J Bionic Mem 2023; 3(2): 39-45 DOI: 10.53545/jbm.2023.28

Journal of Bionic Memory Original article

Antegrade cerebral perfusion in thoracic aortic surgery: A single surgeon experience

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ABSTRACT

Aim: To present the experiences and outcomes in patients who underwent thoracic aortic surgery due to aortic aneurysm and/or dissection and in whom unilateral or bilateral antegrade cerebral perfusion was performed.

Methods: A total of 51 patients who underwent unilateral or bilateral antegrade cerebral perfusion during thoracic aortic surgery performed due to aortic aneurysm and/or acute type A aortic dissection were included in the study. Patients' demographic data such as age and gender, comorbidity, diagnosis, type of procedure, type and duration of cerebral perfusion, temperature of hypothermia, and perioperative outcomes were recorded and retrospectively reviewed.

Results: Of all patients, 63.7% were male and 35.3% were female. The mean age of the patients was 55.1±12.0 years. Bilateral antegrade cerebral perfusion was performed in 47.1% and unilateral antegrade cerebral perfusion in 52.9% of the patients. The mean duration of antegrade cerebral perfusion was 60.2±26.6 minutes in patients with bilateral antegrade cerebral perfusion and 33.5±25.9 minutes in patients with unilateral antegrade cerebral perfusion. Mortality occurred in three patients, while one patient developed a major cerebrovascular event.

Conclusion: The present analysis revealed that antegrade cerebral perfusion performed during thoracic aortic surgery was associated with favorable perioperative outcomes.

Key words: Antegrade cerebral perfusion, aortic aneurysm, aortic dissection, thoracic aortic surgery.

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Received: 2023-08-17 / Revisions: 2023-08-30

Accepted: 2023-09-06 / Published: 2023-09-07

Introduction

Despite the advancements in surgical techniques, the rate of mortality from type A aortic dissection remains high [1]. Hypothermic circulatory arrest, retrograde or antegrade cerebral perfusion and open distal anastomosis surgery are among the commonly performed approaches during surgery in acute type A dissections. Circulatory arrest is an important method used for aortic dissection and complex arcus pathologies such as aortic aneurysms. Meanwhile, damages may occur in visceral organs and central nervous system depending on duration. Neurologic dysfunction is a common complication of aortic arch surgery, with an incidence reported between 5.5%-33.3% [2]. In addition, visceral organ damage such as renal failure requiring dialysis is seen in 3-6% of these patients [1]. The most important approaches to prevent this include antegrade cerebral perfusion (ACP) and systemic hypothermia. Hypothermia with ACP has been demonstrated to improve outcomes and reduce neurologic complications [2,4].

ACP can be applied as unilateral or bilateral. Debate in the literature about which method is

superior over the other is continuing for long years [5-7]. Studies in the literature have reported that either unilateral ACP (u-ACP) or bilateral ACP (b-ACP) can be performed as an adjuvant to hypothermic circulatory arrest (HCA) in patients undergoing aortic arch surgery [4]. Some authors have reported that both methods are acceptable, but bilateral method is more reliable in case of prolonged antegrade cerebral perfusion over 40-50 minutes [7]. However, comparative data about superiority of a method in patients with longer circulatory arrest are insufficient.

The concept of using hypothermia in order to temporarily decrease oxygen and metabolic requirements of hypoxic tissues is supported by laboratory and clinical evidence for years. Nevertheless, there is no definitive consensus about the optimum temperature of HCA that will be used during aortic arch surgery [8,9]. Although studies in the literature have reported different results about the optimum temperature of hypothermia, it has been stated that 26-28^{o}C hypothermia would be appropriate as an adjuvant to cerebral perfusion [10].

The aim of this study was to present the experiences and outcomes in patients who underwent thoracic aortic surgery due to aortic aneurysm and/or dissection and in whom unilateral or bilateral antegrade cerebral perfusion was performed.

Materials and methods

This study included a total of 51 consecutive patients who underwent unilateral or bilateral antegrade cerebral perfusion during thoracic aortic surgery performed due aortic aneurysm and/or acute type A aortic dissection between January 2010 and December 2017. Patients' demographic data such as age and gender, comorbidity, diagnosis, type of procedure, type and duration of cerebral perfusion applied, and temperature of hypothermia were recorded. In addition, patients' awakening duration, extubation duration, neurologic deficit status and time to discharge were also recorded. The recorded medical data of patients were analyzed and then retrospectively reviewed. Patients in whom retrograde perfusion was performed or those who did not undergo unilateral or bilateral ACP, and patients with preoperative severe neurologic dysfunction were excluded from the study.

Patients with type A aortic dissection were considered to be in acute phase if the symptoms were initiated within two weeks, subacute if the symptoms were initiated between two weeks and two months, and chronic if the symptoms lasted longer than two months [11,12].

Surgical approach

All patients were operated via median sternotomy under general anaesthesia, by a single experienced cardiovascular surgeon (A.M.). The cannulation strategy mainly included cannulation of the right axillary/subclavian artery with 8 mm polytetrafluoroethylene (PTFE) graft anastomosis, and cannulation of the right atrium with two-stage venous cannula. The innominate artery, or right or left femoral artery were used for arterial cannulation in case of problems for cannulation in the right axillary/subclavian artery. Other surgical approaches included systemic hypothermia, circulatory arrest and bilateral or unilateral ACP (10 mL/Kg, usually 1 L/minute). In addition, when distal open anastomosis procedure was not too short, and if the medium was appropriate, bilateral ACP was performed via the left carotid artery with a 14 Fr folley catheter. During the operations, real-time intraoperative monitoring was performed including perfusion pressure, flow rates and cerebral oxygen saturation. In the case of any

abnormality detected, the type of cerebral perfusion method was changed.

Statistical analysis

Data obtained in the study were entered into a dedicated Microsoft Excel file. Continuous variables were expressed as mean±standard deviation, minimum and maximum values, and categorical variables as number (n) and percentage (%). Statistical analysis was performed using the SPSS version 20 (SPSS, Chicago, IL, USA).

Results

Of all patients, 33 (63.7%) were male and 18 (35.3%) were female. The mean age of the patients was 55.1±12.0 years. When diagnoses of the patients were examined; thoracic aortic aneurysm was present in 17 (33.3%), acute type A aortic dissection in 28 (54.9%), subacute type A aortic dissection in 2 (3.9%) and chronic type A aortic dissection in 4 (7.8%) patients. The most common comorbidities in the patients were hypertension, coronary artery disease and atrial fibrillation. Surgical procedures performed to the patients are presented in Table 1.

b-ACP was performed in 24 (47.1%) and u-ACP in 27 (52.9%) patients. Four (7.8%) patients in whom initially b-ACP was performed, we subsequently converted to u-ACP. The mean duration of ACP was found as 60.2±26.6 (min-max: 17-117) minutes in b-ACP and 33.5±25.9 (min-max: 13-77) minutes in u-ACP group.

Systemic hypothermia was applied at 17-18°C in the first 40 (78.4%) patients, while hypothermia was applied at 20-28°C in the remaining 11 (21.6%) patients. The distribution of degrees of hypothermia applied to the study population is shown in Figure 1.

Mortality occurred in three (5.9%) patients, and one (2%) patient developed a major cerebrovascular event. One (2%) patient who was operated with cardiopulmonary resuscitation was referred to the department of reanimation two weeks after the surgery due to pneumonia. The remaining 46 (90.2%) patients were discharged without a major event in 6.5±4.0 days on average (min-max: 3-23).

Table 1. Surgical procedures performed to the patients.

Procedure	Patients (N, %)
Bentall	5 (9.8)
Bentall + 1/3 arch	6 (11.8)
Bentall + 2/3 arch	2 (3.9)
Bentall + hemiarch	5 (9.8)
David + 1/3 arch	2 (3.9)
David + 2/3 arch	2 (3.9)
David + hemiarch	1 (2.0)
Wheat + 1/3 arch	1 (2.0)
Wheat + hemiarch	2 (3.9)
Hemiarch	17 (33.3)
Hemiarch + 1/3 arch	1 (2.0)
1/3 arch	3 (5.9)
2/3 arch	3 (5.9)
Frozen elephant trunk	1 (2.0)
TOTAL	**51 (100.0)**

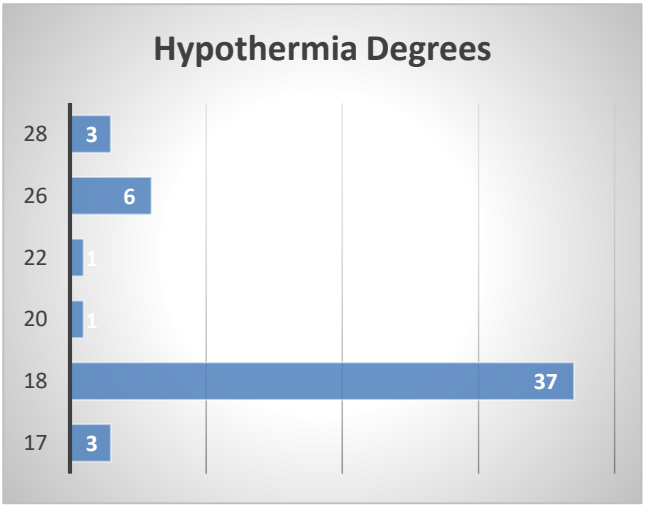

Figure 1. Hypothermia degrees applied to the study population.

Discussion

After the use of deep hypothermia under total circulatory arrest (TCA) was described by the first time by Griepp in 1975, this method has been recognized worldwide within a few years [13]. In general, hypothermia significantly decreases the need for oxygen and cerebral metabolism, but this metabolism can never be zero even in very low temperatures. Therefore, besides hypothermia cerebral protection also includes cerebral blood flow and autoregulation of this flow. Later, selective antegrade cerebral perfusion (SACP) method, which was thought to be more physiologic, has been described. This technique has been supported by numerous experimental studies, and its superiority over the other known methods had been proven [14,15].

Many experimental studies have investigated the optimum temperature of hypothermia [8,9,16]. Suarez et al. reported that moderate hypothermia (20-28^{o}C) with unilateral or bilateral antegrade cerebral perfusion provides cerebral protection and visceral protection up to 80 minutes [17]. In our study, we performed deep hypothermia in the first 40 patients, while temperature of hypothermia was between 20 and 28^{o}C in the subsequent patients. Zierer et al. reported that SACP with mild hypothermia (30 ^{o}C) provides sufficient protection, and SACP can be safely performed in aortic arch surgeries lasting 90 minutes or longer [18].

The most common concern in mild hypothermia is to protect end-organs. Safe limit of TCA in mild hypothermia is not clear. In a study by Asai et al. with 105 patients, no paraplegia was found in 60-minute TCA with 25-28^{o}C hypothermia, while 2% of the patients required dialysis [19]. Aortic surgery centers, have adopted different cerebral perfusion strategies in order to optimize operative outcomes and minimize adverse neurologic events.

Today, axillary or subclavian artery cannulation is thought to be the best method for selective antegrade perfusion with moderate hypothermia in the treatment of acute type A dissection. The use of axillary artery cannulation does not only provide antegrade arterial perfusion during cardiopulmonary bypass, but it also provides continuous antegrade cerebral perfusion, minimizing cerebral ischemia. This technique can be started before opening the chest, provides prolonged cerebral protection and aortic repair, preventing unnecessary complex maneuver during cardiopulmonary bypass. However, although there is no consensus on the perfusion of true lumen cannulation, place of cannulation and type of perfusion are controversial. Urbanski recommends carotid cannulation [20], while Bachet et al. [21] recommend axillary or innominate artery for cannulation.

According to a survey by European Association for Cardio-Thoracic Surgery (EACTS), today b-ACP is the most commonly used method for cerebral protection in acute presentations. However, unilateral perfusion is performed in more than one third of the cases [22]. In a meta-analysis by Malvindi et al. reviewing studies that have compared unilateral perfusion and bilateral perfusion, 17 studies with 3,548 patients were analyzed. Bilateral cerebral perfusion was performed in 2,949 (83.1%) (86-164 minutes) and unilateral perfusion in 599 (16.9%) (30-50 minutes) of these patients. Neurologic deficits were lower than 5% in both groups. ACP duration allowed by bilateral perfusion was significantly longer and b-ACP was underlined to be safer when duration of ACP exceeds 40 to 50 minutes [7]. Again in a meta-analysis by Angeloni et al., b-ACP was performed in 3,206 (62.9%) and u-

ACP in 1,895 (37.1%) of 5,100 patients, and no significant difference was found between the groups in terms of mortality, permanent and temporary neurologic deficits in mean 30-minute TCA and ACP durations with hypothermia at 23-24 degrees [23]. In our series, none of the patients developed neurologic deficits both in b-ACP and u-ACP groups with deep or moderate hypothermia. However, debate is continuing in the literature about which perfusion method is superior over the other. In a study by Angleidner et al., it was found that bilateral ACP was superior in terms of overall survival in patients requiring ACP durations longer than 50 minutes [24]. Again, in another study by Samanidis et al., bilateral ACP was reported to be a valuable method with a low rate of 30-day mortality for the correction of acute aortic dissection type B [25].

Looking at the results of bilateral or unilateral cerebral perfusion used during acute type A aortic dissection surgery, no significant difference was found between the two methods in terms of in-hospital mortality, permanent or temporary neurologic dysfunction, renal failure and the need for dialysis, and lengths of stay in intensive care and hospital [26]. The rates of early mortality and mortality are still high following surgical treatment of acute type A aortic dissection. The most important risk factor of perioperative mortality is preoperative conditions of the patients. Particularly, end-organ malperfusion is the most important cause of perioperative mortality and is seen in about one third of all patients with acute aortic dissection [27]. In our study, in-hospital mortality occurred in three patients. Bilateral ACP was performed with 18^{o}C hypothermia and ACP duration was >50 minutes in all three patients.

The main limitations of this study were retrospective nature and relatively small number of patients. In addition, our study did not include long-term follow-up results. Finally, some procedures used in the study were dependent on the preference and experience of the surgeon rather than randomized or standardized protocols. However, given that there is ongoing debate in the literature and there is no definitive consensus on this issue, we believe that our results will provide contribution to the existing evidence.

In conclusion, our study demonstrated that unilateral or bilateral ACP performed during thoracic aortic surgery was associated with favorable perioperative outcomes. However, further prospective large-scale studies are needed to support our results and obtain stronger scientific evidence

Funding: *The author(s) received no financial support for the research, authorship, and/or publication of this article.*

Conflict of Interest: *The authors declare that they have no conflict of interest.*

Ethical statement: *Ethics committee approval was received from the Local Ethics committee for this study.*

References

[1]Tsai TT, Trimarchi S, Nienaber CA. Acute aortic dissection: perspectives from the International Registry of Acute Aortic Dissection (IRAD). Eur J Vasc Endovasc Surg. 2009;37(2):149-59.

[2]Apostolakis E, Koletsis EN, Dedeilias P, et al. Antegrade versus retrograde cerebral perfusion in relation to postoperative complications following aortic arch surgery for acute aortic dissection type A. J Card Surg. 2008;23(5):480-7.

[3]Williams JB, Peterson ED, Zhao Y, et al. Contemporary results for proximal aortic replacement in North America. J Am Coll Cardiol. 2012;60(13):1156-62.

[4]David TE, Armstrong S, Ivanov J, Barnard S. Surgery for acute type A aortic dissection. Ann Thorac Surg. 1999;67(6):1999-2001.

[5]Olsson C, Thelin S. Antegrade cerebral perfusion with a simplified technique: unilateral versus bilateral perfusion. Ann Thorac Surg. 2006;81(3):868-74.

[6]Misfeld M, Mohr FW, Etz CD. Best strategy for cerebral protection in arch surgery-antegrade selective cerebral perfusion and adequate hypothermia. Ann Cardiothorac Surg. 2013;2:331.

[7]Malvindi PG, Scrascia G, Vitale N. Is unilateral antegrade cerebral perfusion equivalent to bilateral cerebral perfusion for patients undergoing aortic arch surgery? Interact Cardiovasc Thorac Surg. 2008;7:891–897.

[8]Michenfelder JD, Milde JH. The effect of profound levels of hypothermia (below 14 degrees C) on canine cerebral metabolism. J Cereb Blood Flow Metab. 1992;12(5):877-80.

[9]James ML, Andersen ND, Swaminathan M, et al. Predictors of electrocerebral inactivity with deep hypothermia. J Thorac Cardiovasc Surg. 2014;147(3):1002-7.

[10]Frist WH, Baldwin JC, Starnes VA, et al. A reconsideration of cerebral perfusion in aortic arch replacement, Ann Thorac Surg. 1986;42:273-81.

[11]Dong ZH, Fu WG, Wang Y, et al. Retrograde type A aortic dissection after endovascular stent graft placement for treatment of type B dissection. Circulation. 2009;119(5):735-41.

[12]Sun L, Qi R, Zhu J, Liu Y, Zheng J. Total arch replacement combined with stented elephant trunk implantation: a new "standard" therapy for type a dissection involving repair of the aortic arch? Circulation. 2011;123(9):971-8.

[13]Griepp RB, Stinson EB, Hollinswort J, et al. Prosthetic replacement of the aortic arch. J Thorac Cardiovasc Surg. 1975;70:1051-63.

[14]Guilmet D, Roux PM, Bachet J, et al. A new technic of cerebral protection. Surgery of the aortic arch. Presse Med. 1986;15:1096-8.

[15]Kazui T, Inoue N, Yamada O, Komatsu S. Selective cerebral perfusion during operation for aneurysms of the aortic arch: a reassessment. Ann Thorac Surg. 1992;53(1):109-14.

[16]Stecker MM, Cheung AT, Pochettino A, et al. Deep hypothermic circulatory arrest: I. Effects of cooling on electroencephalogram and evoked potentials. Ann Thorac Surg. 2001;71(1):14-21.

[17]Fernández Suárez FE, Fernández Del Valle D, González Alvarez A, et al. Intraoperative care for aortic surgery using circulatory arrest. J Thorac Dis. 2017; 9(Suppl 6):S508–S520.

[18]Zierer A, Detho F, Dzemali O, et al. Antegrade cerebral perfusion with mild hypothermia for aortic arch replacement: single-center experience in 245 consecutive

patients. Ann Thorac Surg. 2011;91:1868-73.

[19] Asai T, Suzuki T, Nota H, et al. Total arch replacement with selective antegrade cerebral perfusion and mild hypothermic circulatory arrest. Ann Cardiothorac Surg. 2013;2(2):235-238.

[20] Urbanski PP. Carotid artery cannulation in aortic surgery. Multimed Man Cardiothorac Surg. 2015 Aug 23;2015.

[21] Bachet J, Guilmet D, Goudot B, et al. Antegrade cerebral perfusion with cold blood: a 13-year experience. Ann Thorac Surg. 1999;67:1874–8.

[22] De Paulis R, Czerny M, Weltert L, et al. Current trends in cannulation and neuroprotection during surgery of the aortic arch in Europe. Eur J Cardiothorac Surg. 2015;47:917-23.

[23] Angeloni E, Benedetto U, Takkenberg J. Unilateral versus bilateral antegrade cerebral protection during circulatory arrest in aortic surgery: a meta-analysis of 5100 patients. J Thorac Cardiovasc Surg. 2014;147(1):60-7.

[24] Angleitner P, Stelzmueller ME, Mahr S, et al. Bilateral or unilateral antegrade cerebral perfusion during surgery for acute type A dissection. J Thorac Cardiovasc Surg. 2020;159:2159-2167.

[25] Samanidis G, Katselis C, Contrafouris C, et al. Predictors of Outcomes after Correction of Acute Type A Aortic Dissection under Moderate Hypothermic Circulatory Arrest and Antegrade Cerebral Perfusion. Braz J Cardiovasc Surg. 2018;33(2):143-150.

[26] Preventza O, Simpson KH, Cooley DA. Unilateral versus bilateral cerebral perfusion for acute type A aortic dissection. Ann Thorac Surg. 2015;99(1):80-7.

[27] Rylski B, Urbanski PP, Siepe M, et al. Operative techniques in patients with type A dissection complicated by cerebral malperfusion. Eur J Cardiothorac Surg. 2014;46(2):156-66.