ORIGINAL PAPER

Nagoya J. Med. Sci. **81**. 549–555, 2019
doi:10.18999/nagjms.81.4.549

Routine presternotomy extracorporeal circulation for redo surgery

Toshikuni Yamamoto, Shunei Saito, Akio Matsuura, Ken Miyahara, Haruki Takemura, and Ryohei Otsuka

Department of Cardiovascular Surgery, Ichinomiya Municipal Hospital, Ichinomiya, Japan

ABSTRACT

To reduce the risk of adverse events, presternotomy extracorporeal circulation (ECC) is routinely performed at our institution for patients who require resternotomy. We report our 10-year experience of performing presternotomy ECC for cardiac reoperation and the clinical results. Fifty-seven consecutive cardiac reoperations involving resternotomy were performed between January 2006 and December 2015. ECC was established prior to median sternotomy in all patients. Two patients sustained injury to the right ventricle during sternotomy. Eleven patients sustained injury to the mediastinal structures during dissection (right atrium in 3; superior vena cava in 2; inferior vena cava in 3; left internal thoracic artery in 1; and saphenous vein graft in 2 patients). Longer ECC time and greater transfusion volume were necessary. Two patients (3.5%) died within 30 days of operation. Perioperative morbidity included reexploration for bleeding in 4 (7.0%), stroke in 1 (1.8%), acute renal failure that required hemodialysis in 5 (8.8%), sepsis in 5 patients (8.8%), prolonged ventilation in 9 (15.8%) and tracheostomy in 5 (8.8%). Routine establishment of presternotomy ECC reduces the risk of injury to the mediastinal structures during reentry and facilitates easier repair in the event of structural injury during reentry or dissection. However, longer ECC time and significantly greater transfusion volume requires attention.

Keywords: cardiac reoperation, extracorporeal circulation

Abbreviations:
NYHA: New York Heart Association
RBC: red blood cell
FFP: fresh frozen plasma
PC: platelet concentrate
ICU: intensive care unit
ECC: extracorporeal circulation
LITA: left internal thoracic artery

INTRODUCTION

Cardiac reoperations involving resternotomy are very stressful for surgeons and are technically

Received: September 13, 2018; accepted: January 15, 2019

Corresponding Author: Toshikuni Yamamoto, MD

Department of Cardiovascular Surgery, Ichinomiya Municipal Hospital, 2-2-22 Bunkyo, Ichinomiya, Aichi 491-8558, Japan.

Tel: +81(586)71-1911, Fax: +81(586)71-1921, E-mail: tskn_10492@yahoo.co.jp

challenging.[1] Adverse events including injuries to the heart, great vessels, or bypass grafts are liable to occur during sternotomy and dissection.[2] In particular, aortic injury with catastrophic hemorrhage is associated with a high mortality rate.[3] To reduce the risk of these events, establishment of presternotomy extracorporeal circulation (ECC) is recognized as a preventive procedure in selected patients.[4] However, it is often difficult to preoperatively predict the precise risk of injury during sternotomy or dissection. Thus, presternotomy ECC has been established as a routine protocol at our institution for patients who require resternotomy. Herein, we report our 10-year experience of performing presternotomy ECC for cardiac reoperation and the clinical results.

MATERIALS AND METHODS

Patient Population and Definition

Fifty-seven consecutive cardiac reoperations involving resternotomy performed at the Ichinomiya Municipal Hospital between January 2006 and December 2015 were included in this study. ECC was established prior to median sternotomy in all patients, and medical records were retrospectively analyzed. Injury to mediastinal structure was defined as the requirement for repair.

Surgical Technique

Defibrillation pads were placed on the chest of patients. In all patients, arterial cannulation was performed either via the femoral or axillary artery and venous cannulation was performed via the femoral vein. Under transesophageal guidance, a cannula with multiple side-holes was introduced into the superior vena cava. When necessary, an additional cannula was placed in the superior vena cava post sternotomy. Arterial cannulation was performed via the femoral artery in 54 patients (94.7%) and via the axillary artery in 3 patients (5.3%). Among the 3 axillary artery cases, bilateral axillary artery was used in 1 patient and unilateral axillary artery was used in the other 2. Following the establishment of ECC, intravascular volume was shifted to the heart lung machine to a possible extent using vacuum assistance. Resternotomy was then performed using an oscillating saw. In most cases, the patient's body temperature was cooled to 32°C (bladder temperature) prior to sternotomy. For patients with aortic pseudoaneurysm or huge true aneurysm, systemic cooling to <28°C was applied prior to sternotomy to achieve deep hypothermic circulatory arrest following aneurysm rupture. In patients with a patent left internal thoracic artery (LITA), cardiac arrest was achieved by clamping the LITA till 2009. After 2010, the LITA was not touched, and cardiac arrest was maintained by hypothermia and hyperkalemia. Left ventricular venting was usually achieved via the right upper pulmonary vein.

RESULTS

Patient characteristics

Preoperative patient characteristics are summarized in Table 1. The mean age of 57 patients was 67.0 ± 9.3 years (range, 38–85 years), and 52.6% of patients were male. First-time cardiac reoperation was performed in 43 patients (75.4%), second-time in 11 (19.3%), third-time in 2 (3.5%), and fourth-time in 1 patient (1.8%). Valvular disease was the most frequent indication for reoperation (42 patients, 73.7%). Ten patients (17.5%) had aortic disease including pseudoaneurysms (4 patients, 7.0%). In 17 patients (29.8%), the primary surgery was coronary artery bypass grafting with or without additional procedures, and 9 patients (15.8%) had a patent LITA. Operations were performed in an urgent setting in 5 patients (8.8%) and in an emergency setting

Table 1 Preoperative Patient Characteristics

	n = 57
Age, years	67.0 ± 9.3
Male	30 (52.6%)
Hypertension	31 (54.4%)
Dyslipidemia	14 (24.6%)
Diabetes mellitus	11 (19.3%)
Class 3 or 4 (NYHA classification)	30 (52.6%)
Left ventricular ejection fraction <40%	5 (8.8%)
Preoperative renal failure	7 (12.3%)
Chronic hemodialysis	2 (3.5%)
Preoperative neurologic deficits	7 (12.3%)
Operative priority	
Emergency	2 (3.5%)
Urgent	5 (8.8%)
Elective	50 (87.7%)
Previous cardiac operations	
Valvular	36 (63.2%)
Aortic	9 (15.8%)
Coronary	17 (29.8%)
With patent LITA	9 (15.8%)
Others	5 (8.8%)
Reoperation number	
1	43 (75.4%)
2	11 (19.3%)
3	2 (3.5%)
4	1 (1.8%)
Indication to reoperation	
Valvular	42 (73.7%)
Aortic	10 (17.5%)
True aneurysm	2 (3.5%)
Pseudoaneurysm	4 (7.0%)
Coronary	2 (3.5%)
Others	3 (5.3%)

LITA: left internal thoracic artery, NYHA: New York Heart Association

in 2 patients (3.5%).

Intraoperative Data

Intraoperative data are presented in Table 2. The mean operative, ECC, and cardiac arrest time was 599 ± 164 min, 403 ± 121 min, and 160 ± 80 min, respectively. The mean ECC time before cardiac arrest was 158 ± 49 min. At the end of the operation, 6 patients (10.5%) required the use of intra-aortic balloon pump and 3 patients (5.3%) required extracorporeal membrane oxygenation because of reduced lung oxygenation and repetitive ventricular fibrillation or right ventricular failure, respectively. Blood transfusion was performed in 56 patients (98.2%). The mean number of units of red blood cell (RBC), fresh frozen plasma (FFP), and platelet concentrate (PC) was 13.2 ± 6.5, 10.3 ± 5.5, and 23.5 ± 8.7, respectively. The number of units

Table 2 Intraoperative Data

	n = 57
Operation time, minutes	599 ± 164
Extracorporeal circulation time, minutes	403 ± 121
Before cardiac arrest	158 ± 49
Cardiac arrest time, minutes	160 ± 80
Arterial cannulation site	
Femoral	54 (94.7%)
Biaxillary	1 (1.8%)
Uniaxillary	2 (3.5%)
Bladder temperature at the time of sternotomy	
≥32°C	50 (87.7%)
28–32°C	2 (3.5%)
25–28°C	3 (5.3%)
<25°C	2 (3.5%)
Cardiac arrest in patient with patent LITA (n = 9)	
Clamp	4
Non-clamp	4
Mechanical circulatory support	9 (15.7%)
Intra-aortic balloon pump	6 (10.5%)
Extracorporeal membrane oxygenation	3 (5.3%)
Intraoperative blood transfusion	
RBC, unit number	13.2 ± 6.5
Before cardiac arrest	3.0 ± 3.1
FFP, unit number	10.3 ± 5.5
PC, unit number	23.5 ± 8.7

RBC: red blood cell, FFP: fresh frozen plasma, PC: platelet concentrate

Table 3 Injuries to the mediastinal structure

Overall	n=13
During resternotomy (n = 2)	
Right ventricle	2
During dissection (n = 11)	
Right atrium	3
Superior vena cava	2
Inferior vena cava	3
Saphenous vein grafts	2
LITA	1

of RBC used before cardiac arrest was 3.0 ± 3.1.

According to the operative records, 2 patients sustained injury to the right ventricle during sternotomy. Eleven patients sustained injury to the mediastinal structures during dissection (right atrium in 3; superior vena cava in 2; inferior vena cava in 3; LITA in 1; and saphenous vein graft in 2 patients). Although unplanned hypothermic circulatory arrest was required in 1 superior vena cava case, all of the injuries were adequately repaired. Details of the injuries are presented in Table 3. In 1 patient, the LITA was injured during dissection. A perfusion cannula connected

Table 4 Postoperative Data

	n = 57
Ventilation time (median, hours)	16
ICU stay (median, days)	4
>7 days	11 (19.3%)
30-day mortality	2 (3.5%)
In-hospital mortality	5 (8.8%)
Morbidity	
Reexploration for bleeding	4 (7.0%)
Stroke	1 (1.8%)
Renal failure requiring hemodialysis	5 (8.8%)
Sepsis	5 (8.8%)
Mediastinitis	0 (0.0%)
Prolonged ventilation (>72 hours)	9 (15.8%)
Tracheostomy	5 (8.8%)
Postoperative blood transfusion	
RBC, unit number	5.2 ± 7.8
FFP, unit number	6.0 ± 18.9
PC, unit number	10.2 ± 21.3

ICU: intensive care unit

to the ECC was immediately inserted into the LITA and deep hypothermic circulatory arrest was established. At the final stage of the operation, the right internal thoracic artery was anastomosed to the distal LITA in an end-to-side fashion and the proximal LITA was ligated. Postoperative echocardiogram showed no sign of left ventricular dysfunction.

Postoperative Data

Postoperative data are presented in Table 4. The median mechanical ventilation time was 16 hours and the median length of stay in the intensive care unit (ICU) was 4 days. Eleven patients (19.3%) stayed in the ICU exceeded 7 days. Two patients (3.5%) died within 30 days of operation due to uncontrolled sepsis or right ventricular failure. In-hospital mortality was 8.8% (5 patients), and it was caused by uncontrolled sepsis in 2, cardiac sarcoma in 1, and acute renal failure in 2 patients. Perioperative morbidity included reexploration for bleeding in 4 (7.0%), stroke in 1 (1.8%), acute renal failure that required hemodialysis in 5 (8.8%), sepsis in 5 patients (8.8%), prolonged ventilation beyond 72 hours after operation in 9 (15.8%) and tracheostomy in 5 (8.8%). None of the patients developed mediastinitis. The mean number of units of RBC, FFP, and PC in postoperative period was 5.2 ± 7.8, 6.0 ± 18.9, and 10.2 ± 21.3, respectively.

DISCUSSION

Injury to the mediastinal structures is associated with poor outcomes during reoperations that require resternotomy. In a study by Roselli et al,[2] the rate of stroke, myocardial infarction, or in-hospital mortality was 19% in patients with intraoperative injury, whereas it was 6.2% in patients without injury. Interestingly, injuries occurred more commonly during dissection (39%) than during sternal reentry (23%). An effective solution to this problem is to establish presternotomy ECC. Shifting of the intravascular volume to the heart lung machine with sufficient

venous drainage reduces the risk of injury to the innominate vein, aorta, and right ventricle during sternotomy. Moreover, ECC facilitates adequate and comfortable repair in the event of injury during reentry or dissection.[4] In our series, potentially catastrophic injuries to the LITA graft, saphenous vein graft, superior vena cava, or inferior vena cava were encountered, which were adequately dealt with. Based on our experience, we believe that presternotomy ECC relieves surgeons' stress and anxiety and facilitates safer reoperation.

According to 3 previous reports,[4-6] presternotomy ECC is indicated in the following situations: close adhesions between the sternum and aorta, right ventricle or bypass grafts; presence of pseudoaneurysm; tricuspid regurgitation with a dilated right ventricle; pulmonary hypertension; low ejection fraction; and a history of mediastinitis, >2 sternotomies or chest radiation. However, we believe that it is difficult to accurately predict the risk of reentry injury based on computed tomography scan. Clearly, preoperative assessment of the risk of injury during dissection is inherently difficult. Thus, we introduced the strategy to establish ECC prior to reentry for all patients who require redo sternotomy.

The likely concerns of surgeons who have a negative perception of presternotomy ECC include the risk of excessive bleeding due to longer ECC time and the resultant prolongation of the operation time. However, previous reports have suggested that this is not always true. In their randomized study, Kuralay et al[7] compared 2 groups (n = 100 for each) with and without presternotomy ECC. The group with presternotomy ECC was associated with a longer ECC time (93 ± 9 vs. 71 ± 11 min), shorter operation time (155 ± 23 vs. 185 ± 32 min), lesser postoperative bleeding (450 ± 135 vs. 850 ± 250 mL), and lower requirement for transfusion (3.3 ± 1.2 vs. 5.8 ± 0.9 U) compared with the group without presternotomy ECC. Luciani et al[4] compared 158 matched pairs with and without presternotomy ECC. Similarly, they demonstrated that operative time (231.9 ± 24.3 vs. 278 ± 36.1 min) and postoperative bleeding (264.3 ± 38 vs. 379 ± 35.2 mL/m^2) were reduced in the group that underwent presternotomy ECC. Abe et al[6] reported that presternotomy ECC in redo aortic surgery was not associated with any major adverse outcomes such as death, stroke, or renal failure. In our series, the mean operative, ECC, and cardiac arrest time was 599 ± 164 min, 403 ± 121 min, and 160 ± 80 min, respectively. The mean ECC time before cardiac arrest was 158 ± 49 min. Additionally, the mean number of units of RBC, FFP, and PC was 13.2 ± 6.5, 10.3 ± 5.5, and 23.5 ± 8.7, respectively. Longer ECC time and greater transfusion volume were necessary for patients with the establishment of presternotomy ECC. Our strategy is subject to these disadvantages, although presternotomy ECC does reduce the risk of reentry injury and facilitate adequate and comfortable repair in the event of injury.

According to the annual report by the Japanese Association for Thoracic Surgery,[8] the 30-day and in-hospital mortalities of patients who underwent redo valvular procedure in 2014 in Japan (n = 1210) were 5.7% and 10%, respectively. Likewise, the 30-day and in-hospital mortalities of patients who required redo aortic procedures (n = 549) were 8.9% and 12.6%, respectively. The 30-day (5.7%) and in-hospital (8.5%) mortalities in our series are consistent with the Japanese standards, which indicate that routine establishment of presternotomy ECC is not associated with increased mortality.

The limitation of present study includes its retrospective observational nature and relatively small patient size. Moreover, this is a descriptive study and does not include a comparison between the groups with and without presternotomy ECC.

CONCLUSION

Routine establishment of presternotomy ECC reduces the risk of injury to the mediastinal structures during reentry. Furthermore, ECC facilitates easier repair in the event of structural injury during reentry or dissection. However, longer ECC time and significantly greater transfusion volume requires attention.

CONFLICT OF INTEREST

The authors have declared that no conflict of interest exist.

REFERENCES

1) Yau RM, Borger RA, Weisel RD, Ivanov J. The changing pattern of reoperative coronary surgery: trends in 1230 consecutive operations. *J Thorac Cardiovasc Surg*. 2000;120:156–163.
2) Roselli EE, Patterson GB, Blackstone EH, et al. Adverse events during reoperative cardiac surgery: frequency, characterization, and rescue. *J Thorac Cardiovasc Surg*. 2008;135:316–323, 323e1–6.
3) Dobell AR, Jain AK. Catastrophic hemorrhage during redo sternotomy. *Ann Thorac Surg*. 1984;37:273–278.
4) Luciani N, Anselmi A, De Geest R, et al. Extracorporeal circulation by peripheral cannulation before redo sternotomy: indications and results. *J Thorac Cardiovasc Surg*. 2008;136:572–577.
5) Ghoreishi M, Dawood M, Hobbs G, et al. Repeat sternotomy: no longer a risk factor in mitral valve surgical procedures. *Ann Thorac Surg*. 2013;96:1358–1365.
6) Abe T, Usui A, Yoshikawa M, et al. Reoperation of the proximal aorta: impact of presternotomy extracorporeal circulation on clinical outcomes. *Gen Thorac Cardiovasc Surg*. 2009;57:458–462.
7) Kuralay E, Bolcal C, Cingoz F, et al. Cardiac reoperation by Carpentier bicaval femoral venous cannula: GATA experience. *Ann Thorac Surg*. 2004;77:977–981;discussion 982.
8) Masuda M, Okumura M, Doki Y, et al; Committee for Scientific Affairs TJAfTS. Thoracic and cardiovascular surgery in Japan during 2014: annual report by The Japanese Association for Thoracic Surgery. *Gen Thorac Cardiovasc Surg*. 2016;64:665–697.