Interactive CardioVascular and Thoracic Surgery

Tepid hypothermic (32 °C) circulatory arrest for total aortic arch replacement: a paradigm shift from profound hypothermic surgery

Go Watanabe, Hiroshi Ohtake, Shigeyuki Tomita, Shohjiro Yamaguchi, Keiichi Kimura and Noriyoshi Yashiki

Interact CardioVasc Thorac Surg 2011;12:952-955; originally published online Mar 22, 2011;
DOI: 10.1510/icvts.2010.250605

doi:10.1510/icvts.2010.250605

INTERACTIVE
CARDIOVASCULAR AND
THORACIC SURGERY

Interactive CardioVascular and Thoracic Surgery 12 (2011) 952–955

www.icvts.org

Institutional report - Vascular thoracic

Tepid hypothermic (32 °C) circulatory arrest for total aortic arch replacement: a paradigm shift from profound hypothermic surgery

Go Watanabe, Hiroshi Ohtake*, Shigeyuki Tomita, Shohjiro Yamaguchi, Keiichi Kimura, Noriyoshi Yashiki

Department of General and Cardiothoracic Surgery, Kanazawa University, 13-1 Takara-machi, Kanazawa 920-8641, Japan

Received 10 August 2010; received in revised form 28 February 2011; accepted 2 March 2011

Abstract

In total aortic arch replacement (TARCH) using hypothermic circulatory arrest (HCA) and selective cerebral perfusion (SCP), postoperative cerebral complications, including metabolic abnormalities, are by no means rare. Furthermore, there is a lack of international guidelines for the optimal perfusion temperature and flow for SCP. Starting in 2008, TARCH was performed using tepid HCA at 32 °C. In the present study, 27 patients (group C) who underwent TARCH with deep hypothermia at the lowest rectal temperatures of 20–25 °C were retrospectively reviewed and compared with 23 patients (group W) who underwent TARCH with 32 °C tepid hypothermia. Preoperative patient characteristics and intraoperative and postoperative parameters were compared. Preoperative patient characteristics did not differ significantly between the two groups. Circulatory arrest time, cardiopulmonary bypass time, operating time, amount of blood transfused and postoperative neurological complications were significantly reduced in group W compared with group C. Our procedure of TARCH using tepid hypothermia at 32 °C was safe, and it significantly reduced all parameters of extracorporeal circulation time. However, this study has several limitations. To indicate the safety and usefulness of tepid HCA for TARCH, a further multifaceted study should be performed with a greater number of patients.

Keywords: Thoracic aortic aneurysm; Open surgery; Hypothermic cardiac arrest

1. Introduction

Total aortic arch replacement (TARCH) is generally performed with hypothermic circulatory arrest (HCA) at 15–22 °C plus selective cerebral perfusion (SCP) [1–4]. This procedure has been found to protect the brain, but postoperative cerebral complications are by no means rare, including malperfusion and a shift of the oxygen dissociation curve to the right [4, 5]. In addition, the cooling and rewarming phases of HCA are time-consuming, and the complications because of prolonged cardiopulmonary bypass (CPB) remain a serious problem even now [6, 7].

However, there is a lack of international guidelines for the optimal perfusion temperature and flow for SCP, the safe time limit for HCA, and the optimal lowest urinary rectal temperature. Prior to 2006, we had performed TARCH using HCA and SCP at 20–22 °C. In 2007, TARCH was performed using 25–28 °C, with good results. Since 2008, TARCH has been performed using tepid HCA together with SCP at 32 °C.

In the present study, TARCH with deep HCA (at the lowest rectal temperatures of 20–25 °C) was compared with TARCH with tepid HCA (32 °C), retrospectively. The purpose of the present study is to clarify the usefulness of tepid hypothermia in TARCH.

*Corresponding author. Tel.: +81-76-2652355; fax: +81-76-2226833.
E-mail address: ohtake@med.kanazawa-u.ac.jp (H. Ohtake).

2. Materials and methods

2.1. Patients

Fifty patients who underwent three-branch reconstruction with TARCH were investigated. The aetiology was dissecting aortic aneurysm or atherosclerotic aortic aneurysm. Patients were divided into two groups: group C consisted of 27 patients who underwent deep HCA at a rectal temperature of 20–25 °C from 2004 to 2006, while group W consisted of 23 patients who underwent tepid HCA at a rectal temperature of 32 °C from 2008 to May 2010. Both groups consisted of consecutive patients encountered during this period. Group C and group W were compared in terms of preoperative patient characteristics (Table 1), intraoperative parameters (Table 2) and postoperative parameters (Table 3).

2.2. Surgical techniques

In both group C and group W, arterial access was established by cannulating the femoral and brachiocephalic artery. In group C, the patient was cooled until the patient's rectal temperature reached 22–25 °C. In group W, the patients' rectal temperature was maintained at 32 °C. After arterial cross-clamping, blood cardioplegia was infused. After the target temperature had been attained, perfusion from the femoral artery was stopped, and circulation was switched to SCP and HCA distal to the descending

Table 1. Preoperative patient characteristics

	Group C (n=27)	Group W (n=23)	P-value
Age (years)	59.4±13.1	62.0±12.7	NS
Male/Female (n)	20/7	14/9	NS
Dissection/non-dissection (n)	18/9	10/13	NS
Left ventricular ejection fraction (%)	64.8±6.6	63.5±9.5	NS
Diameter of aorta (mm)	61.9±12.9	65.1±14.3	NS
Complications (n):			
Marfan syndrome+aortic regurgitation	1	5	NS
Arteriosclerosis obliterans	3	3	NS
Cerebrovascular accident	1	2	NS
Ischemic heart disease		4	0.038
Chronic obstructive lung disease		2	NS
Atrial fibrillation	2	2	NS
Re-do		1	NS
Carotid stenosis	1		NS
Recurrent nerve paralysis	1	1	NS
Takayasu disease	1		NS

NS, not significant.

aorta. SCP was established via the cannula from the brachiocephalic artery using the main pump and via the cannulae from the left carotid and subclavian arteries using another pump to attain a total flow rate of 10 ml/kg/min or above and a radial artery pressure of 60–70 mmHg. After the open distal anastomosis, perfusion from the femoral artery was resumed, and the patients in group C were rewarmed. In group W, 32 °C was maintained. After reconstruction of the left subclavian and carotid arteries, proximal anastomosis was performed along with another additional cardiac surgery if necessary. Upon infusion of terminal warm blood cardioplegia, the aortic cross-clamp (ACC) was released. Finally, the brachiocephalic artery was reconstructed, and the patient was weaned from CPB.

These procedures were performed with the approval of the Medical Ethics Committee at Kanazawa University. Written informed consent was obtained from the patients prior to participation.

2.3. Statistical analysis

For group comparisons, the Mann–Whitney test was used for continuous data and a χ^2-test or Fisher's exact test was used for dichotomized data. A two-tailed $P<0.05$ was considered statistically significant.

3. Results

Group C and group W did not differ significantly in terms of all parameters without ischemic heart disease (Table 1). With regard to the surgical modality, five patients in group W underwent the Bentall procedure in addition to aortic arch replacement.

A comparison of operative parameters (Table 2) showed that the circulatory arrest (CA) time, CPB time and operating time were significantly reduced, and SCP time tended to be more reduced for group W than for group C. Moreover, bleeding was significantly decreased and the volume of blood transfused was greatly reduced for group W compared with group C.

Table 2. Comparison of operative parameters

	Group C (n=27)	Group W (n=23)	P-value
Operation time	431±102 min	303±63.1 min	0.000
Lowest temperature	23.1±3.0	31.6±0.8	0.000
Circulatory arrest time	58.1±27.8 min	25.0±7.1 min	0.000
Selective cerebral perfusion	65.5±34.9 min	40.2±12.0 min	0.012
Cardiopulmonary bypass time	197±46.3 min	128±31.9 min	0.000
Aortic cross-clamp time	123.6±46.3 min	90.6±30.4 min	0.006
Bleeding	1945±1075 ml	1202±688 ml	0.002
Transfusion	1490±1109 ml	682±962 ml	0.010
Concomitant cardiac surgery	5	16	0.000
Bentall operation	2	9	0.021
CABG	3	6	NS
Pulmonary vein isolation		1	NS

CABG, coronary artery bypass grafting; NS, not significant.

As for postoperative cerebral complications, transient quadriplegia occurred in one patient and cerebral infarction in five patients in group C, while no cerebral complications were observed in group W (Table 3). One patient in group C had a prolonged intubation of over 72 hours, while two patients in group W were extubated in the operating room.

4. Discussion

4.1. The present results

Two TARCH modalities with different rectal temperatures were compared. CA at 32 °C proved superior to deep HCA because of a significant shortening in CA time, CPB time, operating time and postoperative intubation time. This shortening was thought to be achieved for several reasons stated as follows: the surgical technique was improved upon, coagulopathy was not found, and additional sutures were not needed. However, ACC time was not significantly reduced for group W, and this can be explained by the additional Bentall procedure performed for five patients in group W. The procedure in group C required waiting with the aorta clamped until the patient's body temperature reached deep hypothermia. In group W, however, the ACC time was the time taken for the additional surgery plus open distal anastomosis.

Furthermore, there was not one case of cerebral complication after surgery despite a considerably high rate of preoperative cerebral complications in group W. These results provide evidence that aortic arch replacement at 32 °C is an innovative method for TARCH surgery. Although SCP time did not differ significantly, it tended to be reduced for group W. In addition, intraoperative bleeding and the amount of blood transfused decreased significantly for

Table 3. Postoperative data

	Group C (n=27)	Group W (n=23)	P-value
Postoperative extubation (h)	88.1±116	23.5±28.9	0.000
Length of hospital stay (days)	41.7±23.1	28.2±10.4	0.015
Cerebral infarction (n)	5	0	0.030
Transient ischemic attack/delirium (n)	1	0	NS
Prolonged intubation >72 hours (n)	1		NS
Operating room extubation (n)		2	NS

NS, not significant.

Institutional Report

Table 4. Comparison of reports on total aortic arch replacement (hypothermic circulatory arrest and antegrade selective cerebral perfusion)

Reference	Year	Author	Number of patients	Early death (%)	CVA (%)	Op. time	CPB time	ACC time	SCP time	CA time	Lowest body temp.	SCP temp.
[8]	2009	Salazar et al.	38	8	11	–	220	116	62	31	11	15
[3]	2002	Bachet and Guilmet	206	17	6	–	125	–	68	32	25	–
[9]	2001	Okita et al.	30	6.6	6.6	451	213	103	117	55	22	–
[2]	2008	Sundt et al.	50	8	5		188	–	–	41	23	–
[1]	2008	Khaladj et al.	145	11.6	9.6	290	184	115	23	29	25	14
This study		Watanabe	12	0	0	439	174	89	50	40	22	–
			12	0	0	290	121	83	39	22	32	–

CVA, cerebrovascular accident; Op. time, operating time; CPB, cardiopulmonary bypass; ACC, aortic cross-clamp; CA, circulatory arrest; temp, temperature.

group W. Moderate HCA is reported to reduce the amount of blood transfused more than low HCA, but an extremely small amount of blood was transfused (an average of 682 ml) with tepid HCA. This suggests that disruption of the coagulation system was minimal.

4.2. Does hypothermia in TARCH prevent cerebral damage?

A majority of facilities perform TARCH using 11–25 °C HCA plus 15 °C SCP [1–3]. Mortality is 6–17% and has improved substantially from when deep HCA was used. However, the rate of neurological complications reported is relatively high, ranging from 5 to 11% (Table 4) [1–3, 8, 9]. Of course, not all the neurological complications are caused by cerebral perfusion; some are caused by the preoperative conditions and surgical procedures. Experimentally, hypothermia has been found to protect brain tissue. For every 1 °C drop in temperature, cerebral metabolism decreases by 7% [5]. However, brain protection by hypothermia does not mean an improvement in brain perfusion during hypothermia. Cerebral demand is determined by cerebral blood flow, cerebral vascular resistance and venous pressure. During hypothermia, cerebral vascular resistance increases and perfusion worsens [5]. SCP causes cerebral damage not only by cooling, but also by the temperature imbalance during the rewarming phase that has been reported to induce brain damage [5–7]. In recent years, TARCH using HCA and SCP at around 25 °C has been reported in Japan [10] and other countries. These reports describe favourable surgical outcomes with cerebrovascular accident rates $<5\%$. These relatively large-scale studies provide clinical evidence that moderate HCA and SCP reduce brain damage. Moreover, recent reports have revealed further advances in aortic arch surgery performed at rectal temperatures as low as 25–32 °C [11, 12].

At the current authors' facility, TARCH is performed under the following conditions: (1) a time limit for HCA of 30 minutes, which should allow ample time for open distal anastomosis of an aortic aneurysm; (2) CA of the lower body at the lowest rectal temperature of 32 °C; and (3) perfusion of the cervical branch at 32 °C. When SCP is performed, the optimal perfusion volume is indicated by the perfusion pressure and controlled with an extracorporeal circulation pump that increases the perfusion volume until the mean pressure of the perfusion-side radial artery reaches 60–70 mmHg. Among the current patients, some required a blood flow of 15–20 ml/kg to maintain their blood pressure. Sufficient blood flow and pressure are crucial to avoid cerebral complications.

4.3. What is the effect of lower body HCA?

The merit is that the lower the temperature, the longer the CA can theoretically be sustained. Reports that have described the SCP temperature and deep HCA time have indicated that surgery is generally performed at 22 °C and with HCA lasting around 60 minutes [4, 9, 13]. However, whether open distal anastomosis takes as long as 60 minutes has to be questioned. With continuous improvement in surgical techniques, open distal anastomosis of the descending aorta can be performed in <30 minutes. In the present study, the mean CA lasted for 25.1 minutes in 23 patients. Open distal anastomosis was completed within the safe HCA time limit of 30 minutes. There was absolutely no postoperative complication involving the spinal cord or renal function in group W, indicating that CA at 32 °C for <30 minutes provides favourable results.

4.4. Limitations

The present study is a retrospective study. Both groups consisted of consecutive patients and were not specially matched by characteristics. The number of patients was relatively small. Moreover, re-do cases or some type A dissection cases would present another situation because complex operations are needed.

5. Conclusion

TARCH using tepid HCA at 32 °C was found to be safe and significantly decreased CA time, SCP time, CPB time and operating time. Furthermore, bleeding as well as the amount of blood transfused decreased, and no postoperative cerebral complications were observed. However, this study has several limitations. To indicate the safety and usefulness of tepid HCA for TARCH, a further multifaceted study should be performed with a greater number of patients.

References

[1] Khaladj N, Shrestha M, Meck S, Peterss S, Kamiya H, Kallennbach K. Hypothermic circulatory arrest with selective antegrade cerebral perfusion in ascending aortic and aortic arch surgery: a risk factor analysis for adverse outcome in 501 patients. J Thorac CardioVasc Surg 2008; 135:908–914.

[2] Sundt TM, Orszulak TA, Cook DJ, Schaff HV. Improving results of open arch replacement. Ann Thorac Surg 2008;86:787–796.
[3] Bachet J, Guilmet D. Brain protection during surgery of the aortic arch. J Card Surg 2002;17:115–124.
[4] O'Dwyer C, Prough DS, Johnston WE. Determinants of cerebral perfusion during cardiopulmonary bypass. J Cardiothorac Vasc Anesth 1996;10:54–65.
[5] Usui A, Oohara K, Murakami F, Ooshima H, Kawamura M, Murase M. Body temperature influences regional tissue blood flow during retrograde cerebral perfusion. J Thorac Cardiovasc Surg 1997;114:440–447.
[6] Greeley WJ, Ungerleider RM, Kern FH, Brusino FG, Smith LR, Reves JG. Effects of cardiopulmonary bypass on cerebral blood flow in neonates, infants, and children. Circulation 1989;80(3 Pt1):I209–I215.
[7] Croughwell ND, Frasco P, Blumenthal JA, Leone BJ, White WD, Reves JG. Warming during cardiopulmonary bypass is associated with jugular bulb desaturation. Ann Thorac Surg 1992;53:827–832.
[8] Salazar J, Coleman R, Griffith S, McNeil J, Young H, Calhoon J, Serrano F, DiGeronimo R. Brain preservation with selective cerebral perfusion for operations requiring circulatory arrest: protection at 25 °C is similar to 18 °C with shorter operating times. Eur J Cardiothorac Surg 2009; 36:524–531.
[9] Okita Y, Minatoya K, Tagusari O, Ando M, Nagatsuka K, Kitamura S. Prospective comparative study of brain protection in total aortic arch replacement: deep hypothermic circulatory arrest with retrograde cerebral perfusion or selective antegrade cerebral perfusion. Ann Thorac Surg 2001;72:72–79.
[10] Minatoya K, Ogino H, Matsuda H, Sasaki H. Rapid and safe establishment of cardiopulmonary bypass in repair of acute aortic dissection: improved results with double cannulation. Interact CardioVasc Thorac Surg 2008; 7:951–953.
[11] Cook RC, Gao M, Macnab AJ, Fedoruk LM, Day N, Janusz MT. Aortic arch reconstruction: safety of moderate hypothermia and antegrade cerebral perfusion during systemic circulatory arrest. J Card Surg 2006;21:158–164.
[12] Bakhtiary F, Dogan S, Zierer A, Dzemali O, Oezaslan F, Therapidis P, Detho F, Wittlinger T, Martens S, Kleine P, Moritz A, Aybek T. Antegrade cerebral perfusion for acute type A aortic dissection in 120 consecutive patients. Ann Thorac Surg 2008;85:465–469.
[13] Strauch JT, Spielvogel D, Lauten A, Galla JD, Lansman SL, McMurtry K, Griepp RB. Technical advances in total aortic arch replacement. Ann Thorac Surg 2004;77:581–590.