A Simplified Delivery Frozen Elephant Trunk Technique to Reduce Circulatory Arrest Time in Hybrid Aortic Arch Surgery

Short running title: Simplified frozen elephant trunk

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Abstract

A simplified delivery technique for the frozen elephant trunk procedure allows the distal suture to be performed on a perfused and loaded aorta in moderate hypothermia—or even normothermia—reducing circulatory arrest time to just a few minutes. Two surgical sealing tourniquets are placed around the aortic arch, usually between the brachiocephalic trunk (BCT) and the left common carotid artery and the aorta is cross-clamped and cardioplegia started. Once in mild hypothermia, the BCT is disconnected and circulatory arrest is initiated while cerebral perfusion is maintained. This modified technique can be used in all pathologies, including dissections.

Since 1983 and Borst's innovative "elephant trunk" procedure, surgical treatment of extensive arch and thoracic aortic disease has evolved to be hybrid and multidisciplinary, epitomized in the Frozen Elephant Trunk (FET) that in turn has seen numerous modifications and simplifications as well as incremental device improvements.[1–3] Hypothermic circulatory arrest duration remains 40—60 min, however.[4–7] We propose a simplified delivery FET (SD-FET) technique that consists of releasing the FET prosthesis in zone 0 (or 1) with very limited circulatory arrest and moderate hypothermia—or even normothermia.

The Thoraflex Hybrid Plexus (4-branch configuration) device (Terumo Aortic, Inchinnan, Scotland, UK) is our center's standard FET prothesis and the most widely used in France (Figure 1).[8] Aortic arch aneurysms can be managed in a single stage and 15—20% oversizing (compared to the native aorta diameter at the distal sealing zone) is applied. In acute or subacute aortic dissections, the stent-graft diameter should be same as the diameter of the true aortic lumen with no oversizing. Our default length is 100 mm to limit the risk of spinal cord injury associated with long thoracic coverage, but the longer, 150 mm option may be appropriate for patients with an aneurysm limited to the aortic arch to obtain a distal seal without the addition of an extension. The study has been accepted by the local ethical committees. Patients provided an informed consent.

Data sharing: data available on request.

How to do it

A 20 Fr aortic cannula is first inserted and secured by two silk threads on the lateral anterograde perfusion branch of the prosthesis provided for this purpose. The compacted stent section is previously modeled by hand so that it fits into the concavity of the aortic arch and conforms to its curvature. The SD-FET technique does not require modification of conventional monitoring for any aortic arch surgery: multiple arterial blood pressure monitoring (double or single radial artery and/or femoral artery); Near Infrared spectroscopy (NIRS) to monitor cerebral perfusion; No spinal cord drainage.

Operation is performed through median sternotomy. Arterial and venous cannulation sites are left to the surgeon's discretion according to the center's habits, but a selective or semi-selective cerebral

perfusion is required before release of the FET device. Myocardial protection and cardioplegia are left to the surgical habits of the centers.

During the dissection and release of the aortic arch, it is important not to dissect the arch extensively to keep the attachment tissue, especially posteriorly, for the effectiveness of the "sealing tourniquets". Supra-aortic vessels are released and controlled.

The critical point of the technique is the placement of two surgical sealing tourniquets around the aortic arch, usually between the brachiocephalic trunk (BCT) and the left common carotid artery (LCCA). The LCCA and left subclavian artery (LSA) are clamped or sectioned from the arch. The aorta is cross-clamped and cardioplegia started. The aorta is transected and the root is prepared if necessary. Once in mild hypothermia (≥33°C), the BCT is disconnected and circulatory arrest is initiated while cerebral perfusion is maintained. The cross-clamp is then removed.

The compacted stent section of the prosthesis is inserted into the horizontal and descending aorta either by sight or on guidewire depending on anatomy and angulation of the aortic arch with the descending aorta (Figure 2A). The stent is deployed after checking the correct position of the collateral branches; particular attention must be paid to the correct deployment of the sewing collar facing the aortotomy. The ancillary instrument is then removed (Figure 2B and 2C).

Systemic cardiopulmonary bypass (CPB) is restarted via the fourth branch of the prosthesis (Figure 1D). Once the aorta is vented, the aortic tube is clamped and CPB output reaches normal value. Branches were previously clamped independently.

The two sealing tourniquets are gradually tightened on the aortic arch facing the stent (Figure 2E) until sealing is achieved in zone 0. The tourniquets should be carefully tightened under pressure of the antegrade arterial blood flow to minimize the risk of stent distortion due to tightening. At this point the lower body is perfused after a short lower body circulatory arrest (usually 5 to 10 min). Complete stent aortic wall apposition at the tourniquets clamping area allows for almost complete sealing in zone 0 according to the same principle as a hose-clamp to seal a hose onto a fitting. Distal anastomosis is

performed on a loaded aorta in zone 0 (figure 3), using running suture of 4.0 Prolene. At the end of the suture, the tourniquets can be removed in order to check hemostasis under full pressure.

The proximal end of the hybrid graft is finally anastomosed to the ascending aorta. After deairing, the aortic clamp is removed, and myocardial perfusion started. Then the collateral branches of the prosthesis are anastomosed to the LCCA and BCT respectively. LSA reimplantation is essential to optimize the medullary perfusion.

Comment

Previous reports have proposed modifications to the FET technique that reduce or avoid hypothermic circulatory arrest using aortic balloon occlusion (to block blood flow from the femoral perfusion) or the femoral and right axillary arteries for systemic cooling with no distal anastomosis.[9,10] However, clamping the distal arch can produce other problems as can ballooning in dissections.[11] A large meta-analysis of 4,178 FET procedures reported a mean hypothermic circulatory arrest time of 46 minutes occurring at 23°C and showed the CPB, myocardial ischemia, and circulatory arrest times strongly correlated with perioperative mortality (with moderate correlations between circulatory arrest time and spinal cord injury).[12] SD-FET can significantly reduce circulatory arrest time and allow the FET procedure to be carried out in moderate hypothermia and—with experience and mastery of the technique—even without cooling. In addition, suturing in zone 0 is generally simpler and more comfortable than in zone 1 or 2 and preserves the phrenic and the recurrent laryngeal nerves.

Clinical outcomes with this new technique will be published soon and report on the advantages of ST-FET over a conventional deep hypothermia approach. All thoracic aneurysmal pathologies are treatable via the SD-FET procedure although redo surgery is a more difficult indication due to the difficulty to free the aneurysmal aortic arch. For surgical teams interested in this new delivery technique, we recommend starting the first cases at 28°C.

Author contributions

Concept/design: NB/EB/TS/JCR/GG

Drafting article: GG/JCR/CHD

Critical revision of article: JCR/CHD/NB/EB

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REFERENCES

1. Borst HG, Walterbusch G, Schaps D. Extensive Aortic Replacement using "Elephant Trunk" Prosthesis. *Thorac Cardiovasc Surg*. 1983;31(1):37-40. doi:10.1055/s-2007-1020290

2. Di Bartolomeo R, Murana G, Di Marco L, et al. Frozen versus conventional elephant trunk technique: application in clinical practice. *Eur J Cardiothorac Surg*. 2017;51(suppl_1):i20-i28. doi:10.1093/ejcts/ezw335

3. Di Marco L, Votano D, Leone A, Pacini D. Frozen elephant trunk: assets and liabilities of a challenging technique. *Vessel Plus*. 2020;4. doi:10.20517/2574-1209.2020.23

4. Shrestha M, Kaufeld T, Beckmann E, et al. Total aortic arch replacement with a novel 4-branched frozen elephant trunk prosthesis: Single-center results of the first 100 patients. *J Thorac Cardiovasc Surg*. 2016;152(1):148-159.e1. doi:10.1016/j.jtcvs.2016.02.077

5. Shrestha M, Haverich A, Martens A. Total aortic arch replacement with the frozen elephant trunk procedure in acute DeBakey type I aortic dissections. *Eur J Cardiothorac Surg*. 2017;51(suppl_1):i29-i34. doi:10.1093/ejcts/ezw341

6. Chu MWA, Losenno KL, Dubois LA, et al. Early Clinical Outcomes of Hybrid Arch Frozen Elephant Trunk Repair With the Thoraflex Hybrid Graft. *Ann Thorac Surg*. 2019;107(1):47-53. doi:10.1016/j.athoracsur.2018.07.091

7. Kehoe M, Goldblatt J, Stamp N, Larbalestier R. Single-Centre Experience With the Thoraflex Hybrid Frozen Elephant Trunk Device. *Heart Lung Circ*. 2019;28:S91-S92. doi:10.1016/j.hlc.2019.02.077

8. Chabry Y, Porterie J, Gautier C-H, et al. The frozen elephant trunk technique in an emergency: THORAFLEX French National Registry offers new insights. *Eur J Cardiothorac Surg*. Published online November 3, 2020. doi:10.1093/ejcts/ezaa325

9. Sun X, Guo H, Liu Y, Li Y. The aortic balloon occlusion technique in total arch replacement with frozen elephant trunk. *Eur J Cardio-Thorac Surg Off J Eur Assoc Cardio-Thorac Surg*. 2019;55(6):1219-1221. doi:10.1093/ejcts/ezy369

10. Li Q, Ma W-G, Sun L-Z. Optimization of the total arch replacement technique: Left subclavian perfusion with sequential aortic reconstruction. *J Thorac Cardiovasc Surg*. Published online December 4, 2020. doi:10.1016/j.jtcvs.2020.11.110

11. di Eusanio M, Cefarelli M, Alfonsi J, Berretta P, Gatta E. Normothermic frozen elephant trunk surgery without circulatory arrest: how we do it in Ancona. *Ann Cardiothorac Surg*. 2020;9(3):244-245-245. doi:10.21037/acs.2020.02.01

12. Tian DH, Ha H, Joshi Y, Yan TD. Long-term outcomes of the frozen elephant trunk procedure: a systematic review. *Ann Cardiothorac Surg*. 2020;9(3):144-151-151. doi:10.21037/acs.2020.03.08