



Total aortic arch replacement with frozen elephant trunk using FROZENIX for residual aortic dissecting aneurysm after replacing the ascending aorta for acute type A aortic dissection

Department of Cardiovascular Surgery, Nagoya University Graduate School of Medicine

Akihiko Usui, M.D., Ph.D.



INDICATION AND LIMITATION

We principally perform a central repair with total aortic arch replacement (TAR) with frozen elephant trunk (FET) using FROZENIX for patients with residual chronic aortic dissecting aneurysm after the ascending aorta replacement for acute type A aortic dissection. This procedure can be applied in cases with chronic type B aortic dissection that expands to the aortic arch. However, it is sometimes difficult to insert FET into an extremely narrow true lumen of the descending aorta, limiting the applicability of TAR + FET. When the minimum size FROZENIX (21 mm) cannot be inserted into the true lumen, direct repair of the descending aorta should be considered. TAR + FET can manage the proximal entries around the aortic arch or the distal arch, but the distal entries of the lower descending aorta or thoracoabdominal aorta cannot be treated. When the descending and/or thoracoabdominal aorta is severely enlarged, cautious follow-up by CT examination is essential after the central repair. When the residual aortic dissection becomes enlarged after the first surgery, direct repair with total descending or thoracoabdominal aortic replacement via left thoracotomy should be immediately scheduled. Some cases promptly reveal enlargement after the first surgery. In such cases, large reentries are generally open on the thoracoabdominal aorta.

SURGICAL PROCEDURE

In supine position, arterial pressure should be securely obtained on both the radial artery and either dorsalis pedis artery. The left axillary artery is exposed under the subclavian incision and an 8-mm ringed artificial graft is anastomosed to it in end-to-side fashion. The right femoral artery and vein

are exposed using a groin incision. The heart is exposed by median sternotomy. When injury of the aorta or heart is expected, a partial cardiopulmonary bypass is created before the sternotomy.

After the sternotomy, the innominate vein is dissected and taped first because adhesions around the ascending aorta and the heart are usually severe. It is sometimes easy to dissect around the brachiocephalic artery and left common carotid artery beneath the innominate vein. The removal of adhesions inside the pericardium can usually be limited to around the right side of the right atrium only to expose the right superior pulmonary vein in order to insert a left ventricular vent securely. After heparinization, a cardiopulmonary bypass is established with groin cannulation; an outflow cannula is added into the superior vena cava, and core cooling is applied. In cases with minor atherosclerotic plaque on the aortic arch, reconstruction of the arch branches is performed during cooling. The brachiocephalic artery is simply clamped, transected, and anastomosed with the main branch of a trifurcated graft in end-to-end fashion. Thereafter, selective cerebral perfusion (SCP) is initiated via the trifurcated graft. The left common artery is also anastomosed with the second branch of the trifurcated graft in the same fashion, and SCP is also established.

When the nasopharyngeal temperature reaches 25°C, main perfusion of the cardiopulmonary bypass is stopped and only SCP is continued. The aortic arch is transected just above the previous distal anastomotic site, and the proximal entries are inspected first. Entries are usually placed around the proximal anastomosis site. The left subclavian artery is clamped at the proximal site or sutured at the orifice, and SCP is added via an 8-mm ringed graft anastomosed to it. Cold blood cardioplegia is antegradely given via a balloon catheter placed into the

previous graft.

The distal suture line should be remained on the proximal site of the aortic arch. Entries on the distal aortic arch can be closed with a patch or direct sutures; however, FROZENIX can cover them without sutures. The adventitia and intima of the aortic arch are conjugated to make the anastomosis site. A felt strip is placed on the outer side of the arch, and four pieces of 3-0 monofilament U suture are placed from outside to inside in a cross direction (Fig. 1a). Then FROZENIX is inserted into the true lumen and deployed (Fig. 1b). When the true lumen is narrow or kinked, a guidewire is useful. FROZENIX can be safely inserted with a cable on wire technique¹⁾. A guidewire should be placed in the aortic arch via the femoral artery before circulatory arrest.

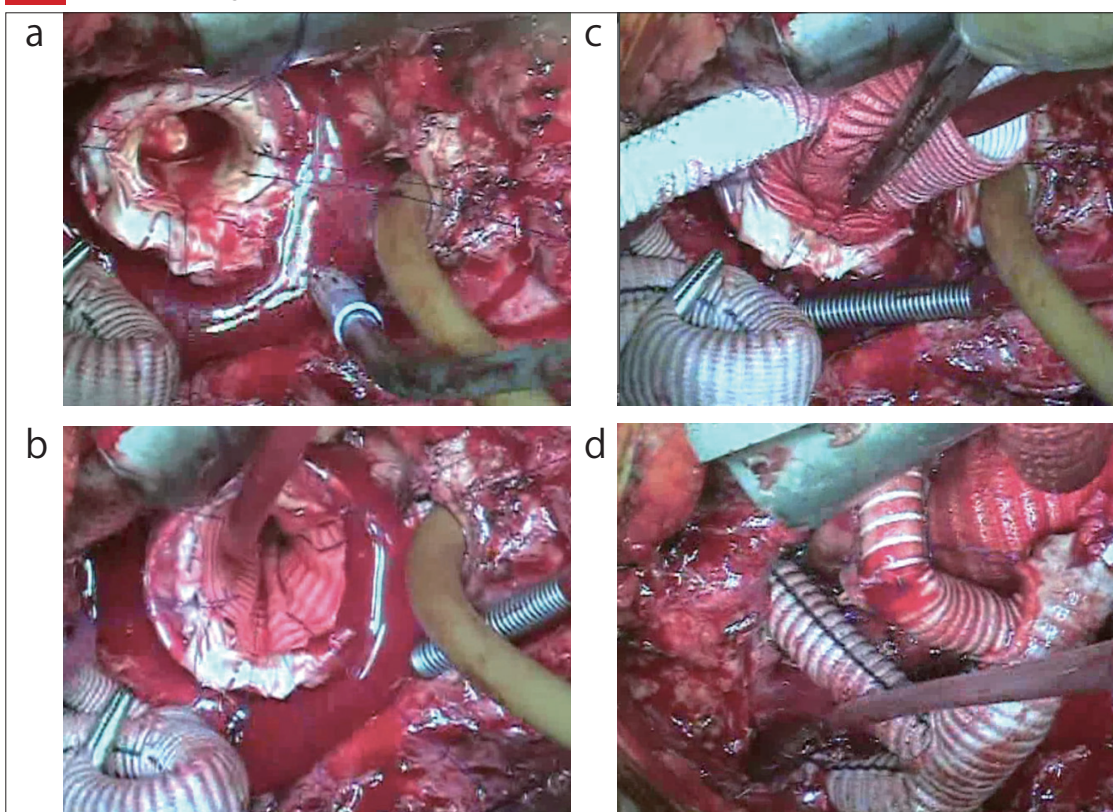
A balloon catheter is inserted into FROZENIX to confirm that it is not kinked. Then the aortic arch is reconstructed with a one-branched J Graft. FROZENIX and the J Graft are anastomosed with four pieces of 3-0 U suture that have been placed in advance and over-over running sutures are applied to conjugate the adventitia, intima, FROZENIX, and J Graft (Fig. 1c). After the anastomosis, air is removed by blood

perfusion via the femoral artery; subsequently, antegrade blood perfusion is resumed via the J Graft, and rewarming is initiated. At this time, sufficient hemostasis of the anastomotic line is confirmed.

The proximal site of the J Graft is anastomosed to the previous graft by continuous running suturing with 4-0 monofilament sutures.

The trifurcated graft is anastomosed with the one-branched main graft in side-by-side fashion to make a bigger anastomosis area; it is better placed on the right side of the main graft to avoid compression by the sternum. Proximal anastomosis can be performed using a side-bite clamp. The proximal end of the trifurcated graft is used as an air vent after reperfusion of the heart, and it is lastly closed. The cardiopulmonary bypass is disconnected after complete rewarming. The 8-mm ringed graft anastomosed to the left axillary artery is introduced into the pericardial space via the second intercostal space and is anastomosed with the last branch of the trifurcated graft. Heparin is neutralized with protamine sulfate after sufficient hemostasis (Fig. 1d).

Fig. 1 Operative findings



- a: The adventitia and intima of the aortic arch are conjugated.
- b: FROZENIX is inserted into the true lumen and deployed.
- c: FROZENIX and J Graft are anastomosed.
- d: Reconstruction of the aortic arch with a trifurcated graft.

KNACKS AND TIPS

In patients undergoing the ascending aortic replacement for acute type A aortic dissection, adhesions within the pericardium are generally severe, and it is important to remove the adhesions only within the necessary area, namely around the right side of the right atrium, the ascending and aortic arch. First the innominate vein is dissected and taped. Thereafter, it is generally easy to tape the arch branches. Adhesions around the replaced artificial graft are always severe, especially on the distal anastomosis side above the pulmonary artery. Cautious removal is essential to avoid injury of the pulmonary artery. When adhesions around the right atrium are severe, a left ventricular vent via the right superior pulmonary vein can be skipped.

The range of arch replacement remains within a short length in many cases. In such cases a trifurcated graft is useful for arch branch reconstruction instead of a four-branched graft.

The most important point to keep in mind in this procedure is not to resect the distal part of the aortic arch. In many cases, the main entries are placed around the proximal arch just above the previous anastomosis site. The distal anastomosis site should remain within the proximal arch for a secure procedure because the distal aortic arch is generally enlarged.

SIZE SELECTION FOR FROZENIX

It is mandatory to precisely measure the size of the true lumen by CT examination. The diameter is calculated using

the following equation: (maximum diameter + minimum diameter)/2 or circumferential length of the true lumen/3.

The size of FROZENIX is usually 10% larger than the diameter of the true lumen. The length of FROZENIX is generally 9 or 12 cm. It is determined by the distal anastomosis site and the area where FROZENIX is deployed. Extra part of FROZENIX is cut off to remain about 1 cm of the non-stented part for anastomosis.

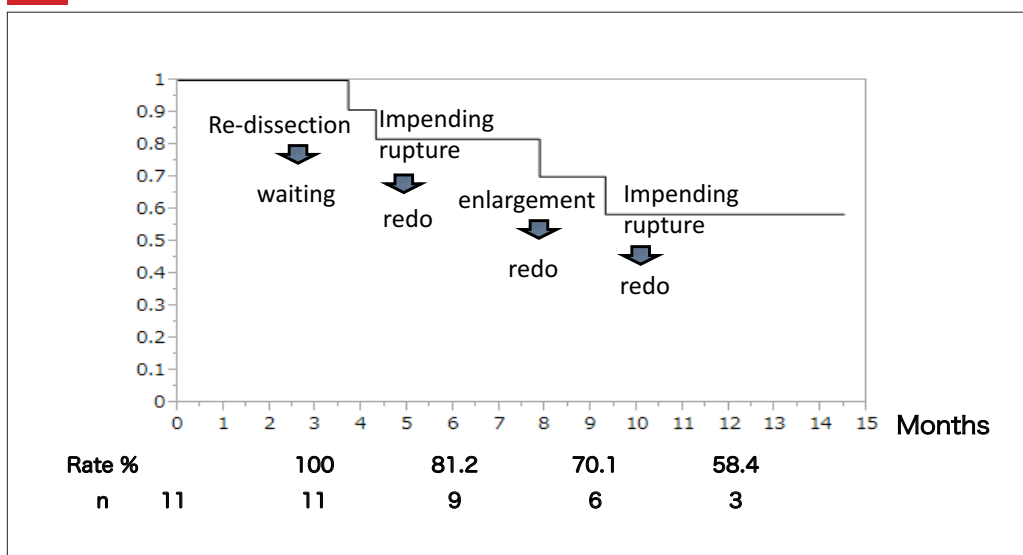
SURGICAL RESULTS

Eleven cases underwent TAR + FET with FROZENIX from 2014 to 2016. There were six men (54%) and one case of Marfan syndrome. The initial operation for acute type A aortic dissection was the ascending aorta replacement in nine cases and the Bentall procedure in two, and they were done an average 6.6 ± 4.1 years before the present surgery.

Average operation time, cardiopulmonary bypass time, cardiac ischemia time, lower limb ischemia time, and SCP time were 618, 296, 138, 72, and 165 minutes, respectively. The minimum body temperature was 24.4°C . ICU stay was 8.3 days (2-35), and hospitalization was 37.7 days (14-75). There were no hospital deaths and no stroke, but incomplete paraplegia was complicated in one case, who recovered well by rehabilitation.

The false lumen was thrombosed in the distal arch to the upper descending aorta after closure of the proximal entries by TAR + FET in all cases. The diameter of the false lumen was decreased, but the diameter of the true lumen was increased;

Fig. 2 Freedom from aortic events



therefore, the diameter of the descending aorta demonstrated no change. Aortic events were observed after TAR + FET in four cases (36%) during an average follow-up period of 20 months (Fig. 2). Total descending aorta replacements were performed in three of these patients. Aortic events frequently occurred after a central repair with TAR + FET; therefore, to be cautious, periodical CT follow-up is mandatory²⁾. When expansion of the residual dissection becomes visible, direct repair of the total descending aorta or thoracoabdominal aorta via a left thoracotomy should be scheduled (Fig. 3). Furthermore, acute aortic events may happen by stent graft-induced new entries (SINEs). In such a case, thoracic endovascular aortic repair is the first concern, but direct repair has to be rapidly performed due to anatomical limitations in some cases³⁾. Any aortic event should be kept in mind after TAR + FET.

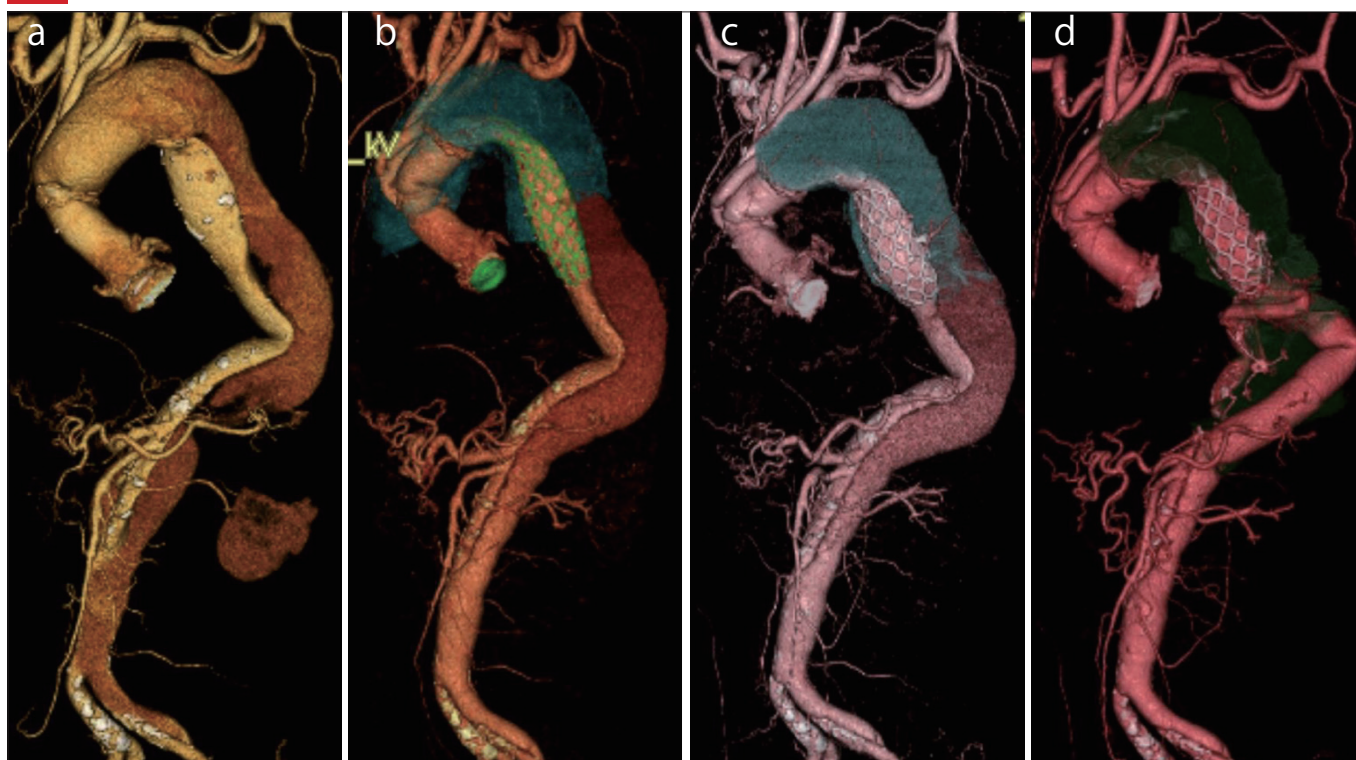
Spinal cord injury may occur during TAR + FET, even in patients with aortic dissection^{4, 5)}. It is essential to check the location and patency of intercostal arteries. In cases where the main intercostal arteries branch from the true lumen,

it is important to establish that the insertion length is not too far above the aortic valve position by transesophageal echocardiography. On the contrary, in cases where the main intercostal arteries branch from the false lumen, there is a risk of late spinal cord injury accompanying thrombosis of the false lumen. It is also important to keep the blood pressure high after surgery; a blood pressure higher than 140 mmHg is recommended. Spinal cord fluid drainage should be applied without delay when symptoms occur.

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Fig. 3 Follow-up with multidetector CT



- a: Preoperative findings.
- b: Postoperative findings.
- c: Re-enlargement of the distal arch.
- d: Findings after replacement of the total descending aorta.