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Fast – Track Total Arch Replacement

Tomoaki Suzuki and Tohru Asai

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1. Introduction

Total arch replacement (TAR) is still a challenging procedure for cardiovascular surgeons because of the high incidence of mortality and brain accident. We have developed a fast-track TAR technique which is completed within 3-4 hours. In the present chapter, we describe in detail our surgical procedure for improving TAR outcomes.

Historically, TAR has required deep hypothermic circulatory arrest (DHCA) or retrograde cerebral perfusion with DHCA during distal anastomosis. However, DHCA has been shown to have adverse effects upon multiple organ systems. Moreover, these techniques do not give the surgeon adequate time to complete the aortic arch repair, the safety margin for which is limited to 40 to 60 minutes.

The antegrade selective cerebral perfusion (SCP) technique has been applied worldwide with various modifications. However, there is no common guideline as to the temperature that should be achieved before extracorporeal circulation can be stopped and replaced by initiation of SCP. Many institutions have recently attempted to elevate body temperature and reported excellent results in SCP with mild to moderate hypothermic circulatory arrest. We have begun to use milder levels of hypothermia based on a tympanic temperature of 25-28°C. We present our experience of using an SCP technique with mild hypothermia in total arch replacement.

2. Preoperative evaluation

A contrast enhanced computed tomography of the chest and the abdomen was performed to evaluate systemic atherosclerotic disease. A coronary angiography was performed routinely to evaluate the coronary artery disease in elective cases and also magnetic resonance angiography of carotid, vertebral and intracranial arteries to evaluate potential cerebral ischemia.

3. Indication for open surgery

Our threshold diameter for the treatment of aneurysm was 5 cm, however, the presence of risk factors influenced the individual indication for surgery such as age, pain symptom, chronic obstructive pulmonary disease, renal insufficiency and the expansion rate of the aneurysm. A saccular type aneurysm was indicated for surgery regardless of the size.

4. Surgical technique

The arterial cannulation site is decided according to preoperative computed tomography (CT) and intraoperative epiaortic ultrasonography findings. Our first-choice site is the ascending aorta. If the ascending and arch aorta is severely atherosclerotic, we use axillary artery cannulation. Venous cannulae are inserted into the superior and inferior vena cava. A left ventricular vent cannula is inserted through the right superior pulmonary vein and systemic cooling is started immediately. The head is packed in ice to maintain cerebral hypothermia until cardiopulmonary bypass (CPB) is restarted. Myocardial protection is ensured by retrograde infusion of cold blood cardioplegia solution. Tympanic and bladder temperature are monitored; systemic cooling is considered adequate for circulatory arrest when the tympanic temperature falls to 25°C-28°C. Circulatory arrest is achieved at a tympanic temperature of 25-28°C, at which point the arch aorta is opened. SCP is always used in total arch replacement. A 14Fr balloon-tipped cannula is inserted into the brachiocephalic artery, and 12Fr cannulae into the left common carotid and left subclavian arteries. Antegrade SCP flow is 10-13ml/kg/min, brain oxygen monitoring is carried out using INVOS 5100C (Somanetics, Troy, Mich.), and bilateral radial artery pressure is monitored. Distal anastomosis is performed with a 4-0 monofilament continuous suture reinforced with Teflon felt strips. An ESTECH retractor is often used during the distal procedure to create a comfortable surgical field. (Fig 1) A sealed quadrifurcated Dacron graft is always used for arch repair. After completion of the distal repair, the vascular prosthesis is clamped, antegrade systemic circulation restarted through the side-branch of the prosthesis, and rewarming begun. Next, proximal anastomosis is performed with Teflon felt strip reinforcement approximately 1 cm above the sinotubular junction after completion of which, coronary circulation is started. Finally, the three arch vessels are reconstructed using 5-0 monofilament continuous sutures from the left subclavian artery to the brachiocephalic artery. (Fig 2,3) When this is completed, systemic rewarming and heart-beat adequate for weaning from CPB can be achieved.

Sequence of surgical procedure

1. CPB establishment with ascending aortic cannulation and bicaval venous drainage
2. Systemic cooling with topical head cooling in ice pack
3. Circulatory arrest at tympanic temperature of 25-28°C
4. SCP insertion into three arch vessels

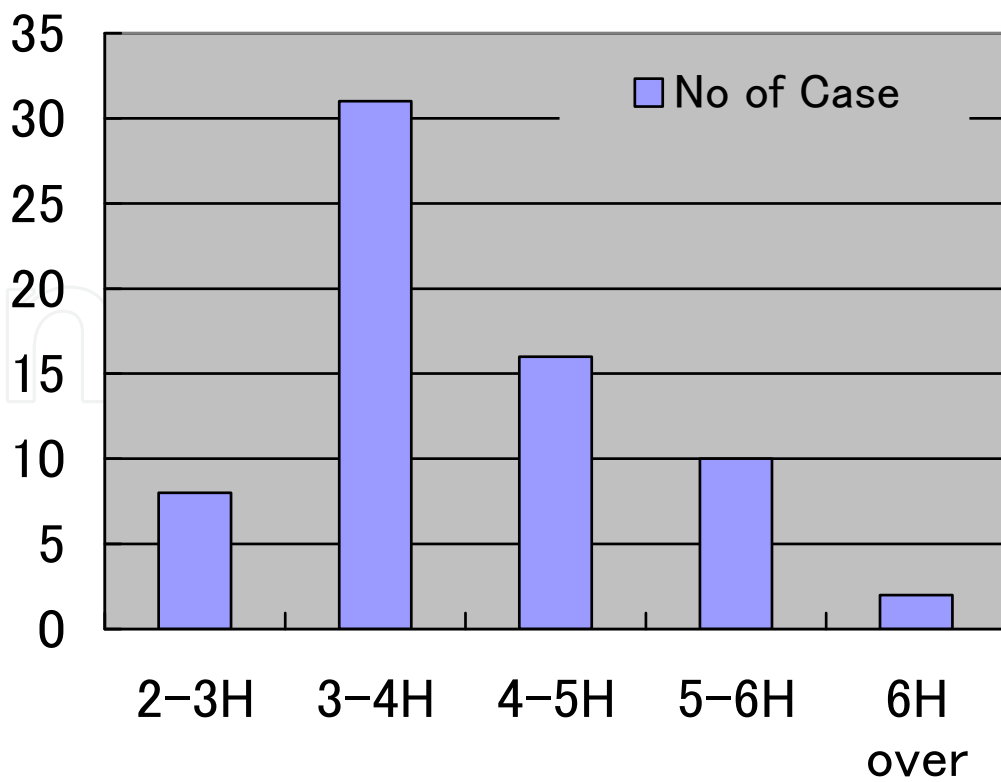


Figure 1. Operation Time (Hours)

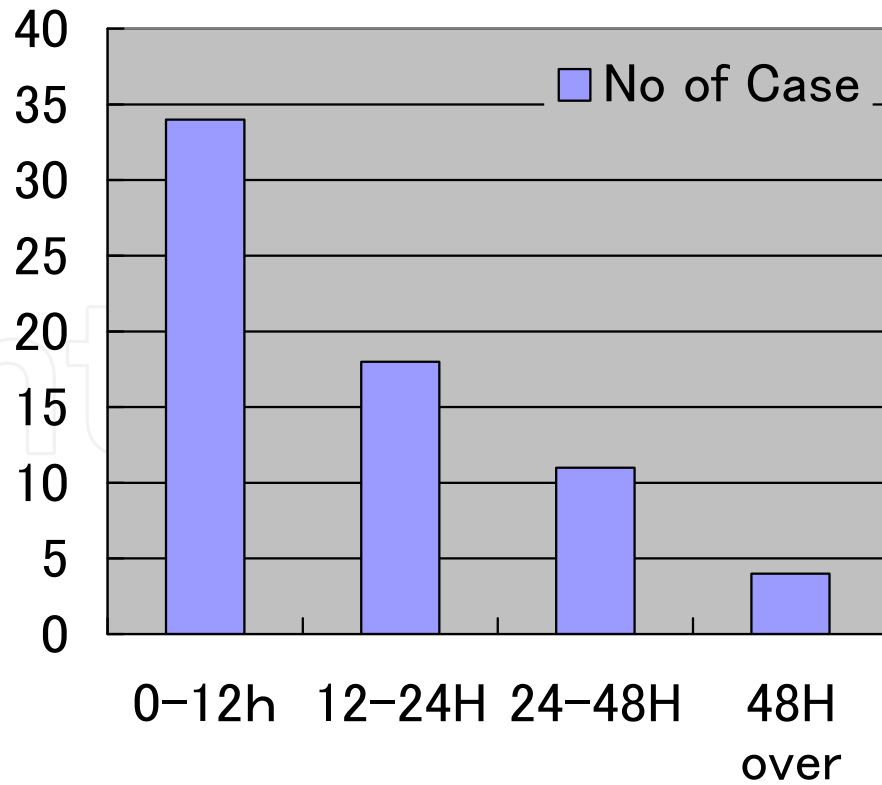


Figure 2. Postoperative Intubation Time (Hours)

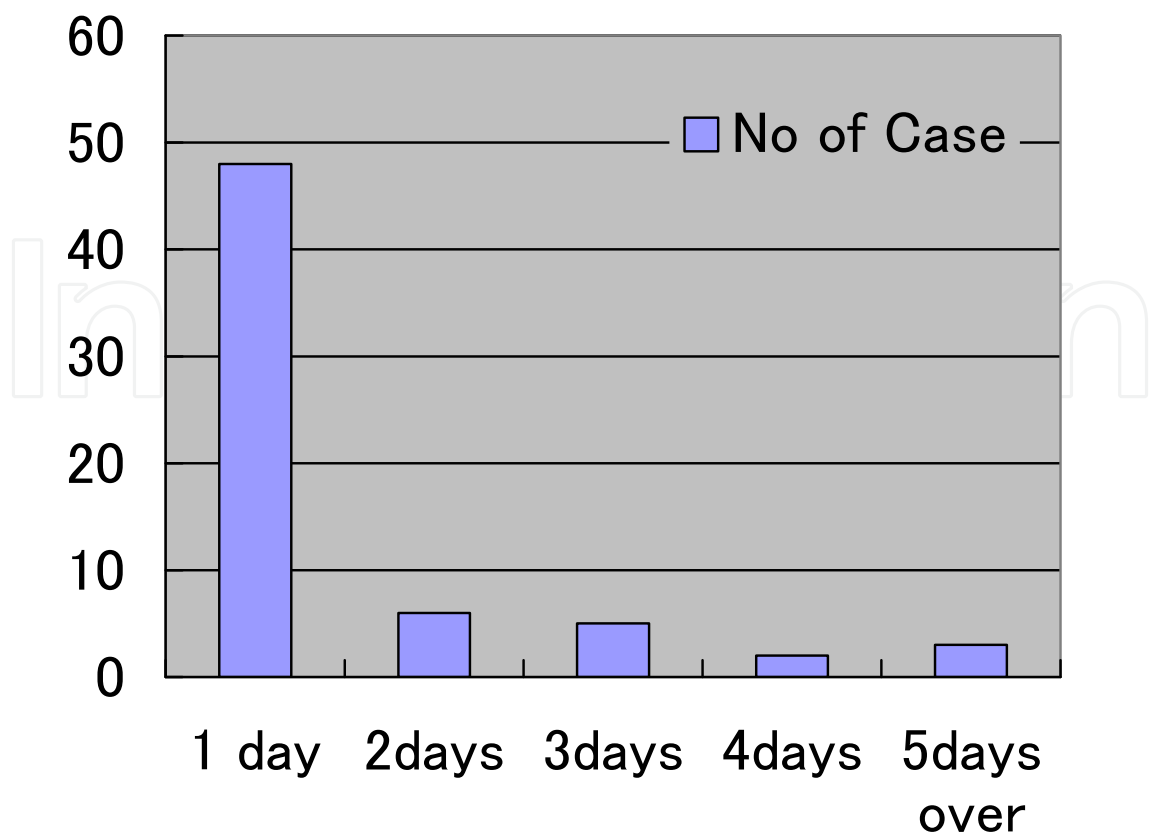


Figure 3. Stay of Intensive Care Unit (day)

5. Distal anastomosis using ESTECH retractor to create good surgical field
6. CPB restart from side branch and start of systemic rewarming to 35°C
7. Proximal anastomosis to ascending aorta
8. Coronary reperfusion and heartbeat start
9. Arch vessel reconstruction from subclavian artery to brachiocephalic artery
10. Weaning from CPB immediately after reconstruction of arch vessels

5. Clinical presentation

From January 2008 to July 2012, a total of 112 patients underwent total arch replacement under a single surgeon (A.T.) at Shiga Medical University Hospital. Of these 112 patients, the 45 requiring concomitant procedures were excluded and the remaining 67 isolated TAR patients (including 11 emergent cases), whose mean age was 73.3 years were admitted as subjects. The type of aortic disease was aortic dissection in thirteen (including three emergent) cases and atherosclerotic true aneurysm in 54 (including eight emergent) cases.

The operation time was 2.5 to 3 hours in eight cases, 3 to 4 hours in 31 cases, 4 to 5 hours in 16 cases, and more than 5 hours in 12 cases. The CPB time was 82-268 minutes (mean 140 ± 36), the coronary ischemic time 38-158 minutes (mean 76 ± 26), the circulatory arrest time 28-137 minutes (mean 45 ± 21), and the SCP time 57-212 minutes (mean 83 ± 29). (Fig 4)

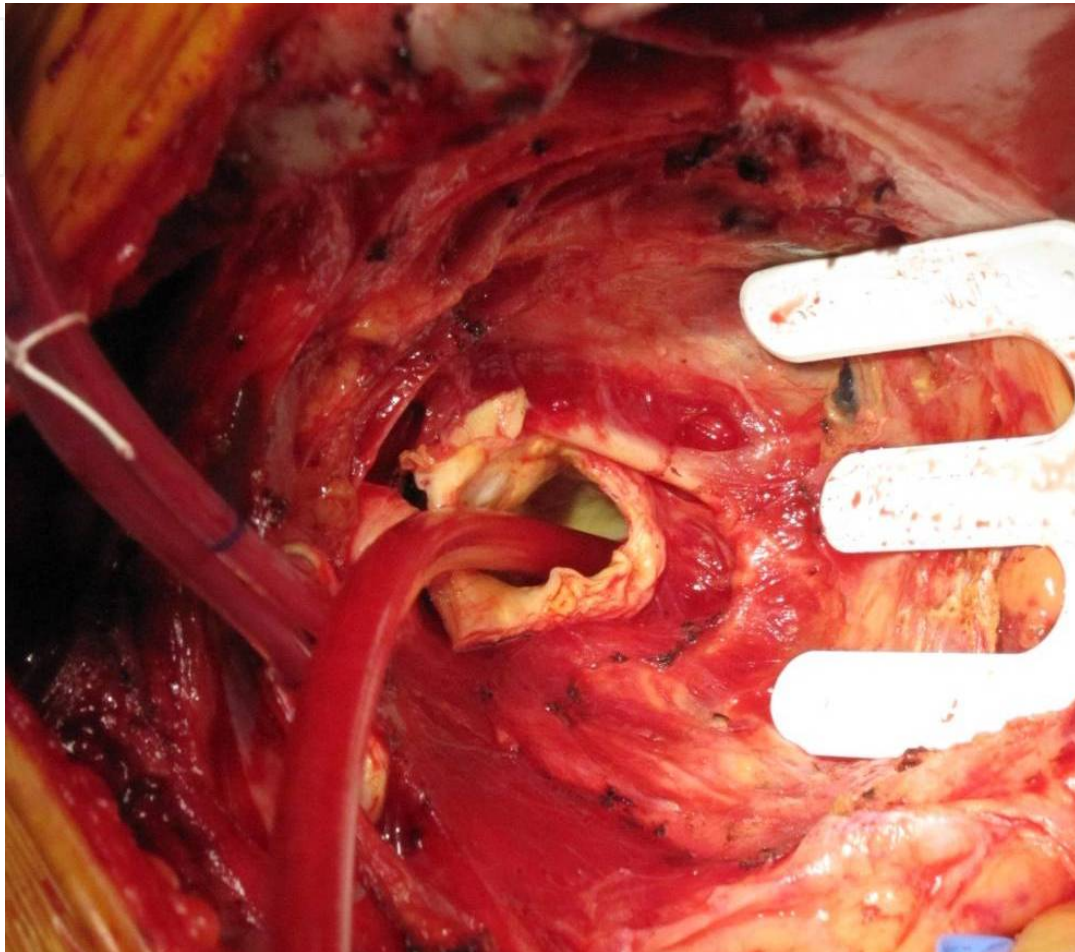


Figure 4. Surgical view of distal anastomose site using ESTECH retractor

5.1. Early morbidity

Hemorrhage requiring rethoracotomy occurred in three patients (4.5%), cerebrovascular deficit in three patients (4.5%), mediastinitis in two patients (3%), pulmonary failure in four patients (6%), and acute renal failure in four patients (6%). Prolonged intubation (>48H) was required in four patients (6%), and prolonged intensive care unit stay (>72H) in five. (Fig 5,6) The hospital stay from surgery to discharge was from 9 to 102 days with a mean of 14 days.

5.2. Mortality

No thirty-day mortality occurred. Two hospital mortalities occurred (3%), one due to multi-system organ failure following emergent rupture and the other to cerebrovascular accident.

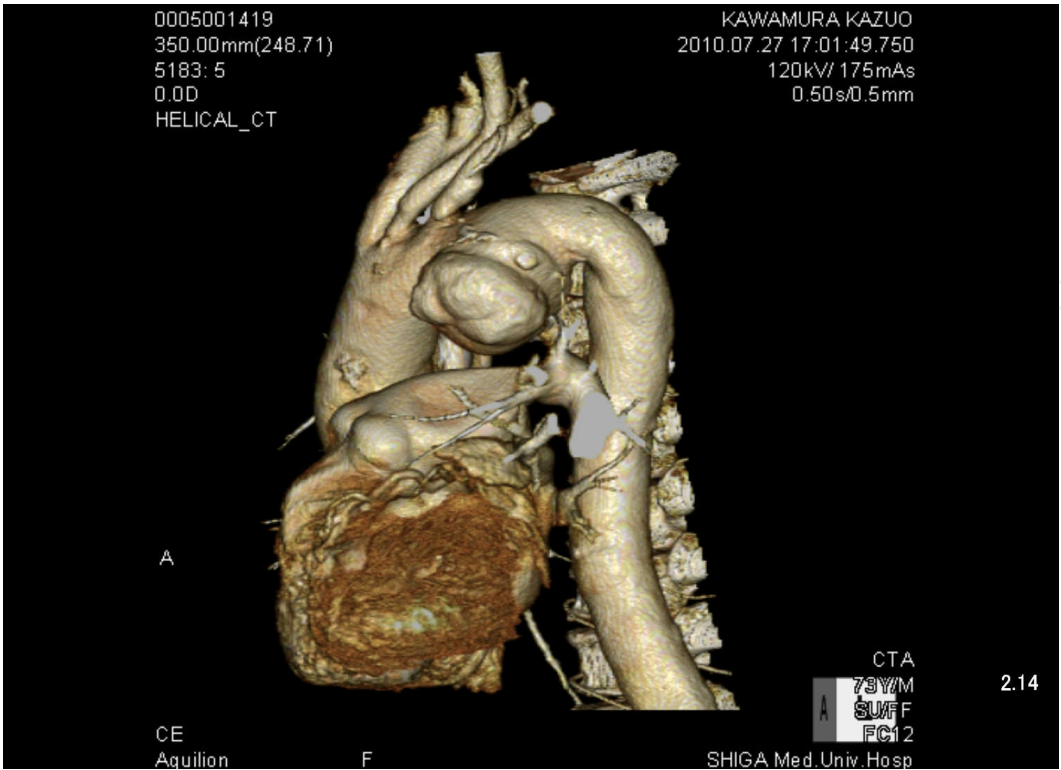


Figure 5. CT finding of distal arch aneurysm of thoracic aorta

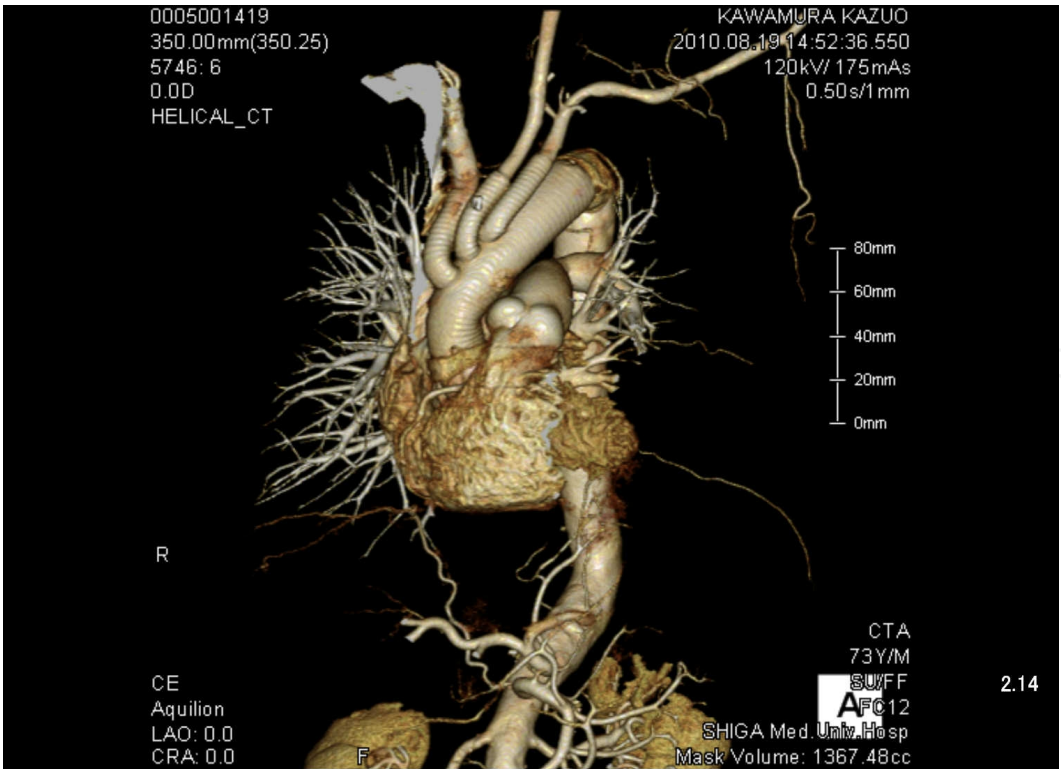


Figure 6. CT finding of repaired arch with a sealed quadrifurcated Dacron graft

6. Comment

6.1. Moderate hypothermia

Historically, total arch replacement has required deep hypothermic circulatory arrest (DHCA) or retrograde cerebral perfusion with DHCA during distal anastomosis.[1,2] However, these techniques do not give the surgeon adequate time to complete the aortic arch repair. The SCP technique, which extends the safe limits of time for arch surgery, has now gained acceptance.[4,5,6] As reliable SCP allows a high temperature setting during distal anastomosis, we have begun to use more moderate levels of hypothermia based on a tympanic temperature of 25-28°C. Core temperature based on bladder or rectal temperature has generally been used as the minimum setting and the safety of using tympanic temperature as the minimum setting is controversial. Ehrlich and coworkers [7] showed that brain oxygen consumption is reduced to 50% of baseline values if the patient is cooled systemically to a core temperature of 28°C, while Zierer and coworkers [6] showed that SCP in combination with mild hypothermia (core temperature of 30°C) offers sufficient cerebral protection and may be safely applied to aortic arch surgery requiring SCP time of up to 90 minutes or more. Our minimum temperature setting is tympanic temperature of 25-28°C. In almost all cases, when the tympanic temperature reaches 25°C, which takes approximately 10-20 minutes, the core temperature is still at 30-32°C. Our clinical outcomes show a low incidence of neurologic deficits and suggested that the application of this perfusion and temperature management protocol to aortic arch surgery was safe.

6.2. Sequence of reconstruction procedure

After completion of distal anastomosis, CPB was restarted from the side branch of the graft and rewarming initiated immediately. This early rewarming protocol with SCP is also controversial. Okada, who also used the INVOS system for monitoring brain oxygenation and increased SCP flow to maintain the INVOS index at preoperative values, reported that early rewarming can minimize CPB time, but that monitoring of brain oxygenation during rewarming is particularly important. [8]

After restart of CBP and rewarming, the proximal anastomosis is performed next and coronary perfusion restarted. Infusion of cardioplegic solution is thus needed only once. During arch vessel reconstruction, the heart-beat and progress of rewarming were sufficient to allow weaning from CPB, so that CPB could be discontinued immediately after reconstruction of the brachiocephalic artery. This sequence of reconstruction procedures minimizes CPB time and coronary ischemic time.

Recently, a number of studies have reported the safety of SCP with mild-moderate hypothermia for protection of the brain and visceral organs. In the present chapter, the excellent surgical results also indicate the safety of SCP under mild hypothermia.

| Operative Data | Total arch replacement (n=67) |
|--------------------------|---------------------------------|
| Operative time | 156-419 minutes (mean 238 ± 64) |
| CPB time | 82-268 minutes (mean 140 ± 36) |
| Coronary ischemic time | 38-158 minutes (mean 76 ± 26) |
| Circulatory arrest time | 28-137minutes (mean 45 ± 21) |
| SCP time | 65-212 minutes (mean 83 ± 29). |
| (Postoperative Data) | |
| Reoperation for bleeding | 3 (4%) |
| Deep sternal infection | 2 (3%) |
| Permanent stroke | 3 (4%) |
| Respiratory failure* | 4 (6%) |
| Mortality | |
| 30days | 0 (0%) |
| Hospital | 2 (3%) |

CPB = cardiopulmonary bypass

*Requiring prolonged ventilation support of more than 48 hours

ICU = intensive care unit

Table 1. Operative and Postoperative Data

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