Outcome of Less Invasive Proximal Arch Replacement With Moderate Hypothermic Circulatory Arrest Followed by Aggressive Rapid Re-Warming in Emergency Surgery for Type A Acute Aortic Dissection

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Background The mid-term outcome of quick proximal arch replacement with moderate hypothermia followed by aggressive rapid re-warming in emergency surgery for type A acute aortic dissection (AAD) was assessed.

Methods and Results Eighty-five patients were divided into 2 groups: group I consisted of 43 patients undergoing surgery for deep hypothermic circulatory arrest and selective cerebral perfusion; and group II consisted of 42 patients who recently underwent aggressive rapid re-warming. During open distal anastomosis in group II patients with a rectal temperature of 28°C but who did not suffer any cerebral perfusion, circulating blood in the cardiopulmonary bypass (CPB) circuit was warmed to 40°C. As soon as distal anastomosis was completed, rapid re-warming was initiated by a 40°C blood perfusion. The duration of CPB (I: 182.1 vs II: 85.3 min), overall operation (305.0 vs 150.8 min), postoperative mechanical ventilation (44.3 vs 9.1 h), and hospital stay (31.4 vs 9.6 days) were significantly shorter in group II patients. The incidence of postoperative brain complication (I: 14.0 vs II: 2.4%), renal failure (14.0 vs 0%), pneumonia (18.6 vs 4.8%), and mortality (9.3 vs 0%) was significantly less in group II patients.

Conclusions Moderate hypothermia followed by a rapid re-warming procedure was safe and effective in the proximal arch replacement for AAD. (*Circ J* 2009; 73: 69–72)

Key Words: Aorta; Cardiovascular diseases; Dissection

Surgical mortality rates during emergency operation for type A acute aortic dissection (AAD) are still estimated to range from 9 to 30%, and is associated with postoperative complications such as cerebral injury, bleeding, renal failure, and pneumonia caused by longer operation time (>6 h), longer cardiopulmonary bypass (CPB) time (>4 h), deep hypothermia, and circulatory arrest (DHA).¹ If surgical stress could be minimized by shortening the duration of brain ischemic stress, CPB and operative procedures, the surgical outcome for patients with AAD could be further improved. In the majority of patients, an ascending or hemiarch replacement is sufficient, as the intimal tear is generally located in the ascending or the proximal aortic arch.² Recently, it has been reported that moderate hypothermic arrest at 26–28°C without any adjunctive cerebral protection was safe in patients undergoing hemiarch aortic replacement.³ We have established a

new procedure for proximal arch replacement for patients with moderate hypothermic arrest without cerebral perfusion, which is followed by aggressive rapid re-warming to shorten the duration of brain ischemia, CPB, and overall surgery. We report here on the initial results of this procedure for an octogenarian with AAD⁴ and have since performed this procedure for all the patients undergoing an emergency proximal arch replacement for AAD. The aim of this study is to assess the mid-term outcome of our newly modified technique.

Methods

Between March 2002 and February 2008, 114 patients underwent emergency surgery for AAD at our institution. The extent of aortic replacement was decided based on the location of the intimal tear (tear-oriented surgery). Ascending/hemiarch aortic replacement was performed in patients with the intimal tear localized in the ascending aorta or in the lesser curvature of the transverse aortic arch proximal to the left subclavian artery. In this series, 85 (74.6%) consecutive patients underwent ascending/hemiarch aortic replacement. We retrospectively reviewed these patients. Institutional review board approval was provided before publication of this manuscript and reporting of the information. Fifty patients (58.8%) were female, and the average age was 66.9±12.0 years, ranging from 36 to 90 years.

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Table 1 Preoperative Morbidity

	Group I	Group II	P value
Age (years)	69.2±9.8	64.5±13.6	NS
Sex (M/F)	13/30	22/20	0.038
Occlusion type	19 (44.2%)	21 (50%)	NS
AR	6 (14.0%)	5 (11.9%)	NS
Tamponade	16 (37.2%)	12 (28.6%)	NS
AMI	3 (7.0%)	2 (4.8%)	NS
CRF	2 (4.7%)	2 (4.8%)	NS
Cerebral infarct	2 (4.7%)	0	NS

NS, not significant; AR, aortic regurgitation; AMI, acute myocardial infarction; CRF, chronic renal failure.

Contrast computed tomography (CT) was performed for all patients as soon as they were referred to our hospital. Trans-thoracic echocardiography was then performed to detect pericardial effusion, assess aortic valve regurgitation (AR) and cardiac function. The contrast CT revealed a thrombosed occlusion type condition in 40 patients (47.1%). Twenty-eight patients (32.9%) were in a pre-shock state because of cardiac tamponade. Eleven patients (12.9%) had moderate AR and 2 patients (2.4%) had minor cerebral infarction. We divided these patients into 2 groups: group I consisted of 43 patients with deep hypothermic circulatory arrest (DHA) and antegrade selective cerebral perfusion (ACP) who underwent a standard emergency surgery during 2002 and 2005, to protect the brain; and group II consisted of 42 recent patients with moderate hypothermic circulatory arrest followed by aggressive rapid re-warming who underwent our newly developed method from January 2006. We compared the 2 groups in terms of in-hospital mortality and morbidity.

Surgical Procedure for Group I

CPB was implemented through femoral arterial cannulation. During the cooling phase, the temperature setting of the heat exchanger was 16°C. Both DHA and ACP for 3 arch vessels were used for cerebral protection. Each patient was cooled to 20°C (rectal temperature). The ascending aorta and/or aortic arch were then opened longitudinally under DHA. The aortic segment containing the intimal tear was resected and gelatin resorcinol formalin (GRF) glue was applied between the 2 dissected walls on both the distal and proximal stumps of the aorta. We used minimal amounts of glue and mixed approximately 1 part formalin to 10 parts gelatin. Furthermore, the aortic walls were reinforced by securing Teflon felt strips both inside and outside the aorta. Antegrade systemic circulation was established through a side branch of the Dacron prosthesis after completion of open distal anastomosis.

Surgical Procedure for Group II

During the cooling phase, the temperature setting of the heat exchanger was 16°C. Circulatory arrest was implemented at a rectal temperature of 28°C without any cerebral perfusion. GRF glue was also used, but only the outside of the aortic walls were reinforced by Teflon felt. During open distal anastomosis, circulating blood in the CPB circuit was warmed to 40°C by a heat exchanger and the patient's body (with the exception of the head) was also warmed using a hyper-hypothermia system (Medi-Term II; GAYMAR Inc, Orchard Park, NY, USA). As soon as distal anastomosis was completed, antegrade systemic circulation was established through a side branch of the Dacron prosthesis and rapid re-

warming was initiated by 40°C blood perfusion. As soon as the patient's blood was mixed first by a shot of 40°C blood, their drainage blood temperature increased to 30°C and the arterial blood decreased in temperature to 34°C. Therefore, the temperature balance between the infusion and drainage blood was kept under 5°C during rapid re-warming.

In both groups, if the additional procedure of coronary bypass (CABG) was required, distal anastomosis was completed during the cooling phase, and proximal anastomosis to the Dacron graft was performed just after graft replacement during the re-warming stage.

Statistical Analysis

Results were expressed as the mean ± standard deviation. Statistical calculations were conducted using StatView (SAS Inc, Cary, NY, USA). Using parametric and non-parametric data, statistically significant differences were determined using Student's t-test and Fisher's exact test, respectively. A P value of less than 0.05 was considered statistically significant.

Results

There was no difference between the groups in terms of average age, incidence of thrombosed occlusion, AR, cardiac tamponade, acute myocardial infarction, chronic renal failure, and cerebral infarction (**Table 1**). There were slightly more female patients in group I (**Table 1**). In group I, the ascending and proximal hemiarch replacements were carried out in 29 and 14 patients, respectively. An intimal tear was resected in 38 patients, but in 5 patients, it was not identified. In group II, the ascending and proximal hemiarch replacements were carried out in 25 and 17 patients, respectively. An intimal tear was resected in 35 patients, but in 7 patients, it was not identified. Additional CABG (Saphenous vein to right coronary artery) was required for 2 patients in both groups. There was no difference in terms of operative characteristics. The rectal temperature was significantly higher in group II (26.9±1.3°C) compared to group I (20.4±1.1°C, $P<0.0001$). The durations of cerebral protection (I: 63.8±13.0 vs II: 20.6±5.1 min, $P<0.0001$), and CPB (I: 182.1±55.1 vs II: 85.3±17.2 min, $P<0.0001$) were significantly shorter in group II. The duration of overall operation in group II was 150.8±32.6 min, ranging from 101 to 225 min, which was significantly shorter than that for group I (305.0±56.4 min, $P<0.0001$). The duration of postoperative mechanical ventilation in group II was 9.1±4.7 h, which was significantly shorter than that for group I (44.3±25.7 h, $P<0.0001$). The duration of postoperative hospital stay in group II was 9.7±1.9 days, which was significantly shorter than that for group I (31.4±19.4 days,

Table 2 Operative Outcome

	Group I	Group II	P value
Core temperature (°C)	20.4±1.1	26.9±1.3	<0.0001
Brain exclusion (min)	63.8±13.0	20.6±5.1	<0.0001
CPB (min)	182.1±55.1	85.3±17.2	<0.0001
OPT (min)	305.0±56.4	150.8±32.6	<0.0001
Ventilation (h)	44.3±25.7	9.1±4.7	<0.0001
HP stay (day)	31.4±19.4	9.7±1.9	<0.0001
TND	6 (14.0%)	1 (2.4%)	0.0446
Permanent brain damage	5 (11.6%)	1 (2.4%)	NS
Re-exploration	3 (7.0%)	3 (7.1%)	NS
ARF	6 (14.0%)	0	0.0101
Pneumonia	8 (18.6%)	2 (4.8%)	0.039
Tracheostomy	5 (11.6%)	0	0.0196
Mortality	4 (9.3%)	0	0.0429

CPB, cardiopulmonary bypass; OPT, operating time; HP, postoperative hospital stay; TND, temporally neurological dysfunction; NS, not significant; ARF, acute renal failure.

$P<0.0001$; **Table 2**). In group I, 6 patients experienced complications of postoperative temporally neurological disorder (TND), 5 had permanent cerebral damage, 3 were taken back to the operating theater because of bleeding, 6 required hemodialysis for postoperative renal failure, 8 had pneumonia (including 5 who required a tracheostomy), and the hospital mortality rate was 9.3% (4 patients). In contrast, just 1 or 2 patients had such complications and hospital mortality was not observed in group II. The incidence of TND ($P=0.0446$), postoperative renal failure ($P=0.0101$), pneumonia ($P=0.039$), tracheostomy ($P=0.0196$), and mortality ($P=0.0429$) was significantly less in group II than in group I (**Table 2**). In group I, 2 patients died because of coronary malperfusion and another 2 died in hospital because of brain damage. In group I, 6 patients died because of a traffic accident, cerebral infarction, pneumonia, heart failure, or senility during the follow-up period. In contrast, in group II, 1 patient died because of a traffic accident 6 months postoperatively, 1 patient died of cerebral bleeding 3 months postoperatively and 1 patient died because of a ruptured abdominal aortic aneurysm 7 months postoperatively. The actual survival rate at 2 and 5 years was 87.2 and 83.6%, respectively in group I. It was 91.2% at 2 years follow-up for group II. There was no difference in terms of the mid-term survival rate between the groups.

Discussion

The extent of aortic replacement and operating time has been reported as significant risk factors for hospital mortality in previous reports.^{1,5} This is because the patients often might not be able to tolerate the aggressive surgical stress of deep hypothermia, a long duration of cerebral exclusion or CPB. Furthermore, a prolonged operation can increase mortality through coagulopathy, cerebral ischemia, infection, or multiple organ failure.⁶ In the present study, the incidence of postoperative complications such as TND, renal failure, or respiratory failure was markedly less in those patients undergoing mild hypothermia and rapid re-warming. And there was no mortality in group II. In contrast, in group I, however, approximately 10% of the patients developed a brain injury, renal failure, or respiratory failure during deep hypothermia with ACP. And finally, 4 patients died in hospital. This might be associated with too much stress caused by DHA and a longer duration of CPB. Cook et al reported that systemic temperatures below 22°C might

not be necessary and might be associated with a higher incidence of neurologic injury when using ACP during DHA.⁷ Greeley et al reported that those patients cooled to 28°C had a predicted brain ischemic tolerance of 11–19 min.⁸ Our results suggest that moderate hypothermic arrest at 28°C without any adjunctive cerebral protection within 20 min is safe. Therefore, we consider that performing surgery with the minimum invasive stress is considered to be a key factor for saving lives and maintaining of quality of life.

In the surgical intervention for AAD, a partial or hemi-arch replacement is sufficient in the majority of patients. In particular, for patients with serious dissection-related organ malperfusion, a conservative limited ascending/hemiarch replacement would be preferable. In the present study, 2 patients died because of coronary malperfusion and another 2 patients died because of brain damage in group I. In contrast, in group II, the 2 patients with coronary malperfusion survived without any mechanical support. Aortic repair and decompression of the false lumen should be performed before malperfusion causes irreversible damage to the malperfused organs. Therefore, several unique diagnosis techniques have recently been developed⁹ and early recognition of the disease and earlier referral to surgical units would improve the outcome of emergency surgery for this lethal disease. As the main goal of emergency surgery for acute dissection is saving the patient's life, conservative tear-oriented surgery might be appropriate. In our new technique, moderate hypothermic (28°C) circulatory arrest without any cerebral perfusion for distal anastomosis was performed. Although it took approximately 20 min to complete the distal anastomosis, the durations for CPB and overall operation were approximately 85 and 150 min, respectively, which was much quicker than those of previous reports.³ The shortest operation time in our study was 101 min from skin-to-skin. In general, quicker is not always better. However, we believe that quicker surgery definitely makes for a better outcome because it can minimize the surgical stress caused by hypothermia or CPB for such a lethal disease.

In our new procedure, the patients' bodies were re-warmed quite rapidly as soon as the distal anastomosis was completed. It has been generally accepted that re-warming upon hypothermia should be conducted as slowly as possible!¹⁰ In DHA, cerebral metabolism and oxygen extraction remain significantly reduced during re-warming and after CPB, suggesting disordered cerebral metabolism and oxygen utilization after DHA. Furthermore, cerebral blood flow (CBF)

significantly decreases in patients with DHA during the re-warming phase!¹¹ If the cerebral circulation was unable to regulate oxygen delivery after DHA, the brain would be at an increased risk of hypoxic injury during episodes of hypoxemia in the re-warming phase!¹² Therefore, we speculate that the potential mismatches in flow/metabolism after DHA are most likely expressed during rapid temperature or perfusion changes such as that which occurs during re-warming. In contrast, Greeley et al reported that those patients who were cooled to 28°C demonstrated a return to baseline in CBF during re-warming and after weaning from CPB. However, in patients exposed to DHA, cerebral reperfusion was significantly lower during re-warming and after CPB.⁸ Therefore, we believe that there is no problem to induce rapid re-warming after circulatory arrest in cases of moderate hypothermia (28°C). Moreover, it can shorten the durations of CPB and overall operation time.

Study Limitations

This study has several limitations. It was a retrospective analysis of a study conducted at a single institution. Aggressive rapid re-warming seems to be bit eccentric as a standard approach, however, we believe that the data from this newly modified surgical technique, which can be completed in approximately 2 h in patients with AAD, is quite unique. Future studies involving more patients from a variety of institutions need to be conducted in order to determine how effective this method really is.

Conclusion

Moderate hypothermia followed by an aggressive rapid re-warming procedure was safe and effective in the proximal arch replacement for AAD.

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