

The Frozen Elephant Trunk Technique Combined with Beating Heart in Complicated Type B Dissection

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Abbreviations:

FET - Frozen Elephant Trunk; SMP - Selective Myocardial Perfusion; UHS - Upper hemisternotomy; CPB - Cardiopulmonary Bypass; SACP - Selective Antegrade Cerebral Perfusion; USACP - Unilateral Selective Antegrade Cerebral Perfusion; CTA - CT Angiography; TND - Temporary Neurological Dysfunction; PND - Permanent Neurological Deficit; HCA - Hypothermia Circulatory Arrest; RBC - Red Blood Cell; FFP - Fresh Frozen Plasma; LVEF - Left Ventricular Ejection Fraction; CA - Circulatory Arrest; ICU - Intensive Care Unit; CNY - Chinese Yuan; ALT - Alanine Transaminase; Tnt - Troponin T; MHCA - Moderate Hypothermia Circulatory Arrest

1. Abstract

1.1. Backgrounds: Frozen Elephant Trunk (FET) combined with beating heart which was carried out by Selective Myocardial Perfusion (SMP) technique might be beneficial for the recovery of patients with acute complicated Type B aortic dissection. However, the safety of FET with beating heart used in acute complicated Type B aortic dissection treatment is ambiguous.

1.2. Methods: We retrospectively analyzed 35 consecutive patients with acute complicated Type B aortic dissection who underwent FET combined with SMP or not between February 2012 and April 2021. These individuals were divided into SMP group (n = 11, surgery performed with SMP) and control group (n = 24, surgery conducted without SMP). Perioperative characteristics were recorded.

1.3. Results: No significant difference in any of the pre- and intra-operative variables was observed between two groups. After operation, FFP transfusion [0 (0-0) ml vs. 165 (0-600) ml, p = 0.040] and Tnt [324 (236-357) ng/L. 376.5 (311.5-570.5) ng/L, p = 0.022] were significantly less in the SMP group compared with control group.

1.4. Conclusions: The frozen elephant trunk technique combined with beating heart in complicated type B dissection is safe and feasible with a significantly lower postoperative Tnt, which might be beneficial for patients recover.

2. Introduction

Type B Aortic Dissections (TBADs) involve the descending aorta and are further classified by time of onset and presence of complications, the standard treatment for which is thoracic endovascular aortic repair (TEVAR) [1]. However, some patients with no sufficient proximal landing zone, unfavorable aortic anatomy or connective tissue disease require various degrees of supra-aortic transposition to achieve stable stent graft deployment. The Frozen Elephant Trunk (FET) technique may also be appropriate for the treatment of acute complicated Type B aortic dissection [2].

Selective Myocardial Perfusion (SMP) technique is to make a separate perfusion to the proximal ascending aorta by a separate roller pump to maintain coronary blood flow during cerebral perfusion and hypothermia circulatory arrest [3], which can avoid myocardial ischemia and keep the heart beating during surgery. SMP technique were often used in congenital aortic anomalies which

may reduce cross-clamping times, shorten instances of myocardial ischemia, and offer improved postoperative cardiac function [4, 5]. However, FET combined with SMP and beating heart in TBADs, especially via minimal invasive incision was rarely reported.

The aim of the present study was to show the feasibility and safe of the FET combined with SMP and beating heart. Furthermore, to evaluate whether SMP can result in less myocardial damage or not.

3. Materials and Methods

3.1. Patient Data

Between February 2012 and April 2021, 35 consecutive patients with acute complicated type B dissection who underwent FET implantation. Based on combined with SMP or not, patients were divided into a SMP group (combined with SMP) and a control group (with no SMP). The operation in the control group was carried out between February 2012 and April 2019, while in the SMP group, it was carried out between April 2019 and April 2021. All of the surgeries were carried out by the same surgery group including surgeons, anesthetist, perfusionist, cardiologist, and nurses. All of the patients were diagnosed definitively as acute type B aortic dissection based on CT angiography (CTA). The inclusion criteria were acute type B dissection with no sufficient proximal landing zone for TEVAR or involved left subclavian artery. While the exclusion criteria included neurologic complications including cerebral infarction and cerebral hemorrhage, malperfusion syndrome and concomitant operations (type A dissection, coronary heart disease, mitral valve disease and congenital heart disease, etc.) The study was approved by the Ethics Committee of General Hospital of Northern Theater Command, Shenyang City, China. All of the patients provided informed consent.

3.2. Surgical Procedure

We used a single upper hemisternotomy approach (Upper hemisternotomy is the only incision without extra axillary or femoral artery incisions) or full sternotomy incision for FET with/without SMP. The upper hemisternotomy was made from the sternal notch to the level of the fourth intercostal space and then extended to the right fourth intercostal space, which can provide adequate exposure of the surgical field [6]. Other surgical procedures were same in upper hemisternotomy approach and full sternotomy incision.

Cardio Pulmonary Bypass (CPB) with Selective Antegrade Cerebral Perfusion (SACP) was established by cannulation of the direct innominate artery as the artery cannulation, and direct right atrial cannulation as the venous cannulation. A left ventricular vent was placed through the right superior pulmonary vein. A cardioplegic cannula was placed in the proximal ascending aorta. During cooling, left subclavian artery was anastomosis with the prosthetic graft. When the nasopharyngeal temperature reached 33°C to 34°C, ascending aorta was clamped distally to the cardioplegic cannula and SMP was carried out [6] (Figure 1A). Briefly, SMP was carried out using a separate roller pump and provide 250-400ml/min blood flow at 33°C which was maintained by a separate heat exchanger. In the rare event of monitored ST-elevations, SMP flow was increased until changes in the electrocardiogram could be reversed. At the same time, systemic cooling continued until the rectal temperature reached 28°C-30°C. Unilateral SACP was started through the arterial cannulation after the brachiocephalic arteries were cross-clamped and the brain was perfused. Then, moderate hypothermia circulatory arrest (MHCA) was instituted. Aortic arch was made a 3-5cm vertical incision between innominate artery and left subclavian artery, while, FET technique was carried out as in our previous reports [6, 7] (Figure 1B). Briefly, a stent graft (Micro Port Medical Co. Ltd., Shanghai, China) was inserted into the true lumen of the distal aorta in a bound, compressed state after the distal aorta was transected between the origin of the left subclavian artery and the left carotid artery. After the incision of aortic arch sewing closed, blood perfusion of whole body was gradually returned to normal flow by removing the cross-clamp on brachiocephalic arteries and ascending aorta, and rewarming started. During rewarming, left subclavian artery was connected to the ascending aorta via prosthetic graft (Figure 1C). During the whole surgery, the heart was beating without complete myocardial ischemia.

Trans esophageal echocardiography was used extensively during de-airing. All of the patients in both groups received a temporary pacing wire to the right ventricle and drainage tubes for pericardial draining. Perioperative characters especially pre- and 24h post-operation troponin T (Tnt) were collected for study.

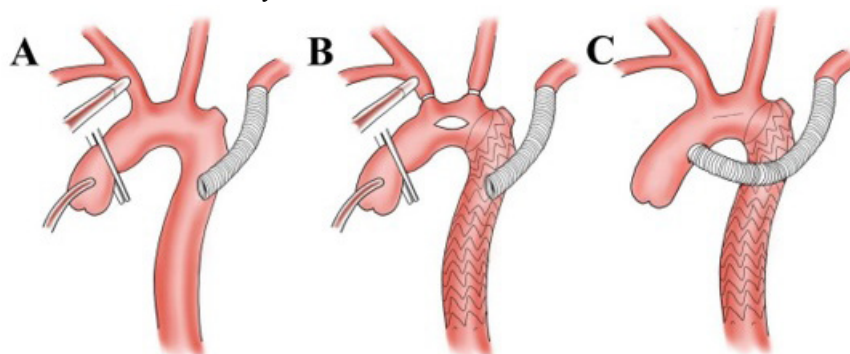


Figure 1: FET and SMP technique (A) left subclavian artery was anastomosis with the prosthetic graft and SMP was carried out. (B) SMP and FET were carried out. (C) FET and left subclavian artery bypass were carried out.

3.3. Definitions for Complications

For the purpose of this study, Temporary Neurological Dysfunction (TND) was defined as the presence of reversible postoperative motor deficit, confusion, or transient delirium with complete resolution of symptoms prior to discharge from the hospital. Permanent Neurological Deficit (PND) was defined as the presence of either new stroke or coma with permanent neurological dysfunction confirmed by means of CT imaging of the brain.

3.4. Statistical Analysis

All of the perioperative data were collected prospectively. All of the analyses were performed with SPSS version 22.0 software (SPSS Inc, Chicago, IL). Normally distributed data are presented as group means \pm SEM or SD, and non-normally distributed data are presented as the median and interquartile range. Student's *t* tests and Mann-Whitney *U* tests were used to compare continuous variables. Categorical variables were analyzed by the χ^2 test or the Fisher exact probability test (if necessary). A value of $P < 0.05$ was considered significant.

4. Results

The preoperative characteristics of 35 patients are summarized in (Table 1). No significant differences in preoperative variables were observed between the two groups especially in preoperative Tnt.

The intra- and post- operative variables are summarized in Table 2. CPB time (137.3 \pm 35.7 min vs. 148.79 \pm 29.4 min, $p = 0.322$), cross-clamp or SMP time 35.9 \pm 10.0 min vs. 41.5 \pm 8.2 min, $p = 0.093$), and circulatory arrest time (25.7 \pm 7.2 min vs. 28.6 \pm 4.5min, $p = 0.161$) did not significantly differ between SMP group and Control group.

In the operative outcomes, there is no died and PND in both the two groups. There was no difference between the two groups in terms of perioperative RBC transfusion, TND, postoperative ALT, creatinine, ventilation time, ICU stay, length of stay, and hospitalization cost. However, Postoperative FFP transfusion [0 (0-0) ml vs. 165 (0-600) ml, $p = 0.040$] and postoperative Tnt [324 (236-357) ng/L vs. 376.5 (311.5-570.5) ng/L, $p = 0.022$] were significantly less in the SMP group compared with control group.

Table 1: Preoperative characteristics of patients

Variable	SMP group (n = 11)	Control group (n = 24)	P Value
Age (years)	49.7 \pm 10.8	46.4 \pm 11.2	0.417
Male	11 (100)	21 (87.5)	0.22
Weight (kg)	83 (80-85)	78 (71.5-93.75)	0.151
LVEF (%)	58 (57-60)	58 (57.5-59.5)	0.903
Diabetes (%)	1 (9.1)	3 (12.5)	0.769
Hypertension (%)	11 (100)	19 (79.2)	0.102
Hyperlipidemia (%)	8 (72.7)	15 (62.5)	0.554
Preoperative ALT (U/L)	31(18-34)	20.5 (12.25-36.25)	0.494
Preoperative creatinine (μ mol/L)	85(61-92)	77.5(66.25-94.5)	0.875
Preoperative Tnt (ng/L)	6(4-11)	9.5 (5.25-15.75)	0.252

LVEF: left ventricular ejection fraction; ALT: Alanine transaminase; Tnt: troponin T

Table 2: Intra and post-operative data of patients

Variable	SMP group (n = 11)	Control group (n = 24)	P Value
CPB time (min)	137.3 \pm 35.7	148.79 \pm 29.4	0.322
Cross-clamp time/ SMP time (min)	35.9 \pm 10.0	41.5 \pm 8.2	0.093
Circulatory arrest (min)	25.7 \pm 7.2	28.6 \pm 4.5	0.161
Ventilation time (h)	24 (20-38)	18.5 (16-22.75)	0.078
ICU stay (d)	3 (2-3)	3 (2-4.75)	0.211
First 24 h chest tube drainage (ml)	350 (280-420)	370 (295-574.5)	0.39
Postoperative RBC transfusion (U)	0 (0-1)	0(0-2)	0.612
Postoperative FFP transfusion (ml)	0 (0-0)	165 (0-600)	0.04
Preoperative ALT (U/L)	26 (17-340)	34.5 (24.75-50.75)	0.142
Preoperative creatinine (μ mol/L)	112(92-170)	117(102.75-169.25)	0.636
Preoperative Tnt (ng/L)	324 (236-357)	376.5 (311.5-570.5)	0.022
TND (%)	2 (18.2)	3 (12.5)	0.656
Total length of stay	12(11-19)	11 (9-16)	0.316
Hospitalization costs (10,000 CNY)	21.2(14.0-51.1)	15.25 (13.75-16)	0.678

RBC: Red blood cell; FFP: Fresh frozen plasma; TND: Transient neurological dysfunction; PND: Permanent neurological dysfunction; ALT: Alanine transaminase; Tnt: troponin T

5. Discussion

Recently, most type B dissection patients were treated by TEVAR, Lower extremities artery disease, severe tortuosity of the iliac arteries, a sharp angulation of the aortic arch, and the absence of a proximal landing zone for the stent graft are factors that indicate open surgery for the treatment of acute complicated Type B dissection [8]. Open surgeries for type B dissection contained descending aorta replacement via a lateral thoracotomy and FET technique via full sternotomy in deep hypothermic circulatory arrest. In contrast to surgery via a lateral thoracotomy, the FET technique provides simultaneous treatment of the ascending aorta and aortic arch, which has been demonstrated feasible and safe as an alternative therapeutic option for TEVAR [2, 9].

When the FET technique was carried out, cardioplegia was carried out simultaneously which was only a subordinate operation for the FET technique. However, cardioplegia need cross-clamp and cause myocardial ischemia. So, whether cardioplegia during FET technique can be canceled or not in order to avoid myocardial ischemia and improve cardiac protection was worth to discuss.

SMP technique was often used in congenital aortic or aortic arch anomalies, which made the complex aortic or aortic arch surgeries to beating heart thoracic aortic surgery [4, 5, 10, 11]. In these studies, beating heart with SMP technique was demonstrated feasible and safe, which reduced the myocardial ischemic time and resulted in less myocardial damage. However, SMP technique was rarely used in dissection patients. Maier and his colleges [3] reported that selective heart, brain and body perfusion in open aortic arch replacement in this small series obtained excellent outcomes in this small series and considered this perfusion strategy was also applicable for redo procedures. In our studies, SMP was carried out according to previous reports [3-5] with some key points as follow. First, SMP should be carried out by a separate roller pump and cardioplegia device with a separate heat exchanger in order to control the flow and temperature exactly. Moreover, when cardiac arrest is required, cardioplegic solution can be infused for myocardial protection immediately. Second, SMP kept the temperature of myocardium at 33°C to maintain sinus rhythm, because ventricular fibrillation and myocardial injury will be occurred below 32°C [12]. Third, the flow of SMP was adjusted between 250 to 400ml/min referred to observation on myocardial hue, heart rate, and ST-T changes on electrocardiography. Forth, SMP requires effective left ventricle venting and a competent aortic valve to avoid left ventricle dilated.

Based on our results, postoperative Tnt [324 (236-357) ng/L vs. 376.5 (311.5-570.5) ng/L, $p = 0.022$] was significant lower in SMP group compared with control group, which was in accordance with previous studies [4, 5]. These results illustrated that continuous myocardial perfusion with SMP might be beneficial for myocardial protection. However, better myocardial protection did not provide better outcome, which might be caused by the small sample size.

In our study, all patients needed to reconstruct left subclavian artery to the ascending aorta, which can be carried out during systemic cooling. Because most patients in our study were treated in minimal incision, the exposure of left subclavian artery was deep, narrow and insufficient. Based on our previous experience, an elastic occlusion band instead of an occlusion clamp to occlude the innominate artery, left carotid artery, and left subclavian artery combined with reasonable pulling by an assistant could improve the exposure for left subclavian artery reconstruction [6].

6. Limitations

This study has a number of limitations. First, the retrospective study, including the small number of patients and long duration time is a time-based comparison, and thus may impose time bias. Second, SMP flow modification was based on ST-elevations, which should be further examined in our next study. Third, myocardial injury was only evaluated by Tnt, which need other cardiac markers for more exact evaluation. These limitations may be avoided in future studies by improving sample size, using randomized controlled trials, and using long-term follow-up.

7. Conclusion

The frozen elephant trunk technique combined with selective myocardial perfusion and beating heart in complicated type B dissection is safe and feasible with a significantly lower postoperative Tnt. The method provides continuous myocardial perfusion and avoids myocardial ischemia, which might be beneficial for patients recover. Randomized prospective studies using a larger number of patients are warranted.

8. Funding

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