Perfusion Technique in Total Arch Replacement to Prevent Cerebral Stroke in Patients Over 75 Years Old a Single Center Retrospective Cohort Study

keiichiro kasama (cvsl2012-007@yahoo.co.jp)
Yokohama City University
Keiji Uchida
Yokohama City University Medical Center
Motohiko Goda
Yokohama City University School of Medicine
Shinishi Suzuki
Yokohama City University School of Medicine
Kiyotaka Imoto
Yokohama City University Medical Center
Shigeo Takebayashi
Yokohama City University Medical Center: Yokohama Shiritsu Daigaku Fuzoku Shimin Sogo Iryo Center
Toshihiro Misumi
Yokohama City University School of Medicine Graduate School of Medicine: Yokohama Shiritsu Daigaku Igakubu Daigakuin Igaku Kenkyuka
Munetaka Masuda
Yokohama City University School of Medicine

Research article

Keywords: Aneurysm, Aorta, aortic arch, Aortic operation, Perfusion, Stroke

Posted Date: September 23rd, 2020

DOI: https://doi.org/10.21203/rs.3.rs-80680/v1

Abstract

Background

To evaluate the efficacy of isolated cerebral perfusion (ICP) for the prevention of cerebral infarction and the occurrence of early mortality, we retrospectively compared the outcomes between old patients with or without ICP in total arch replacement (TAR)

Methods

Between January 2003 and March 2019, 74 patients aged older than 75 years underwent elective TAR for arch aneurysm. The participants were divided into two groups according to the brain protection method used: the ICP method (ICP group, n = 46) and the selective antegrade cerebral perfusion method (non-ICP group, n = 28).

Results

The 30-day mortality rates of both groups were zero. The in-hospital mortality rates of the ICP and non-ICP groups were 4.3% and 3.5%, respectively. The median follow-up duration was 34 months, and the 1-year survival rates were 90.1% in the ICP group and 90.7% in the non-ICP group. The incidence of postoperative cerebral infarction was significantly lower in the ICP group (n = 1, 2.1%) than in the non-ICP group (n = 5, 17.8%).

Conclusions

ICP could result in a lower incidence of postoperative cerebral infarction in old patients who undergo TAR.

Background

The outcomes of open surgery for aortic aneurysm have improved with the development of surgical techniques and innovation in brain protection methods [1,2]. Intraoperative cerebral infarction is a complication of such procedure that has not been resolved [3]. Although the incidence of hemodynamic infarction may have decreased with improvements in selective cerebral perfusion, embolic infarctions are still considered a problem, particularly in old patients [4]. To decrease the incidence of cerebral infarctions in aortic surgery, we introduced the use of isolated cerebral perfusion (ICP), a novel procedure for extracorporeal circulation [5]. To evaluate the efficacy of ICP for the prevention of cerebral infarction and the incidence of early mortality, we retrospectively compared the outcomes between old patients with or without ICP in total arch replacement (TAR).

Methods

Between January 2003 and March 2019, 74 patients aged older than 75 years underwent elective TAR for arch aneurysm at Yokohama City University Medical Center. We excluded emergency cases of type A acute aortic dissection and aortic rupture and cases of redo aortic surgery for ascending aorta and aortic arch. Patients who underwent emergency surgery for aortic dissection or rupture of the aorta were not included because these conditions might have preoperative influence on the brain. Preoperatively, magnetic resonance imaging (MRI) or head computed tomography (CT), MR angiography (MRA), and carotid ultrasound were conducted to assess the brain, cerebral circulation, and the neck vessels, respectively.

We have been performing ICP during TAR since 2010. Until 2009, TAR was performed with conventional selective cerebral perfusion, in which the cannulae were directly inserted from the inside of the aorta after systemic perfusion cooling via various arterial cannulations.

All patients (n = 74) were divided into two groups according to the brain protection method used: the ICP method (ICP group, n = 46) and the SCP method (non-ICP group, n = 28).

Set-up during the ICP procedure

The bilateral axillary arteries were exposed before sternotomy. A 9-mm Dacron graft was anastomosed to the bilateral axillary arteries for systemic perfusion. After median sternotomy, bi-caval venous drainage was performed. The left common carotid artery (LCCA) was exposed without touching the aorta. The LCCA was proximally clamped and dissected, and a 12-Fr balloon-tipped cannula with a pressure monitor was inserted immediately. Extracorporeal circulation via the bilateral axillary artery and selective perfusion to the LCCA were simultaneously started. Separate roller pump was used to regulate the blood flow to LCCA. The mean pressure at the radial artery and LCCA were monitored and controlled between 40 and 70 mmHg. Circulatory arrest was induced at rectal temperature of 25°C. The brachiocephalic artery and left subclavian artery were clamped. ICP was immediately completed with blood flow through the bilateral axillary arteries and the LCCA (Figure 1).

Set-up during the non-ICP procedure

Systemic perfusion was achieved via the bilateral axillary and femoral arteries (n = 13), right axillary and femoral arteries (n = 5), bilateral axillary artery (n = 5), ascending aorta (n = 4), and ascending aorta and the bilateral axillary artery (n = 1).

With perfusion via the ascending aorta or the right axillary artery, the selective cerebral perfusion canulae were directly inserted from the inside of the aorta after circulatory arrest. When the bilateral axially arteries were used, the brachiocephalic artery and the left subclavian artery were clamped just after circulatory arrest, and the cerebral perfusion cannula was directed into the left carotid artery.

Neurological diagnosis

The postoperative neurological symptoms based on the clinical records were retrospectively reviewed. Postoperatively, intensivists checked the neurologic state of the patients every day in the intensive care unit. For symptomatic patients, the Department of Neurology was always consulted, and neurologists completed a neurological examination via CT scan in symptomatic patients. Postoperative cerebral infarction was defined as the persistence of permanent neurological dysfunction at discharge, which was accepted with the image and diagnosed by a neurologist. Transient neurologic dysfunction, which includes delirium, transient ischemic attack, and any neurologic dysfunction that was not judged as postoperative cerebral infarctions, was not assessed in this study.

Definitions

Cerebrovascular and carotid abnormality was defined as a carotid artery stenosis diagnosed via carotid ultrasound, which revealed >70% of stenosis in the area, or the occluded lesion of carotid or vertebral arteries and circle of Willis diagnosed by MRA. Previous stroke was defined as the preoperative clinical history of cerebrovascular disease that did not include transit ischemic attack.

Statistical analysis

Continuous data were expressed as median and interquartile range (25^{th}–75^{th} percentile). Discrete data were shown as counts and percentage. Continuous variables were compared with the Mann–Whitney U test, and categorical variables were compared with Pearson X^2 test or Fisher exact test. Kaplan–Meier analysis was performed to calculate survival.

Results

The characteristics of the patients are summarized in Table 1. There was significant difference in age, sex, hyperlipidemia, and chronic renal failure.

Table 1: Patient characteristics

	ICP (N = 46)	Non-ICP (N = 28)	P-Value
Age (years)	79 (77–81)	77 (76–79)	0.005
Sex (male)	36 (78%)	27 (96%)	0.044
Hypertension	42 (91%)	23 (82%)	0.209
Diabetes Mellitus	7 (15%)	3 (11%)	0.570
Hyperlipidemia	28 (60%)	5 (15%)	0.002
Smoking	34 (74%)	16 (57%)	0.135
Chronic renal failure (Cr>1.3)	12 (26%)	0 (0%)	0.002
Coronary artery disease	15 (33%)	12 (43%)	0.458
Previous Stroke	1 (2%)	4 (14%)	0.065
Cerebrovascular and carotid abnormality	3(7%)	3(11%)	0.372
PVD including AAA	13 (28%)	9 (32%)	0.796
LVEF (%)	70.7% (64.9–74.6)	69.8% (63.3–74.3)	0.714

PVD: Peripheral vascular disease, AAA: Abdominal aortic aneurysm, LVEF: Left ventricular ejection fraction

Surgical outcomes are summarized in Table 2. No significant difference was observed in terms of operative time, pump run, aortic clamp time, lower circulatory arrest time, and amount of fluid balance between the two groups. The 30-day mortality rates of both groups were zero. The in-hospital mortality rates in the ICP and non-ICP groups were 4.3% and 3.5%, respectively. The causes of death were sepsis in the ICP group and sepsis due to respiratory failure in the non-ICP group. The occurrence of postoperative cerebral infarction was significantly lower in the ICP group than in the non-ICP group (2.1% vs 17.8%, $p = 0.026$). The distribution of postoperative cerebral infarction concerning number and laterality is shown in Figure 2. Prolonged ventilation time (>72 h) and ICU stay did not significantly differ between the two groups (Table 3). The median follow-up duration was 34 months, and the 1-year survival rates were 90.1% in the ICP group and 90.7% in the non-ICP group.

Table 2: Operative results

	ICP (N = 46)	Non-ICP (N = 28)	P-Value
Operation time, min	502 (451–561)	483 (417–544)	0.286
Pump run, min	209 (181–235)	191 (170–225)	0.285
Aortic clamp time, min	127 (106–154)	112 (95–141)	0.352
Lower body Circulatory arrest time, min	65 (47–78)	53 (40–77)	0.511
Fluid Balance, ml	5044 (3478–6187)	5885 (4827–7249)	0.088
Concomitant procedure	12	5	0.301
CABG, n	4	4	0.350
Valve surgery, n	5 (TAP:2, TAP+PVI:2 AVR+TAP:1)	1 (AVR:1)	0.258
Frozen elephant trunk, n	4	0	0.142
Other, n	1 (PFOclosure:1)	0	0.622

CABG: Coronary artery bypass grafting, TAP: Tricuspid annuloplasty, PVI: Pulmonary vein isolation

AVR: Aortic valve replacement, PFO: Patent foramen ovale closure

Table 3: Postoperative outcomes

	ICP (N = 46)	Non-ICP (N = 28)	P-value
30-day mortality	0	0	
Hospital mortality	2	1	0.681
Postoperative cerebral infarction	1	5	0.026
Prolonged Ventilation > 72 H	22	10	0.463
ICU stay, days	4 (2–8)	3 (2–6.5)	0.432

ICU: Intensive care unit

In the ICP group, there was one case with perioperative stroke. He was an 84-year-old man who had a plaque in his BCA on enhanced CT. He had left hemiparesis after operation; a subsequent CT scan revealed multiple small infarctions on the right side of the brain. Although he had left hemiparesis after operation, he recovered to an extent that he could walk and was therefore transferred to a rehabilitation hospital.

Discussion

Antegrade cerebral perfusion (ACP) and hypothermic circulatory arrest with or without retrograde cerebral perfusion (HCA/RCP) are often used in aortic arch surgery. Okita et al. [3] revealed the clinical outcomes concerning aortic arch surgery in Japan and showed that the incidence of stroke was 6.7% in ACP and 8.6% in HCA/RCP.

Axillary artery perfusion for arch repair was reported to be effective in preventing embolic stroke and reducing early mortality [6,7]. Kim et al. have revealed that the incidence of right-side hemisphere stroke is significantly lower with axillary artery perfusion in open arch repair, which indicates that axillary artery perfusion could be useful in reducing early embolic stroke and mortality [7].

However, the risk of stroke in SCP procedure with axillary perfusions is unacceptably high at about 10% in our institution until 2009 [8]. We assumed that even bilateral axillary perfusion cannot completely prevent the effect of embolisms in the aorta due to turbulent blood flow with the artificial heart–lung machines around the arch. To reduce cerebral infarction during aortic surgery, we introduced the use of ICP, which is a novel procedure for extracorporeal circulation.

The important advantage of this procedure is that it could prevent aortic embolism during operation. It is possible for ICP to prepare the cerebral perfusion seldom touching the ascending aorta. In ICP, the systemic perfusion blood flow from the bilateral axillary perfusion went into the aorta, and the LCCA was clamped just before systemic perfusion was started to prevent turbulent flow with emboli from going to the cerebral circulation. The effectiveness of establishing cerebral perfusion before circulatory arrest for severe atheromatous aortas was reported by Shiiya et al [9]. Our method may have more advantages than their method because perfusion can be initiated without touching the arch and neck vessels, other than the LCCA.

In the non-ICP group, several methods of systemic perfusion were used based on preoperative CT findings and surgeon's preference to prevent the occurrence of morbidity. Although in the non-ICP group, axillary artery perfusion was used in 86% (24/28) of patients and bilateral axillary artery perfusion was used in 68% (19/28) of patients, stroke occurred in 17.8% (5/28) of patients. Furthermore, cerebral infarctions of the left dominant hemisphere were recognized in three patients. (Figure 2) According to our study, using axillary artery perfusion alone cannot effectively prevent serious cerebral infarction. It was found that the incidence of stroke was lower in the ICP group than in the non-ICP group, even if the mean age was >2 years. According to our study, using axillary artery perfusion alone cannot effectively prevent cerebral infarction.

Perioperative stroke induced by aortic emboli can be prevented by isolating the blood flow to the brain completely from the atheromatous aorta by clamping the LCCA just before initiation of systemic perfusion. In the ICP group, there was one case of stroke. The existence of a plaque in his BCA, which may have been the clamp site, might have contributed to the event. In this study, we could not assess the state of arch vessels into which the selective cerebral perfusion cannula was inserted or where the clamp site could be. It could be difficult even for ICP to avoid the emboli completely induced by clamping the arch vessels where the atheroma was rich. More precise examination of the arch vessels using preoperative multidetector CT and/or intraoperative epi-aortic echography may contribute to further improvement.

A disadvantage of the ICP procedure is the long operation time due to preparation of bilateral axillary arteries and anastomosis of the grafts to them. Comparing with other studies of TAR, our operative time in both groups was longer and the amount of fluid balance was higher. Moreover, a longer operative time could result in fluid balance greater than 5000 mL in our study [10].

Our hospital is an educational hospital. Because some perfusion sites were selected in the non-ICP group, there could be no significant difference in operation time. Stroke could make subsequent quality of life worse; therefore, we believe that it is worth performing the ICP procedure even if the operation time is extended because of the possible effect of preventing stroke in aortic surgery.

The present study had some limitations. The current study was a retrospective cohort study and was conducted on patients who underwent total arch repair in a single hospital. Furthermore, because of the small number of cases, risk adjustment was not performed. Postoperative CT scan or MRI of the brain was not performed on patients who did not present with symptoms to rule out asymptomatic stroke after the operation.

Conclusion

ICP could result in a lower incidence of postoperative cerebral infarction in old patients who undergo TAR.

Abbreviations

ACP : Antegrade cerebral perfusion

CT : Computed tomography

LCCA : Left common carotid artery

MRI : Magnetic resonance imaging

TAR : Total arch replacement

ICP : Isolated cerebral perfusion

MRA : Magnetic resonance angiography

Declarations

Ethics approval and consent to participate

The study protocol was approved by the institutional review boards of Yokohama city university. The requirement for informed consent from individual patients was waved because of the retrospective study design. (Approval number B200600024)

Consent for publication

Not applicable.

Availability of data and materials

Supporting data are available through the corresponding author on reasonable request.

Competing interests

The authors have no conflicts of interest.

Funding

None

Authors' contributions

Concept/design: KK, Data collection: KK, KU, Data analysis/interpretation: KK,KU,TM, Drafting article: KK, KU, MM, Critical revision of the article: KU,MG,SS,KI,ST,MM, Approval of the article: All authors read and approved the final manuscript.

Acknowledgments

None

Authors' information (optional)

Keiichiro Kasama,   Phone:+81452615656, Email: cvsl2012-007@yahoo.co.jp

Keiji Uchida, Email: k_uchida@yokohama-cu.ac.jp

Motohiko Goda, Email: go.supra1203@gmail.com

Shinichi Suzuki, Email: sshin1@yokohama-cu.ac.jp

Kiyotaka Imoto, Email: imoto@yokohama-cu.ac.jp

Shigeo Takebayashi, Email: take2922@yokohama-cu.ac.jp

Toshihiro Misumi, Email: misumit@yokohama-cu.ac.jp

Munetala Masuda, Email: mmasuda@yokohama-cu.ac.jp :

References

1. Kazui T, Washiyama N, Muhammad BA, Terada H, Yamashita K, Takinami M, et al. Total arch replacement using aortic arch branched grafts with the aid of antegrade selective cerebral perfusion. Ann Thorac Surg. 2000; 70:3-9.
2. Ueda Y, Miki S, Kusuhara K, Okita Y, Tahata T, Yamanaka K. Surgical treatment of aneurysm or dissection involving the ascending aorta and aortic arch, utilizing circulatory arrest and retrograde cerebral perfusion. J Cardiovasc Surg. 1990;31:553-8.
3. Okita Y, Miyata H, Motomura N, Takamoto S; Japan Cardiovascular Surgery Database Organization. A study of brain protection during total arch replacement comparing antegrade cerebral perfusion versus hypothermic circulatory arrest, with or without retrograde cerebral perfusion: analysis based on the Japan Adult Cardiovascular Surgery Database. J Thorac Cardiovasc Surg. 2015;149:S65-73.
4. Pacini D, Di Marco L, Leone A, Di Bartolomeo R, Sodeck G, Englberger L, et al. Antegrade selective cerebral perfusion and moderate hypothermia in aortic arch surgery: clinical outcomes in elderly patients. Eur J Cardiothorac Surg. 2012;42:249-53.
5. Kasama K, Uchida K, Karube N, Takebayashi S, Imoto K, Masuda M. Impact of isolated cerebral perfusion technique for aortic arch aneurysm repair in elderly patients. Ann Thorac Surg. 2019;107: 533-8.
6. De Paulis R, Czerny M, Weltert L, Bavaria J, Borger MA, Carrel TP, et al. Current trends in cannulation and neuroprotection during surgery of the aortic arch in Europe. Eur J Cardiothorac Surg. 2015;47:917-23.
7. Kim JH, Lee SH, Lee S, Youn YN, Yoo KJ, Joo HC. Axillary artery cannulation reduces early embolic stroke and mortality after open arch repair with circulatory arrest. J Thorac Cardiovasc Surg. 2020;159:772-8.
8. Uchida K. Surgical strategy for the aneurysm of distal arch. Paper presented at: 41st Annual Meeting of the Japanese Society for Cardiovascular Surgery; February 24, 2011; Tokyo, Japan.
9. Shiiya N, Kunihara T, Kamikubo Y, Yasuda K. Isolation technique for stroke prevention in patients with a mobile atheroma. Ann Thorac Surg. 2001;72:1401-2.
10. Okada K, Omura A, Kano H, Sakamoto T, Tanaka A, Inoue T, et al. Recent advancements of total aortic arch replacement. J Thorac Cardiovasc Surg. 2012;144:139-45.

Figures

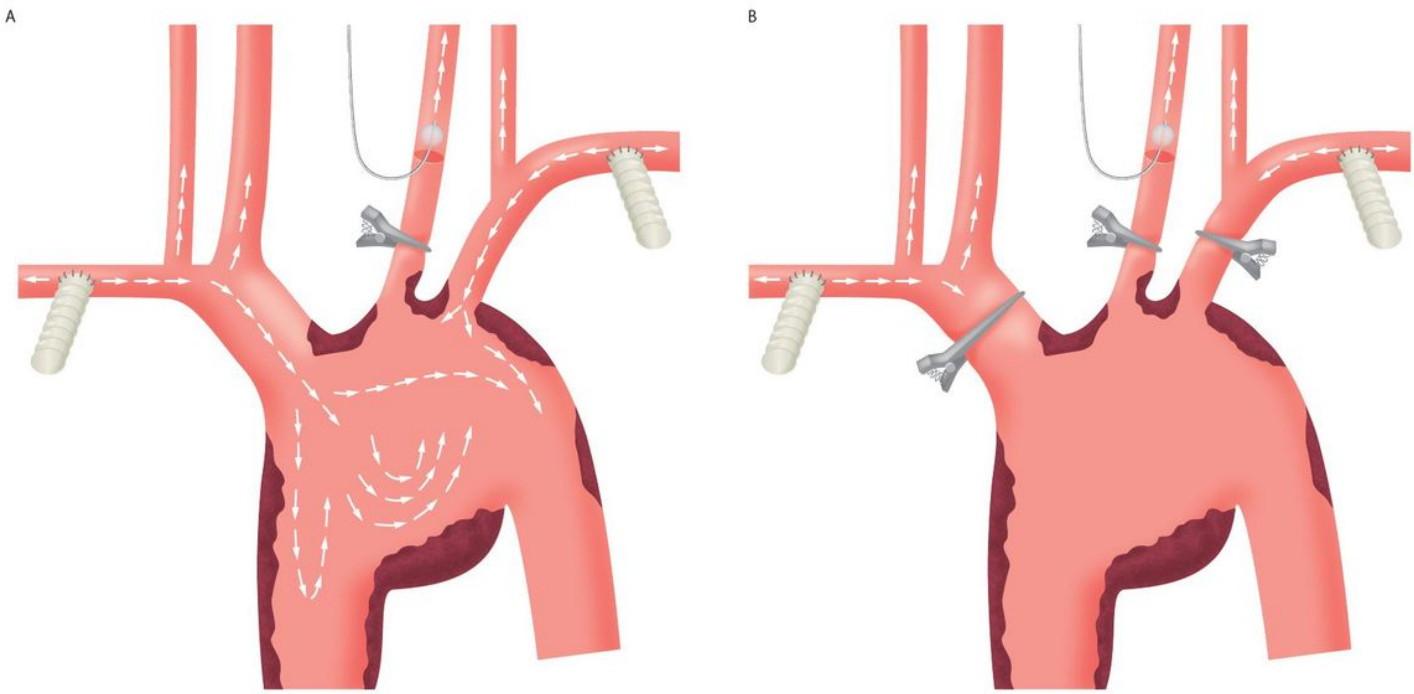
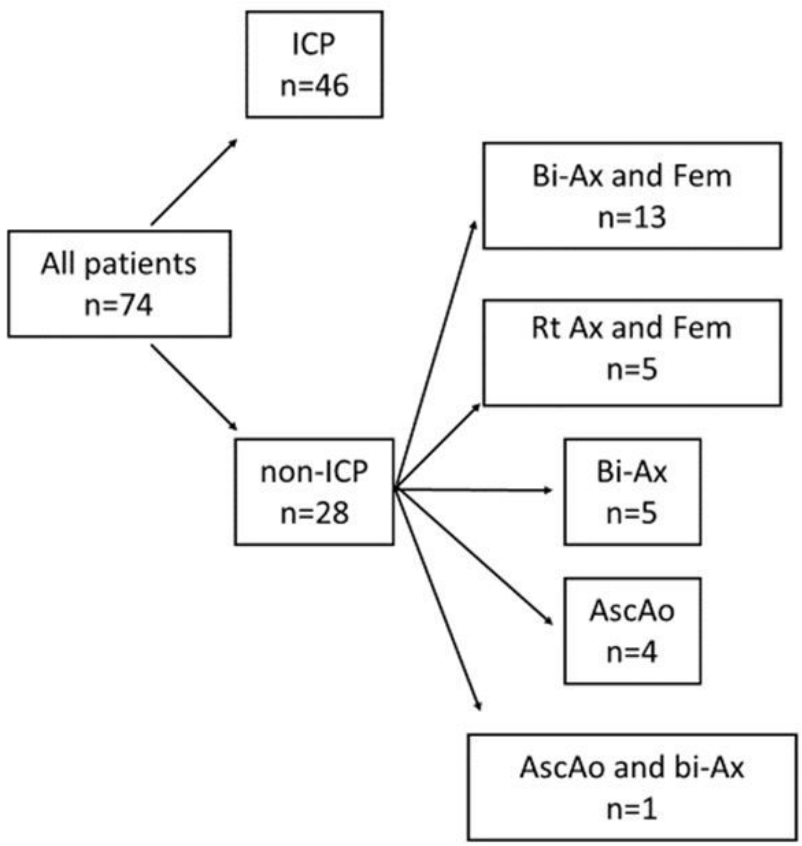


Figure 1

The direction of blood flow in ICP is indicated by arrows. (a) Systemic perfusion during cooling (b) Cerebral perfusion during circulatory arrest

Figure 2



Number and laterality of cerebral infarction		
R	L	Bi-lateral
1	0	0
2	0	0
0	1	1
0	0	1
0	0	0
0	0	0

Figure 2

The distribution of postoperative cerebral infarction concerning number and laterality is shown