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ORIGINAL ARTICLE

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Thoraflex hybrid as frozen elephant trunk in chronic, residual type A and chronic type B aortic dissection

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Key question

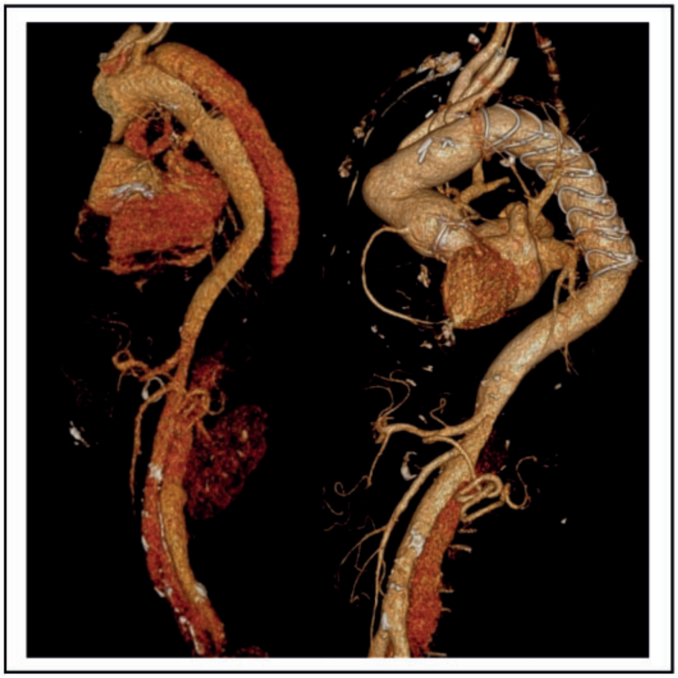
Is the frozen elephant trunk (FET) technique optimal for chronic residual and type B aortic dissection?

Key finding(s)

The FET procedure is a good solution in chronic and residual downstream aorta dissections for inducing positive aortic remodelling.

Take-home message

The FET procedure is a good treatment for chronic or residual aortic dissections; it has a low mortality but a significant risk of stroke.



Abstract

OBJECTIVES: The frozen elephant trunk technique is an increasingly common treatment for extensive disease of the thoracic aorta. The objective of the study was to evaluate the outcomes of frozen elephant trunk specifically in chronic (residual) aortic dissections, focusing on downstream aortic remodelling.

METHODS: Between 2013 and 2019, a total of 28 patients were treated using the Vascutek Thoraflex hybrid graft at our institution for chronic dissections/post-dissection aneurysms. Immediate and follow-up outcomes were studied, as well as the changes in total aortic diameter, true lumen and false lumen diameter and the status of the false lumen at 3 different levels of the thoraco-abdominal aorta.

RESULTS: No in-hospital or 30-day mortality was observed, temporary paraparesis rate was 7% and disabling stroke incidence was 14.3%. Freedom from all-cause mortality at 2 years was 91.6 ± 5.7%, while freedom from reintervention on the downstream aorta at 2 years was 59.1 ± 10.8%. Positive aortic remodelling was achieved in 50.0%, with an enlargement in the true lumen and a reduction of the false lumen not only at the level of the proximal descending aorta with 73.1% of complete thrombosis but also at the level of the distal descending thoracic aorta, with 41.7% of complete thrombosis.

CONCLUSIONS: The frozen elephant trunk is a good solution in chronic (residual) downstream aortic dissections inducing positive aortic remodelling and preventing from II stage operations or allowing an endovascular approach.

Keywords: Frozen elephant trunk • Chronic residual aortic dissection • Aortic remodelling

ABBREVIATIONS

CPB	Cardiopulmonary bypass
CT	Computed tomography
DTA	Descending thoracic aorta
FET	Frozen elephant trunk
FL	False lumen
LCCA	Left common carotid artery
LSA	Left subclavian artery
SCI	Spinal cord injury
TEVAR	Thoracic endovascular aortic repair
TL	True lumen

INTRODUCTION

The frozen elephant trunk (FET) technique represents a well-established technique to treat, in a single stage, patients with extensive disease of the thoracic aorta [1]. It is widely used for complex thoracic aortic aneurysms involving the aortic arch and the proximal descending aorta, as well as acute and chronic aortic dissections, combining the benefits of endovascular and conventional surgery and providing a more convenient landing zone for second-stage downstream endovascular or open repair [2, 3].

This article focuses on its use in chronic (residual) aortic dissections, a clinical scenario often encountered after previous type A repair, or type B not treatable by thoracic endovascular aortic repair (TEVAR) alone [4].

Previously, the patients with post-dissection thoracoabdominal aortic aneurysm (TAAA) would undergo staged repair: stage I would be a total arch replacement with a classic elephant trunk, generally as a reoperation, which would always be followed by stage II open TAAA repair. The use of FET (stent graft vs conventional elephant trunk) has been shown to induce aortic remodelling and potentially prevent the need for stage II operations, and also may favour an endovascular stage II completion instead of open repair [5, 6]. For that reason, we evaluated the outcomes of FET technique in chronic, and residual, downstream dissection.

MATERIALS AND METHODS

Patient characteristics

Between 2013 and 2019, a total of 73 patients were treated using the Vascutek Thoraflex hybrid graft at our institution. Among these 73 patients, 34 (46.6%) underwent surgery for degenerative aneurysm, and were therefore excluded from our study, as well as 11 patients (15.1%) who were treated either for acute aortic dissection (type A and type B) or for intramural hematoma (IMH).

Our study population was then represented by 28 patients, who were treated with FET in a chronic setting, for residual dissection after type A repair (79.0%), chronic type A aortic dissection (7.1%) or chronic type B aortic dissection (14.3%). The mean diameter of the proximal descending aorta before surgery was 49.3 (±11.5) mm with a mean false lumen (FL) diameter of 37.2 (±12.2) mm and a median true lumen (TL) diameter of 13.0 (±6.4) mm.

Eleven patients (39.3%) had a diameter of the distal descending and/or abdominal aorta of >55 mm, so an intervention on the downstream aorta was already planned at the time of the FET procedure; in the other 17 patients (60.7%), the diameter of the downstream aorta was below the threshold for intervention at the time of the FET procedure.

The mean age of our population was 63.7 ± 10.4 years and 57.1% was male. All patients had a preoperative left ventricular ejection fraction >55%, 1 (3.6%) suffered from Marfan syndrome and 3 (10.7%) from other connective tissue disorders (in detail: 1 Familial Thoracic Aortic Aneurysm and Dissection Syndrome, 1 SMAD3 variant, 1 Loeys–Dietz). Twenty-two (78.6%) were reoperations, and the median EuroSCORE value was 10 (Table 1).

This retrospective study was approved by local institutional Review Board and did not require the patients' informed consent. It was also conducted in accordance with the ethical principles established in the Declaration of Helsinki.

Table 1: Baseline characteristics

Variables	*n* (%), mean ± SD, median (range)
Male sex	16 (57.1)
Age (years)	63.7 ± 10.4
Body mass index (kg/m^2)	26.8 ± 6.4
Hypertension	17 (60.7)
Diabetes	1 (3.6)
Hyperlipidaemia	3 (10.7)
Active smoking	3 (10.7)
COPD	6 (21.4)
Marfan	1 (3.6)
Other connective tissue disease	3 (10.7)
Peripheral vascular disease	1 (3.6)
Chronic kidney disease (GFR < 40)	3 (10.7)
Bicuspid aortic valve	2 (7.1)
Stroke	4 (14.3)
Coronary artery disease	1 (3.6)
LVEF >55%	28 (100)
EuroSCORE	10 (5–14)
Reoperation	22 (78.6)
Type of dissection	
Residual after type A repair	22 (78.6)
Chronic type A dissection	2 (7.1)
Chronic type B dissection	4 (14.3)

COPD: chronic obstructive pulmonary disease; GFR: glomerular filtration rate; LVEF: left ventricular ejection fraction; SD: standard deviation.

VASCULAR

Operative strategy

All patients underwent the FET surgery in an elective setting, through median sternotomy. Operative characteristics are listed in Table 2. Arterial cannulation site for cardiopulmonary bypass (CPB) was heterogeneous: the femoral artery was used in 11 patients (39.3%), but the ascending aorta/previous prosthesis (28.6%) and the right subclavian artery (28.6%) were also commonly cannulated. A peripheral cannulation strategy was chosen only if a central cannulation was not possible due to unfavourable anatomy (epiaortic vessels involved in the disease, difficult chest re-entry, small arteries, etc.). Mean CPB time was 262.4 (±60.9) min with 118.6 (±44.3) min of aortic cross-clamp time depending also on the associated procedures performed. Bilateral antegrade selective cerebral perfusion was used in all patients, with a mean time of 116 (±36.8) min, associated with moderate hypothermia (25°C). No cerebrospinal fluid drainage was placed preoperatively.

The prosthesis used was the Vascutek Thoraflex hybrid graft (Inchinnan, Scotland) for all patients, with a proximal graft diameter between 26 and 30 mm and distal stent graft diameter between 28 and 40 mm according to the TL diameter (10–20% oversize). As for the length of the prosthesis, the 150 mm was used in 19 cases (67.9%), and the 100 mm in the rest of patients (32.1%) according to the location of distal entry sites and the level of the arch where the thoraflex cuff was anastomosed. The proximal anastomosis of the stent graft was done between the left common carotid artery (LCCA) and the left subclavian artery (LSA) (zone 2) in 25 (89.3%) cases, and beyond the LSA (zone 3) only in 3 cases (10.7%). As for the management of the LSA, it was reimplanted into the prosthesis in 82.1% of cases. In 3 patients, all more recently in our experience, a staged LCCA-LSA bypass was performed about 2 weeks before the FET procedure, in order to enable an earlier restart of antegrade systemic perfusion, and hence, reduce lower body ischaemic time. None of these patients suffered from (temporary) spinal cord ischaemia or from acute kidney injury or bowel ischaemia. Routine postoperative follow-up included a control computed tomography (CT) scan before discharge, at 3 months postoperatively, and yearly from then on.

Table 2: Operative characteristics

Variables	*n* (%), mean (±SD), median (range)
Arterial cannulation	
Ascending aorta/prosthesis	8 (28.6)
Femoral artery	11 (39.3)
Right subclavian artery	8 (28.6)
Left common carotid artery	1 (3.6)
Venous cannulation	
Right atrium	10 (35.7)
Femoral vein	18 (64.3)
Cardiopulmonary bypass time	262.4 (±60.9)
Antegrade cerebral perfusion time	116.5 (±36.8)
Circulatory arrest time	70.3 (±28.4)
Aortic cross-clamp time	118.6 (±44.3)
Lowest temperature	25 (18–25)
Proximal thoraflex graft diameter (mm)	
26	11 (39.2)
28	11 (39.2)
30	3 (10.7)
Missing	3 (10.7)
Distal thoraflex stent graft diameter (mm)	
28	11 (39.2)
30	11 (39.2)
32	1 (3.6)
34	1 (3.6)
40	1 (3.6)
Missing	3 (10.7)
Thoraflex length (mm)	
100	9 (32.1)
150	19 (67.9)
Associated procedure	
AVR	3 (10.7)
Bentall	5 (17.8)
Bentall + TEVAR	1 (3.6)
Supra-aortic branch vessel procedure (other than LCCA-LSA bypass)	2 (7.1)
Level of distal anastomosis	
Between LCCA and LSA (zone 2)	25 (89.3)
Distal to LSA (zone 3)	3 (10.7)
Left subclavian artery management	
Reimplantation into prosthesis	23 (82.1)
Deliberate sacrifice	1 (3.6)
Simultaneous LCCA-LSA bypass	1 (3.6)
Staged LCCA-LSA bypass	3 (10.7)

AVR: aortic valve replacement; LCCA: left common carotid artery; LSA: left subclavian artery; SD: standard deviation; TEVAR: thoracic endovascular aortic repair.

Aortic computed tomography scan analysis

Additionally, we measured for each patient the total aortic diameter, the TL and FL diameter at 3 different levels of the descending thoraco-abdominal aorta, considering what had already been published in literature [6]:

- Level 1: mid descending thoracic aorta (DTA) at the level of pulmonary artery bifurcation, which is usually covered by the stent graft.
- Level 2: in the distal DTA at the level of the 10th thoracic vertebra, which is usually not covered by the stent graft.
- Level 3: as the distal abdominal aorta below the renal arteries.

The preoperative measurements were taken on the last CT scan performed before the FET surgery, while the follow-up measurements were taken on the most recent CT scan available for every patient or on the last CT scan before eventual second-stage open or endovascular repair (Fig. 1).

The status of the FL (patent/partially thrombosed or completely thrombosed) was also recorded for every level, as previously in literature [6]. Positive aortic remodelling was defined as no reintervention on downstream aorta, absence of total diameter progression, and FL stabilization or diameter decrease with (partial) thrombosis at the level of the proximal and distal DTA.

Statistical analysis

IBM SPSS statistics 24.0 (Statistical Package for Social Science, IBM, Armonk, NY, USA) was used for statistical analysis. Data were reported as mean ± standard deviation if they were normally distributed or as median (range) if they were not. Kaplan–Meier analysis was used to assess midterm follow-up outcomes. The difference between preoperative and postoperative aortic diameters was assessed using Wilcoxon rank test, applying Bonferroni correction for multiple testing, and comparison of FL

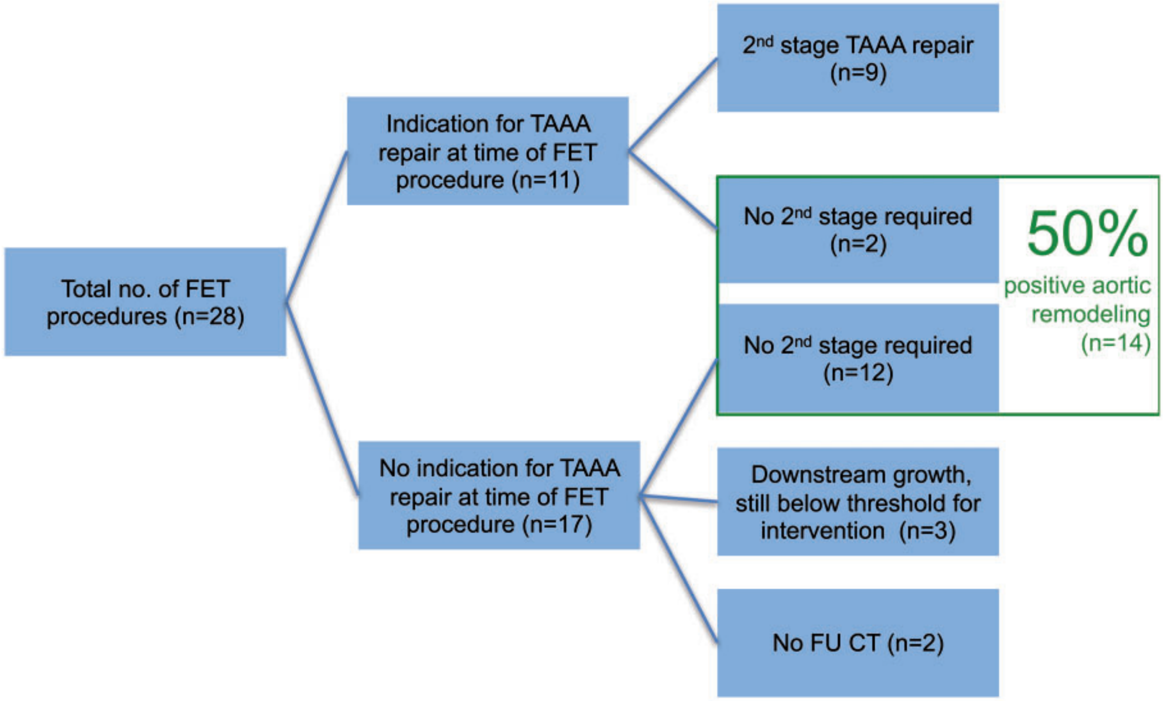


Figure 1: Flow chart of patients treated with a FET procedure. CT: computed tomography; FET: frozen elephant trunk; FU: follow-up; TAAA: thoracoabdominal aortic aneurysm.

status was performed using Fisher's exact test. A *P*-value ≤0.05 was considered statistically significant.

RESULTS

Early results

No in-hospital or 30-day mortality was observed (Table 3). Seven patients (25.0%) required >72 h ventilation. No acute kidney injury requiring dialysis occurred. As for spinal cord injury (SCI), 2 patients (7.1%) suffered from a temporary paraparesis of the lower extremities, which completely resolved after emergent placement of a spinal drain. On the other hand, a relatively high incidence of stroke was observed. In detail, 4 patients (14.3%) suffered from disabling stroke (Modified Ranking Scale ≥ 2) because of a middle cerebral artery infarction with unilateral hemiparesis, while 3 patients (10.7%) experienced minor non-disabling strokes (Modified Ranking Scale = 1) because of an anterior cerebral artery infarction with apraxia, an occipital infarction with hemianopsia and a cerebellar infarction.

Table 3: Postoperative results (30 day)

Variables	*n* (%), median (range)
Mortality	0
Low output syndrome	1 (3.6)
Intubation >72 h	7 (25.0)
Rethoracotomy for bleeding	4 (14.3)
Dialysis	0
GI complication	2 (7.1)
Myocardial infarction	1 (3.6)
Disabling stroke (MRS ≥ 2)	4 (14.3)
Non-disabling stroke (MRS = 1)	3 (10.7)
Spinal cord injury	
Permanent	0
Transient	2 (7.1)
ICU stay (days)	5 (2–45)
In-hospital stay (days)	21 (5–90)

GI: gastrointestinal; ICU: intensive care unit; MRS: Modified Ranking Scale.

Follow-up results

The median follow-up duration was 14.5 (range 0.2–58.7) months. Estimated freedom from all-cause mortality at 2 years was 91.6 ± 5.7%. There were 3 documented deaths during follow-up [in-hospital cardiac arrest after TAAA repair (*n* = 1), paraplegia and renal failure after TAAA repair (*n* = 1), sepsis after cholecystectomy (*n* = 1)]. Estimated freedom from reintervention on the downstream aorta at 2 years was 59.1 ± 10.8% (9 reoperations). In detail, 5 open TAAA repair and 4 TEVAR (2 followed by open TAAA repair). In all 9 patients, a procedure on the downstream aorta had already been planned at the time of the FET procedure. However, in 3 of these patients, this had to be done more urgently due to occurrence of the following negative events: distal SINE in a chronic type B aortic dissection (*n* = 1), rapid dilatation of the FL in the proximal descending aorta (*n* = 1) [7], contained rupture of the distal descending aorta (*n* = 1). One more distal SINE was observed during follow-up in a patient operated on for a chronic type A aortic dissection, but did not require any reintervention. Both SINE were observed with 150 mm Thoraflex prosthesis. Additionally, 4 reinterventions were performed for other indications: proximal false aneurysm repair (*n* = 1), LSA stent for false aneurysm at the suture line (*n* = 1), resternotomy with omentum for mediastinitis (*n* = 2). Follow-up of the stroke patients was median 6 (range 1–26) months. Four out of 7 patients recovered with no significant or mild handicap, while 3

Table 4: Changes in the diameter of the total aorta, of the false lumen and of the true lumen at the 3 different levels and false lumen thrombosis rate

			Preoperative, mean (±SD), *n* (%)	Postoperative, mean (±SD), *n* (%)	Change, mean (±SD), *n* (%)	*P*-value
Proximal descending aorta (pulmonary bifurcation)	Diameter	Total	49.3 (±11.5)	49.9 (±13.8)	+0.6 (±8.7)	1.0
		FL	37.2 (±12.2)	27.1 (±16.7)	-10.1 (±13.6)	0.012
		True lumen	13.0 (±6.4)	23.4 (±7.8)	+10.4 (±8.2)	<0.001
	FL	Patent	28 (100)	4 (15.4)		
		Partial thrombosis	0	3 (11.5)		
		Complete thrombosis	0	19 (73.1)		
Distal descending aorta	Diameter	Total	43.9 (±12.2)	44.8 (±12.1)	+0.9 (±4.2)	0.96
		FL	32.7 (±13.9)	25.5 (±13.0)	-7.2 (±12.2)	0.042
		True lumen	12.1 (±4.7)	19.1 (±9.8)	+6.8 (±11.0)	0.009
	FL	Patent	28 (100)	11 (45.8)		
		Partial thrombosis	0	3 (12.5)		
		Complete thrombosis	0	10 (41.7)		
Abdominal aorta	Diameter	Total	27.3 (±5.7)	28.5 (±5.6)	+1.2 (±2.0)	0.027
		FL	17.2 (±5.9)	17.8 (±5.6)	+0.6 (±2.3)	0.78
		True lumen	10.8 (±2.9)	11.5 (±3.1)	+0.7 (±1.3)	0.081
	FL	Patent	23 (100)	23 (95.8)		
		Partial thrombosis	0	1 (4.2)		
		Complete thrombosis	0	0		

FL: false lumen; SD: standard deviation.

had a moderate or severe handicap [Modified Ranking Scale 1 (*n* = 3), 2 (*n* = 1), 3 (*n* = 2), 4 (*n* = 1)].

Aortic remodelling

Median duration from operation to last postoperative CT scan was 5.2 months (range 0.1–58.7). Positive aortic remodelling was achieved in 50.0% of patients (*n* = 14). In fact, a significant enlargement in the TL diameter, together with a significant reduction of the FL diameter, was observed not only at the level of the proximal descending aorta (at the level of the pulmonary bifurcation, covered by the stent graft), with a 73.1% complete thrombosis rate, but also at the level of the distal descending aorta, which was not covered by the stent graft, with a rate of complete thrombosis of 41.7% (Table 4). At the level of the abdominal aorta, on the other hand, there was a small, but significant increase in the total dimension of the aorta and in the FL diameter, with only one case of partial thrombosis. A second-stage procedure on the downstream aorta was already planned at the time of the FET procedure in 11 patients, but 2 of those (18.2%) no longer required TAAA repair, thanks to positive aortic remodelling with the FET only (fig. 1).

DISCUSSION

Extensive repair including graft replacement of the ascending aorta and aortic arch and integrated stent grafting of the descending aorta ('frozen elephant trunk') is recommended as a single-stage procedure for the treatment of chronic aortic dissections in current guidelines [8]. Its advantage lies in the fact that the stented portion, unlike a conventional elephant trunk prosthesis, can be securely anchored at the desired level distal to the descending aortic aneurysm, thereby allowing thrombus formation within the space between the graft and the wall of the aneurysm [1].

A potential drawback of the FET is the incidence of neurological complications and in particular the issue of SCI to be reported around 5% in literature [9, 10]. In our population, we did not observe any permanent SCI, and only 2 transient paraparesis which completely resolved after emergent placement of a spinal drain. Both cases were observed with the 150-mm Thoraflex prosthesis, which could be easily explained with a longer covering of the descending aorta and consequently of more intercostal arteries.

Recently, in selected cases, we started to perform a staged LCCA-LSA bypass a few weeks before the FET procedure itself. The idea was to reduce both the complexity of the procedure with the reimplantation of just 2 supra-aortic vessels and the systemic arrest time, together with the cross-clamping time of the LSA to improve the spinal cord perfusion during the procedure. With the level of anastomosis between usually the LCCA and LSA, the 100 mm stent graft would be deployed in an unfavourable angle in the descending aorta, potentially causing a SINE. We therefore favour the longer 150 mm stent graft, which has a greater chance of inducing positive remodelling. With the short circulatory arrest time of the staged approach, we have not observed any SCI, despite the fact that we do not routinely install a cerebrospinal fluid drain preoperatively.

On the other hand, the stroke rate observed in our population is a matter of concern. The supposed underlying mechanisms are macro- or microembolism, inflammatory response activation and blood–brain barrier disruption and alterations in neurological metabolism. Stroke rates after total arch replacement are most commonly reported for aneurysm and dissection patients combined. In literature, we can find different rates of neurological complications. In a large meta-analysis of 3000 patients treated with FET, the estimated stroke rate was 7.6% (5.0–11.5%) for all patients combined and 6.6% in non-acute cases [11], while the Bologna group [3] observed a 9% of stroke, and Shrestha *et al.* [2] reported a 10.1% stroke rate specifically for FET in chronic dissections and an 18% in acute aortic dissections. We did not find identifiable risk factors for the increased stroke risk in our small study population. Furthermore, there was no association with the procedure learning curve, as the incidence of stroke was evenly distributed across study years (2 in 2015, 2 in 2017 and 3 in 2018). Previously reported risk factors for neurological complications during any kind of aortic arch surgery and for any indication included increased circulatory arrest time [12] and operative time [13]. We have previously reported an overall incidence of neurological dysfunction of 11.5% (of which 5.3% was due to stroke) [14]. Femoral artery cannulation, progressive CPB, circulatory arrest and antegrade selective cerebral perfusion time were associated with neurological complications after elective arch procedures [14].

With our current data, unfortunately, we are not able to explain this significantly higher incidence of stroke in our population. It is possible to speculate about the influence of femoral artery cannulation (39.3%) or relatively long antegrade selective cerebral perfusion times (116.5 min), but the small size of the current study population did not enable a meaningful regression analysis. Further investigations on a larger number of patients will be necessary to enlighten this issue and find possible risk factors in order to make the procedure safer.

Although the indications for FET include degenerative aneurysm and acute dissections, the prosthesis theoretically offers the greatest advantage in chronic dissections because of its superior ability to induce positive remodelling compared to the conventional elephant trunk, and by facilitating an endovascular option in cases where stage II repair is needed downstream. This procedure should also be considered in type B dissection in case of unfavourable proximal landing zone for TEVAR (dilated, angled, calcified, etc.) or in case of a retrograde component in the arch. In our paper, we noted positive remodelling in 50.0% of our cohort, with 73.1% complete FL thrombosis at the level of the stent and 41.7% in the distal descending.

Furthermore, we observed a significant enlargement in the TL diameter and a significant reduction of the FL diameter not only at the level covered by the stent graft, but also more distally, generating the so-called positive aortic remodelling that we found in the 50.0% of our population. Remarkably, as described above, 11 patients of our population had already a planned second-stage procedure on the downstream aorta at the time of FET surgery. However, in 2 of them, the FL thrombosis and the aortic diameter reduction observed after the first surgery made the second-stage procedure no longer necessary (Fig. 2). Of the 17 patients who had no indication yet for a second-stage procedure at the time of the FET, only 3 experienced a downstream aorta growth, but the diameter is still below the threshold for surgery. These findings are in line with the hypothesis that the FET could be the ideal treatment in chronic aortic dissections because of its ability in promoting FL thrombosis in the DTA, distally to the stent graft position, representing eventually a definitive treatment. Aortic remodelling after FET has been described by Iafrancesco *et al.* [6] in 2017, who studied 137 patients treated with E-Vita Open plus prosthesis in different European centres, regardless of the underlying pathology. In the subgroup treated for chronic dissection, in segments with FL thrombosis, the total aortic diameter remained stable or decreased, whereas the TL diameter remained stable at all levels; in segments with FL patency instead, the total aortic diameter remained stable proximally, but increased in the mid descending aorta and in the lower segments, and the TL remained stable except in the mid descending aorta where it increased. Previously, in 2016, also Dohle *et al.* [15] studied the downstream aorta remodelling after FET in 70 patients, observing

Figure 2: Aortic remodelling after frozen elephant trunk surgery at the 3 different levels of the thoraco-abdominal aorta considered in the study.

a positive or stable remodelling in the 90% of patients along the stent graft aortic segment, in 65% downstream to coeliac trunk and in 58% distally to bifurcation within 1 year. More recently, Iida *et al.* [16] investigated aortic remodelling after acute type A aortic dissections treated with FET using the J-Graft open stent graft (Japan Lifeline, Ichihara, Japan) considering the presence and the position of re-entry tears along the DTA. They found that, when the number of communications between the lumina was 0, complete aortic remodelling was achieved in all patients. On the contrary, aortic remodelling did not occur as long as the most proximal tear was located in the descending aorta. These very interesting findings should be a stimulus to improve preoperative planning, eventually providing FET extension with TEVAR in the short term after the first surgery in selected patients, after analysis of the CT scan and the identification of the re-entry tears. Kozlov *et al.* [17] defined this as 'elongated frozen elephant trunk', using an additional thoracic stent graft implanted down to the coeliac artery, within 30 days after the first stent graft implantation. Then, they analysed aortic remodelling in 3 aortic segments [along the stent graft (A), between the distal edge of the graft and the coeliac trunk (B) and at the abdominal aorta (C)] between the standard FET and the elongated FET group. According to their paper, the elongated FET technique seems to be superior to the standard FET procedure in terms of aortic remodelling.

Finally, we would like to address the fact that 78.6% of our cohort consisted of reoperations after acute type A repair. The distal extent of these initial repairs was limited to the ascending aorta or proximal arch in all cases. As the principal aim of acute type A repair is to prevent death from rupture, tamponade or malperfusion, and promoting aortic remodelling is only a secondary aim, we do not advocate routinely using FET for DeBakey type I dissections. However, with a slightly more extensive distal repair combined with debranching of the arch vessels, if necessary, completed endovascularly at a later stage (so-called type II hybrid arch repair procedure), complex open arch reoperations, with the risks mentioned in the current study, can theoretically be prevented [18].

Limitations

The retrospective and single-institutional nature of our study represents the main limitation. Moreover, our population is relatively small, as we chose to study the distal aorta remodelling only on patients treated in a chronic setting and with the same prosthesis.

CONCLUSIONS

The FET is a good treatment for all aortic pathologies involving the aortic arch and the proximal descending aorta, but it is optimal in case of chronic or residual dissection with low mortality but a significant risk of stroke. In our small cohort, the use of the FET showed very good results in terms of aortic remodelling, proving the theoretical advantage of using the stent graft which promotes FL thrombosis at the stent graft level, but also below it (at the distal descending aorta). In this way, in selected patients, this technique can potentially be 'curative' and prevent a second-stage operation on the downstream aorta, or at least it can enable an endovascular stage II completion instead of open repair.

Conflict of interest: none declared.

Author contributions

Mariafrancesca Fiorentino: Conceptualization; Data curation; Investigation; Methodology; Writing—original draft. **Hector** W.L. **de Beaufort:** Data curation; Formal analysis; Writing—review & editing. **Uday Sonker:** Conceptualization; Writing—review & editing. **Robin H. Heijmen:** Conceptualization; Validation; Writing—review & editing.

Reviewer information

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