Editorial

From Borst into the future—perspectives for the frozen elephant trunk in acute aortic dissection type A

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The search for a surgical treatment method for the multifaceted aortic pathology reached a milestone in 1983 with the development of the so-called elephant trunk (ET) by Hans Georg Borst. The ET technique greatly simplified distal aortic repair after previous total arch replacement. In their how-to-do-it statement, "Extensive aortic replacement using "elephant trunk" prosthesis", Borst and his group heralded a paradigm change in the field of complex aortic arch surgery (1). This initial two-stage procedure was groundbreaking as it allowed for the prosthetic repair of both the aortic arch and the descending aorta. The pioneering development resulted in new perspectives not only in aortic arch surgery, but also for patients with aortic dissections. Although effective, it was still a complex, two-stage process that carried its own set of risks, including the need for a second surgery.

The emergence of the frozen ET (FET) technique

The search for an advantageous single-stage procedure led to another landmark in aortic surgery: the FET. For the first time, this hybrid procedure combined an aortic arch prosthesis with an endovascular stent graft treatment (2). This new technique was capable of treating aortic aneurysms of the arch and the proximal descending aorta in a single operation. It was also applied to aortic dissection. In contrast to the classical ET, where the trunk floated freely in the descending aorta, the FET stent graft expands the narrow true lumen of the dissected descending aorta to prevent distal malperfusion and help promote remodeling of the descending aorta. Progressive thrombotic occlusion of the false lumen is vital for reducing aneurysm wall stress and may help inhibit further increase in aortic diameter.

To date, two commercially available prostheses have become the most established in Europe: E-vita Open Neo (JOTEC GmgH, Hechingen, Germany) and Thoraflex Hybrid (Vascutek, Inchinnan, Scotland, UK). The latter is the only prefabricated FET hybrid graft certified for use in the United States.

In 2015, the FET technique gained international recognition and widespread adoption after its consideration in the European Association for Cardio-Thoracic Surgery (EACTS) position paper. For the first time, FET was to be considered for acute aortic dissections type A with entry tear in the distal aortic arch and complicated acute dissections type B when primary thoracic endovascular aortic repair (TEVAR) was not feasible (3).

However, evidence on whether the FET technique offered specific advantages in the field of aortic dissections compared to established methods such as proximal arch repair or extended arch replacement was still required. In support of this, in their meta-analysis, Yan *et al.* (4) concluded that, although limited arch repair is associated with lower early mortality compared to FET treatment, it also has higher rates of postoperative aortic events, such as reoperation of the distal aorta and dilatation of the false

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lumen. It is now an accepted clinical standard that, given the magnitude of such a procedure (FET), the reported postoperative mortality and morbidity should be adequately considered and not ignored.

Future perspectives

Future perspectives of FET surgery relate to the reduction of surgical complexity, such as endovascular connection strategies for the left subclavian artery and deployment devices that facilitate minimally invasive surgical approaches. Furthermore, future developmental work will concentrate on the biocompatibility of stent graft materials, for example, reducing thrombogenicity and providing stent designs that mimic individual patients' anatomies.

In addition to the FET hybrid graft treatment of the aortic arch and the descending aorta, open hybrid stent graft treatment of the supra-aortic branches will simplify complex aortic arch surgeries in the future. This is conceivable as an individual solution with individualised, size-adaptive hybrid grafts or as a uniform solution integrated into the common FET prosthesis.

Further modifications and innovations will be driven by the need arising from clinical problems.

In an operation where the primary goal is the patient's survival, the level of invasiveness has increasingly become a focus. While minimally invasive access is increasingly becoming established in aortic arch surgery, it is not yet routinely considered in acute aortic dissection type A (AADA). Nevertheless, initial reports of minimally invasive access in AADA patients suggest a decrease in perioperative surgical bleeding (5).

However, two and a half decades after the development of the FET technique, some concerning factors published on scientific platforms still require attention.

Innovative perfusion strategies for the myocardium as well as the brain can potentially minimize neurological complications and shorten operative times. Latest innovations during FET procedures include transfemoral stent graft implantation, balloon clamping, and continuous aortic perfusion (6). The choice of the correct landing zone for the FET also appears to be of increasing importance. Bozso *et al.* showed that the distal anastomosis at zone 2 was associated with a lower incidence of renal failure compared to zone 3 (7).

Further valuable information on procedure improvement was provided by Ferreira *et al.* (8). They demonstrated a lower early mortality rate, at the cost of greater spinal cord risk. This risk needs to be minimized by new neuroprotective strategies. Currently, surgeons can choose from a variety of options that require customization. However, the benefits of proximalization of the FET landing zone are evident here as well (9).

Intraluminal thrombus formation (ILT) is a proven complication involving intraluminal thrombus within the stent component of the frozen elephant stent graft prosthesis, occurring in approximately 6% to 17% of cases. It puts the patient at risk for downstream embolization, potentially resulting in visceral or lower limb ischemia. Future strategies to avoid ILT formation may include anticoagulation management, minimization of postoperative coagulation factor application, and even technical optimizations of the stent graft portion itself (10).

Nevertheless, Wisniewski *et al.* have asked the essential question: "*The frozen elephant trunk in aortic dissection: an ultimate solution?*" (11). The FET has a low mortality rate and high mid-term survival rate in experienced centers. Thus, we can generally assume that FET is the best current solution and represents a crucial element in achieving the ultimate solution for the treatment of aortic dissections—an endovascular solution.

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Footnote

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