest (24–26℃) was routinely performed to maintain cerebral perfusion. From January 2016, b-ACP was initiated until the end of the study. The temperature of circulatory arrest was gradually increased to 26–28℃. In both groups, right axillary artery with right femoral artery cannulations were conducted to establish CPB. In the u-ACP group, cannulation of the right axillary artery was used for cerebral perfusion. Whereas in the b-ACP group, a right axillary artery cannulation was used along with a 12-F or 14-F balloon-tip catheter in the left common carotid artery.

After CPB was established, we cross-clamped the ascending aorta after the nasopharyngeal temperature dropped to 34℃ or lower. Consequently, cold blood cardioplegia was injected into the coronary ostia antegrade or the coronary sinus retrograde directly to stop the heart. We subsequently made a longitudinal incision on the ascending aorta and the aortic root procedure was performed depending on the severity and extent of the disease; including aortic root formation or Bentall procedure with or without CABG.

When the temperature reached 24℃ to 28℃, all three branches of the aortic arch were separately clamped, and the systemic circulation stopped. In the u-ACP group, cerebral perfusion was provided only by the right axillary artery cannulation. 12 of 124 patients, who immediately switched to b-ACP, were classified as b-ACP group patients. In the b-ACP group, both the right axillary artery and left common carotid artery were used for cerebral protection. Flow rates of 5 ml/kg/min to 10 ml/kg/min were used for ACP, with perfusion pressures ranging from 50 mmHg to 80 mmHg. A stented elephant trunk was inserted into the proximal descending aorta and attached to the distal end of the graft. Subsequently, systemic circulation of the lower body was restarted via the right femoral artery. For the u-ACP group, anastomosis of the left common carotid artery was done at first, in order to restore left cerebral perfusion. Afterwards, the proximal aortic root was anastomosed to the prosthetic graft to restore systemic circulation and the temperature increased progressively. The left subclavian artery and innominate artery were sequentially anastomosed to the prosthetic graft. For the b-ACP group, we initially anastomosed the left subclavian artery to the prosthetic graft, followed by the left common carotid artery, proximal aortic root and innominate artery respectively.

Statistical Analysis

All of the perioperative data were analyzed distinctively between two groups (See Tables 2 and 3). The postoperative variables consisted of 30-day mortality rate, awakening time (h), permanent neurological dysfunction (PND), temporary neurological dysfunction (TND), acute kidney injury (AKI, referring to elevated serum creatinine concentration > 1.5 times of baseline or urine volume < 0.5 ml/kg/h for 6 hours within 48 hours after surgery), hypoxia ($PaO_2/FiO2 < 200$ with PEEP ≥ 5cmH2O within 72 hours after surgery), and postoperative bleeding volume within 24 hours of surgery. Patients with neurological symptoms had to be examined by CT scans to confirm the diagnosis. PND was defined as the presence of permanent neurological deficits persisting after being discharged with focal or global cerebral lesions confirmed by CT or MRI, including monoplegia, hemiplegia, paraplegia and coma, confirmed by CT or MRI. TND included transient ischemic attack (TIA) and reversible neurological deficits such as delirium, confusion and agitation with no new lesions on CT. All the diagnoses of stroke were adjudicated by a neurologist who was blinded.

Continuous variables were expressed as mean ± SD; categorical data were expressed as proportions. The T test or Mann-Whitney test were used to compare continuous variables while categorical data were compared using the χ^2 test or the Fisher exact test. We divided the patients into two groups (ND vs non-ND). All potential risk variables were analyzed for significance. For factors with P-values < 0.1, the multivariable logistic regression model was employed to further identify independent risk factors.

Results

Intraoperative Data

There were no significant differences in terms of rates of concomitant surgery, including the Bentall procedure, CABG, and Bentall + CABG between the two groups (Table 2). However, we found that the CPB durations and nasopharyngeal temperatures during the circulatory arrest period were considerably different.

Mortality Rates And Morbidities

After meticulous comparisons of the postoperative data, we didn’t find differences in the 30-day mortality rates, incidence of postoperative renal failure, or bleeding volume > 1 L within 24 hours of surgery. Compared to the u-ACP group, the b-ACP group patients displayed shorter awakening times (9.53 ± 11.24 vs. 16.62 ± 17.27; p = 0.018), and overall lower incidence of hypoxia (16.4% vs. 27.9%; p = 0.037) (See Table 3).

Neurological Events

We compared the postoperative neurological complications between the two groups (See Fig. 1). For the u-ACP group, PND was observed in 22 patients (17.7%): paraplegia (n = 2), monoplegia (n = 4), hemiplegia (n = 11), and coma (n = 5). TND was observed in 32 patients (25.8%): delirium (n = 23), TIA (n = 2), and confusion and agitation (n = 7). Meanwhile for the b-ACP group, a total of 16 patients (8.1%) with PND were observed: paraplegia (n = 1), hemiplegia (n = 9), monoplegia (n = 4), and coma (n = 2). Whilst 31 patients (15.7%) with TND were observed: delirium (n = 25), confusion and agitation (n = 6), and no TIA. The incidence of PND and TND were undoubtedly different between the two groups (See Table 4).

Furthermore,we divided the patients into different groups based on the incidence of postoperative neurological dysfunction: ND and non-ND groups. The results of univariate analyses of all the potential risk variables were listed in Table 5. All variables with P values < 0.05 were included in the multivariable analysis model. Our study showed that preoperative neurological dysfunction (OR = 1.20, P = 0.028), CPB duration (OR = 3.21, P = 0.002) and type of cerebral perfusion (OR = 1.48, P = 0.017) were independent risk factors for genesis of ND (Table 6).

Discussion

We made a comparison for two cerebral perfusion methods with respect to a set of clinical outcomes following each method. We discovered that patients in the b-ACP group had shorter CPB times, higher permissive arrest temperatures, shorter awakening times, and lower incidences of postoperative hypoxia and ND, which is a serious postoperative complication of acute type A AD[7]. Its incidence is highly variable ranging from 0-32.8% [8]. Despite the relatively frequent occurrence of ND in type A AD patients, its major risk factors remain uncertain. Therefore, we analyzed various potential factors retrospectively and found that the preoperative neurological function, CPB time, and type of cerebral perfusion chosen were independent risk factors for postoperative neurological dysfunction. Therefore, we may reduce the occurrence of postoperative ND by shortening the CPB time and choosing the most efficient cerebral perfusion method. The relationship between postoperative neurological complications and the intraoperative ACP method used is further discussed here.

Hypothermic circulatory arrest combined with ACP has been recognized as the first choice for cerebral protection in aortic arch surgery, and were used worldwide [9, 10]. This technique yielded the best results; mostly improved short-term or long-term outcomes. Nevertheless, the use of u-ACP vs b-ACP remains a subject of debate. Previously, we routinely used right axillary artery cannulation for u-ACP in type A AD operations. Its main advantage being that it involves lesser risk of dissection or atherosclerosis in the right axillary artery. Besides, the isolation and cannulation procedure is much easier this way. Nowadays, along with the tremendous improvements in operative technology, intubation methods, and clearer determination of anatomical locations, a substantial body of evidence suggests the superiority of b-ACP by perfusing the left common carotid artery while simultaneously providing sufficient cerebral protection [11, 12]. The possible reasons for this hypothesis can be summarized as follows.

We previously explained the surgical procedures with u-ACP or b-ACP in detail. The anastomosis sequence of the three branches of the aortic arch is different in the two patient groups. For the u-ACP group, we initially anastomosed the left common carotid artery to restore the physiological status of the left cerebral perfusion. Anastomosis of the left subclavian artery followed. Actually, initial anastomosis of the left common carotid artery can hinder the subsequent operation on the left subclavian artery by reducing the surgical field, thus making the procedure more challenging and time-consuming. Consequently, the incidence of anastomotic bleeding of the left subclavian artery rose, and our surgeons needed more time and attention to stop the bleeding. The mean CPB time of the u-ACP group was longer than that of the b-ACP group. This suggested the superiority of the b-ACP procedure for total arch replacement.

The integrity of the circle of Willis is the key for sufficient cerebral perfusion under u-ACP. Nonetheless, there are several anatomical variations of the circle, not to mention cases of vascular dysplasia or deficiency of vascular branches. Studies have proven that the proportion of individuals with intact circles of Willis comprise 21–25% of the population, and the variation rate can be as high as 50%, especially in the posterior circulation [13, 14]. However, some patients are unable to undergo CTA, magnetic resonance angiography (MRA), or digital subtraction angiography (DSA) to determine the integrity of the circle of Willis before surgery due to the severity of the disease itself or for other reasons. Therefore, b-ACP can assure continuous bilateral cerebral perfusion regardless of the integrity of the circle of Willis. Harrer et al. [15] reported that the left cerebral oxygen saturation increased by about 19% when the perfusion approach was switched from u-ACP to b-ACP.

With the advent of deep hypothermic circulatory arrest (DHAC) into clinical practice by Griepp and associates in the 1970s, the outcome of arch surgery was remarkably improved. Hypothermia provides neurological protection essentially by decreasing the global cerebral metabolic rate and increasing the cerebral tolerance to circulatory arrest. Hypothermia can also reduce temperature-dependent release and extracellular levels of excitatory neurotransmitters such as glutamate, thereby inhibiting pro-apoptotic activity and reducing the level of free radicals and inflammatory cytokines [16]. Earlier protocols have utilized temperatures as low as 14℃ with the belief that lower temperature sufficiently diminishes cerebral metabolic demands. In recent years, surgeons began to question the limitations of DHAC. Ehrlich et al. reported that further reduction of temperature beyond 18°C did not further decrease the oxygen requirement in the brain. As a matter of fact, it led to greater cerebrovascular homeostasis impairment and reduced cerebral perfusion [17]. Several experts have cautioned against DHAC because of its related hazards of prolonged CPB time, greater coagulopathy and aggravated inflammatory responses. Recent studies from high-volume aortic centers have demonstrated excellent results of moderate levels of hypothermia combined with ACP [18, 19]. With the increase of the circulatory arrest temperature, the tolerance of cerebral tissue to ischemia or hypoxia reduced. In the b-ACP group, both cerebral hemispheres were perfused directly through cannulation, permitting better perfusion and a higher arrest temperature compared with the u-ACP group. The higher circulatory arrest temperature causes less impaired cerebrovascular homeostasis, thereby avoiding hypo-cerebral or hyper-cerebral perfusion via the physiological regulation of the cerebral vessels themselves. Finally, the higher temperature during circulatory arrest allows for shorter cooling and rewarming time, substantially reducing the CPB time.

Alternatively, the awakening time and incidence of postoperative hypoxia were significantly different between the two groups. The b–ACP group exhibited a shorter awakening time and lower occurrence of postoperative hypoxia. The shorter revival time further validated the superiority of the b-ACP procedure with respect to cerebral protection. Postoperative hypoxia can reduce the oxygen supply to the brain, hence damaging the cerebral tissues and inducing temporary or permanent neurological defects. Both of these effects are associated with the higher incidence of neurological complications in u-ACP.

Conclusions

The b-ACP procedure had many advantages compared to u-ACP, including reduced incidence of postoperative neurological dysfunction, shorter awakening time, shorter CBP time, and lower incidence of postoperative hypoxia according to our research. Consistent with the result above, we found CPB duration and perfusion method were independent risk factors for the generation of ND, which further explained why b-ACP procedure had better effect of cerebral protection. On these grounds, we inferred that b-ACP may be more suitable for patients with type A AD undergoing total arch replacement.

Declarations

Ethics approval and consent to participate

The experimental protocol and informed consent were approved by the Institutional Review Board of our hospital-Qilu hospital of Shandong university. And all patients involved in this study gave their informed consent verbally. Since our research was a retrospective one and we just collected patients' data retrospectively without any intervention that could influence patients' clinical outcome.

Consent for publication

Not applicable.

Availability of data and materials

The datasets analysed during the current study are available from the corresponding author on reasonable request.

Competing interests:

We declare that there are no conflicts of interest to the manuscript submitted. We do not have any commercial or personal relationships with other people or organizations in connection with our work.

List Of Abbreviations

AD Aortic Dissection

ND Neurological Dysfunction

ACP Antegrade Cerebral Perfusion

u-ACP unilateral Antegrade Cerebral Perfusion

b-ACP bilateral Antegrade Cerebral Perfusion

CPB Cardiopulmonary Bypass

MAP Mean Arterial Pressure

CVP Central Venous Pressure

ECG Electrocardiography

SaO_2 Blood Oxygen Saturation

ABG Arterial Blood Gas

NIRS Near-Infrared Spectroscope

PND Permanent Neurological Dysfunction

TND Temporary Neurological Dysfunction

AKI Acute Kidney Injury

TIA Transient Ischemic Attack

DHAC Deep Hypothermic Circulatory Arrest

Declarations

Ethics approval and consent to participate: The experimental protocol and informed consent were approved by the Institutional Review Board of our hospital-Qilu hospital of Shandong university. And all patients involved in this study gave their informed consent verbally. Since our research was a retrospective one and we just collected patients’ data retrospectively without any intervention that could influence patients’ clinical outcome.

Consent for publication: Not applicable.

Availability of data and materials: The datasets analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: We declare that there are no conflicts of interest to the manuscript submitted. We do not have any commercial or personal relationships with other people or organizations in connection with our work.

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Author's Contributions

No.	Author's name	contributions to the article
1.	LZQ	conceptualization, data curation, formal analysis, investigation, methodology and writing
2.	WC	conceptualization, data curation, investigation and methodology
3.	ZXQ	conceptualization, methodology and review
4.	WSM	conceptualization and review
5.	FCC	data curation, investigation and methodology
6.	PXY	conceptualization, formal analysis, investigation, methodology and writing

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Tables

Due to technical limitations, Tables 1-6 are provided in the Supplementary Files section.

Figures

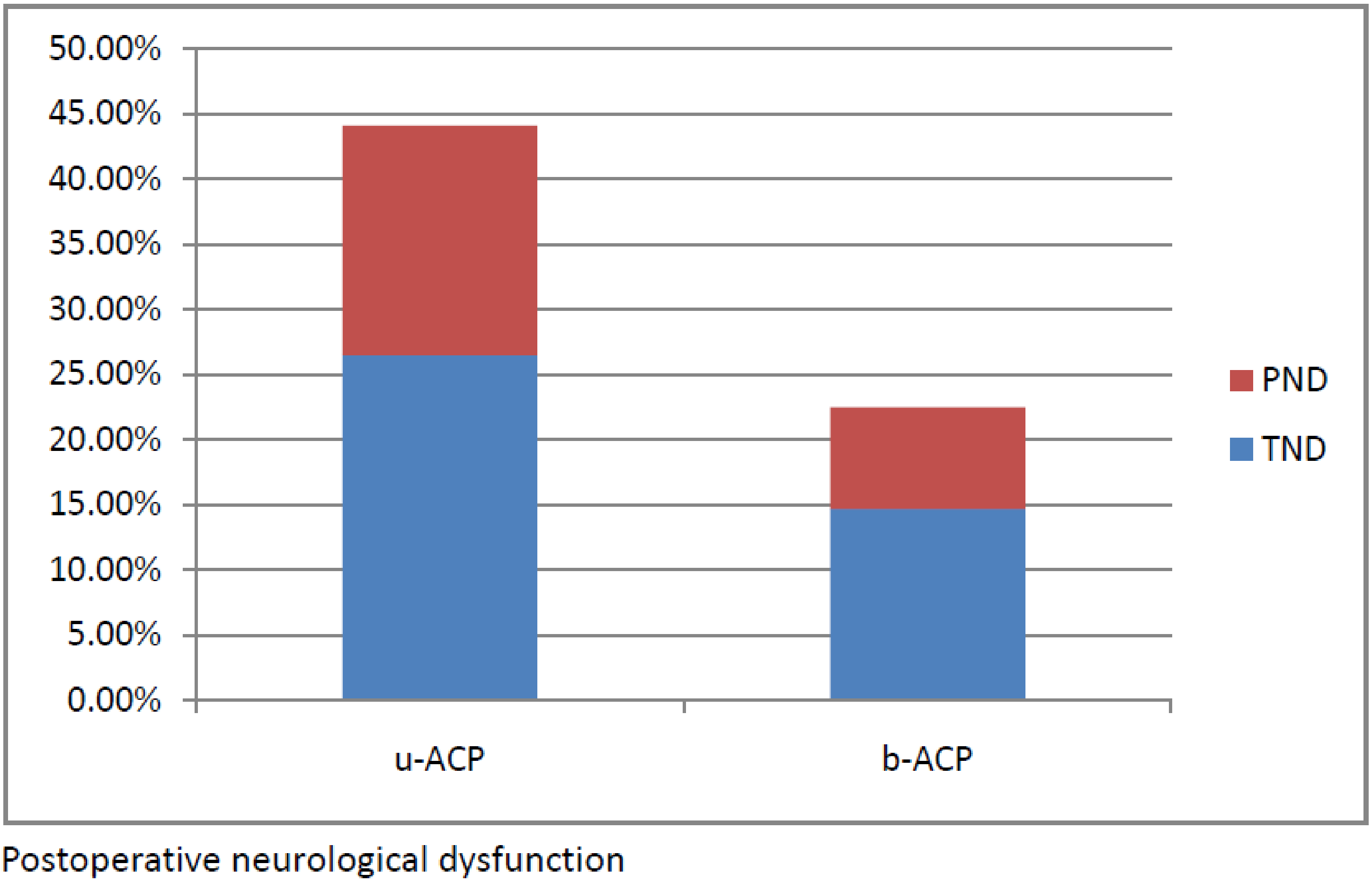

Figure 1

Postoperative neurological dysfunction in the u-ACP and b-ACP groups