

Early- and medium-term results after aortic arch replacement with frozen elephant trunk techniques – a single center study

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Background: The treatment of patients with extensive thoracic aortic disease involving the arch and descending thoracic/thoracoabdominal aorta is often performed using the frozen elephant trunk technique (FET). We retrospectively analyzed our results of the FET operation.

Methods: A total of 51 consecutive patients underwent total aortic arch surgery with the FET technique between January 2006 and August 2013. For all patients, the E-vita hybrid open stent-graft (Jotec, Hechingen, Germany) was used. The patients had a mean age of 64 ± 13 years, with 51.1% being female. Degenerative or atherosclerotic aneurysm was the indication for surgery in 62.7% of patients. Another 15.7% and 13.7% suffered from acute Type A, and Type B aortic dissection, respectively.

Results: The in-hospital and 30-day mortality was 7.8%. Stroke occurred in 11.8% (n=6), and new-onset paraplegia in 19.6% (n=10) of patients. The core body temperature ≥ 28 °C during circulatory arrest, in combination with a prolonged circulatory arrest time of more than 45 minutes, was an independent predictor of permanent spinal cord injury [odds ratios (OR), 4.8; 95% confidence intervals (CI), 1.1-21; P=0.04]. The estimated 1- and 5-year survival was $(80.2\pm 5.5)\%$ and $(59.7\pm 10.2)\%$, respectively, with a mean survival time of 3.4 ± 0.4 years. The estimated mean freedom from endovascular intervention was 4.2 ± 0.4 years. The unadjusted 1- and 5-year freedom from thoracic endovascular aortic repair (TEVAR) was $(84.9\pm 5.9)\%$ and $(69.2\pm 11.2)\%$, respectively.

Conclusions: The FET procedure for extensive thoracic aortic disease is associated with an acceptable early and medium term mortality rate. This procedure is associated with a high incidence of perioperative spinal cord injury. In order to prevent the above complication, deep hypothermia is strongly recommended in patients with expected prolonged circulatory arrest time.

Keywords: Aortic arch surgery; elephant trunk



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Introduction

The standard surgical technique for patients with extensive pathology of the thoracic aorta is still the conventional elephant trunk technique, developed by Borst in 1983 (1). However, this procedure is associated with increased operative medium term mortality, and also with a high incidence of neurological complications (2). In recent years

many new technological solutions based on endovascular methods have been introduced into clinical practice, one of them being a hybrid procedure, the frozen elephant trunk technique (FET) (3).

The current study shows our 7-year institutional experience of using the FET technique for the treatment of patients with extensive thoracic aortic disease. The

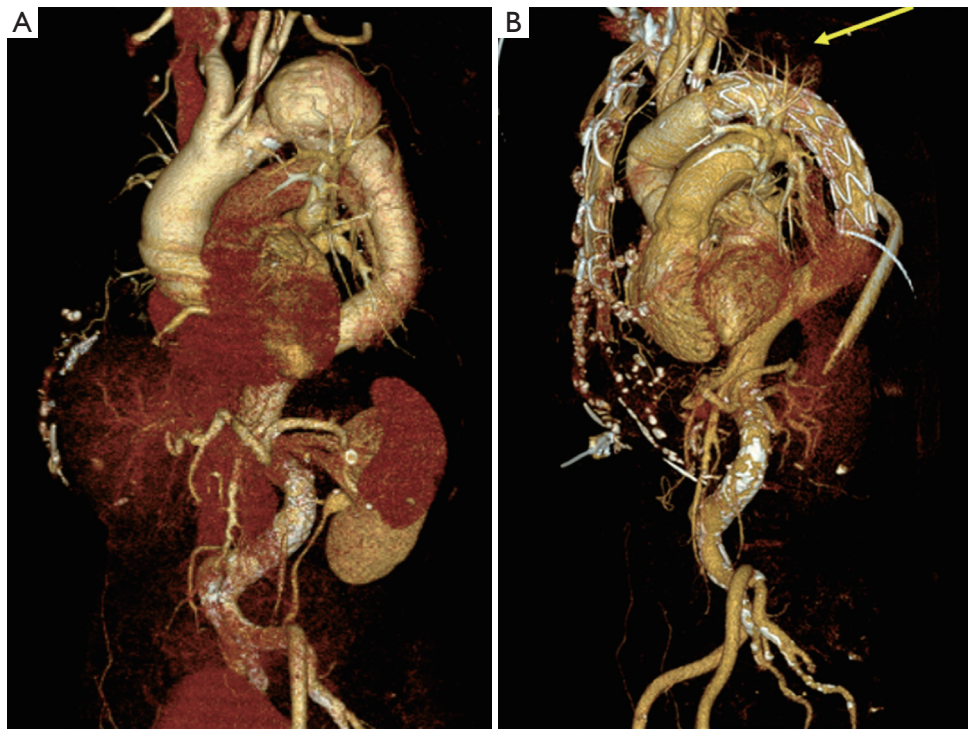


Figure 1 Preoperative CT scan of patient with distal aortic arch aneurysm (A) and after aortic arch surgery using FET technique (B) with completely excluded aneurysm (yellow arrow)

objectives of this study were (1) to evaluate clinical characteristics, and early, and mid-term results, and (2) to determine predictors of clinical and neurological outcome, particularly, spinal cord injury after aortic arch surgery using FET.

Patients and methods

A total of 51 consecutive patients underwent total aortic arch surgery with FET implantation between January 2006 and August 2013 and were included in our analysis. Data were prospectively collected in a database, and retrospective review was approved by the local Ethics Committee. Individual patient consent was waived.

Patients were followed-up annually with a mailed questionnaire or, when needed, by contacting the referring cardiologist or general practitioner. Follow-up was 100% complete.

Operative technique

The FET technique has been performed in our hospital since 2006. In all patients the E-vita hybrid open stent-

graft (Jotec, Hechingen, Germany) was used (*Figure 1*). The surgical technique and indication were as previously described (4).

Definitions

In accordance with STS guidelines, *early mortality* was defined as all-cause mortality at 30 days. Operations were considered *emergent* if performed within 24 hours of hospital admission for cardiovascular instability, and *urgent* if performed during the same hospital admission.

All patients with suspected neurological complications on physical examination underwent computerized tomography or magnetic resonance imaging. *Spinal cord injury* was defined as new-onset transient or permanent paraparesis or paraplegia. *Neurological complications* were defined as *permanent neurological deficit* (PND) for patients with stroke or paraplegia, and *temporary neurological deficit* (TND) for patients with reversible deficits (2).

Statistical analysis

All statistical analyses were performed using SPSS 17.0

Table 1 Demographics and preoperative clinical characteristics

	FET n=51 (%)
Age (years)	69±10
Female	24 (51.1)
COPD	6 (11.8)
Diabetes	9 (17.6)
Hypertension	27 (52.9)
Cerebral vasculopathy	2 (3.9)
Aortic disease	
Degenerative aneurysm	32 (62.7)
Acute Type A aortic dissection	8 (15.7)
Acute Type B aortic dissection	7 (13.7)
Chronic Type A aortic dissection	1 (2)
Chronic Type B aortic dissection	1 (2)
Downstream aneurysm following acute Type A aortic dissection	2 (3.9)
Previous surgery	9 (17.6)
CABG	1 (2.0)
Valve	3 (5.9)
Root	1 (2)
Abdominal aorta	1 (2)
Thoracic aorta	6 (11.8)
Aortic diameter (mm)	
Ascending	46±11
Arch	53±16
Descending	43±12
Abdominal	31±6
Data are presented as numbers of cases unless otherwise indicated. COPD, chronic obstructive pulmonary disease; TEVAR, thoracic endovascular aortic repair; CABG, coronary artery bypass grafting	

(Chicago, IL). Categorical variables were compared using the Chi-square test or Fisher's exact test. Independent continuous variables were compared by unpaired Student's t-test for comparison of normally distributed data between two groups or Kruskal-Wallis test for the comparison of more than two groups as appropriate. Continuous variables are expressed as mean ± SD, and categorical data as proportions throughout the manuscript.

Dichotomous adverse outcome events were analyzed using an uni- and multivariate logistic regression model with backwards stepwise elimination, and were expressed as odds ratios (OR) with 95% confidence intervals (CI). Event-free survival was calculated by Kaplan-Meier methods with

95% CI. Independent predictors of medium-term survival were determined with Cox proportional hazards analysis. $P < 0.05$ was considered statistically significant.

Results

A total of 51 consecutive patients underwent total replacement of the aortic arch using the FET technique during the study period. The majority (62.7%) suffered from degenerative aortic aneurysm. Acute Type A and Type B aortic dissection was the indication for surgery in 15.7% and 13.7% of patients, respectively (*Table 1*).

Operative details and post-operative complications

All operative details are presented in *Table 2*. Mean core body temperature was 26 ± 2 °C. The mean prosthesis size was 33.7 ± 4.8 mm (24–40 mm). Prosthesis over-sizing was observed in 14% (n=7) patients. The distal prosthesis landing zone was T7 and lower in 19.6% (n=9), between T8 and T9 in 52.2% (n=24), and more than T10 in 26.1% (n=12) of patients.

Postoperative outcome

The 30-day and in-hospital mortality for the entire cohort of patients was 7.8% (n=4). PND occurred in 11.8% (n=26) of patients (*Table 2*). The incidence of PND and TND was 11.8% and 9.8%, respectively. The overall rate of paraplegia was 19.6% (n=10). Multivariate analysis identified a core body temperature of 28 °C or higher during circulatory arrest in combination with duration of circulatory arrest greater than 45 minutes, as an independent predictor of permanent spinal cord injury (OR 4.8; 95% CI, 1.1–21; $P = 0.04$).

Predictors of medium-term survival and freedom from thoracic endovascular aortic repair (TEVAR)

The estimated mean follow-up time for all patients was 3.4 ± 0.4 years (0–5.1 years) with a total follow-up of 58.8 patient years. The unadjusted 1- and 5-year survival for the entire group was $80.2 \pm 5.5\%$, and $59.7 \pm 10.2\%$, respectively.

During follow-up TEVAR was performed in 8 patients. The estimate mean freedom from endovascular intervention was 4.2 ± 0.4 years. The unadjusted 1- and 5-year freedom from TEVAR was $(84.9 \pm 5.9)\%$, and $(69.2 \pm 11.2)\%$, respectively (*Figure 2*). One patient underwent re-operative thoracoabdominal aortic surgery 5.5 years after initial

Table 2 Operation data and postoperative clinical characteristics

	FET n=51 (%)
Operation	
CPB time (min)	213±66
Cross clamp time (min)	98±38
Circulatory arrest time (min)	50±14
ASCP	51 (100)
ASCP time (min)	47±14
Minimum rectal temperature (°C)	26±2
Axillary artery cannulation	38 (74.5)
Reimplantation of supraaortic vessels	
Island	40 (78.4)
Separate	11 (21.6)
Aortic valve/root intervention	
ARR	6 (11.8)
AV Reimplantation (David)	1 (2)
AV Reconstruction (Yacoub)	1 (2)
AVR	1 (2)
Concomitant surgery	
CABG	10 (19.6)
Postoperative outcome	
PND	6 (11.8)
TND	5 (9.8)
Paraplegia	10 (19.6)
Respiratory failure	19 (37.3)
Renal failure	13 (25.5)
Reoperation for bleeding	7 (13.7)
30-day mortality	4 (7.8)
In hospital mortality	4 (7.8)

Data are presented as number of cases unless otherwise indicated. CPB, cardiopulmonary bypass; ASCP, antegrade selective cerebral perfusion; AVR, aortic valve replacement; AV, aortic valve; ARR, aortic root replacement; CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; PND, permanent neurologic deficit; TND, temporary neurological deficit

surgery due to progression of extensive thoracoabdominal disease.

Discussion

The current study summarizes our 7-year institutional experience in aortic repair with “FET” for patients

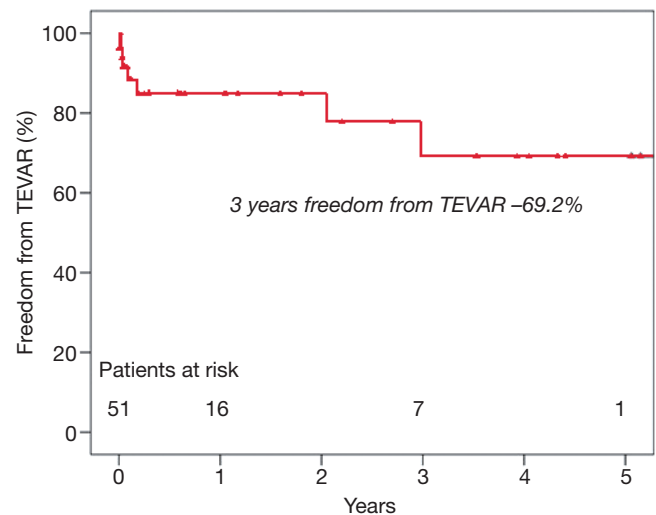


Figure 2 Freedom from TEVAR procedure after initial FET implantation

with extensive aortic pathology, a technique, which was introduced into clinical practice at our institution in 2006.

The 30-day mortality of 7.8%, observed in our study, is comparable to other case series reported in the literature. The in-hospital mortality, reported in 2011 by the International E-vita Open Registry, is 15% (5). The lower mortality rate in the present study must be interpreted with caution, because a lower number of patients suffered from acute type A aortic dissection. This disease has previously been identified as an independent predictor of 30-day mortality in patients undergoing aortic arch surgery (2,6).

The neurological status of patients after extended aortic arch surgery has an important impact on postoperative outcome. The most devastating complications associated with reduced quality of life and long-term survival in these patients are PND and spinal cord injury (6-8).

Permanent or transient spinal cord injury is a rare complication after extended aortic arch surgery with conventional elephant trunk implantation, with incidence rates ranging from 0.4% to 2.8% (9-11). As opposed to that, in patients who received FET, this complication was significantly higher. A multicenter study, including 240 patients with FET, reported a 9% incidence of this dreaded complication (12). Single center studies with relatively small numbers of patients have reported incidences as high as 21-24% after FET implantation (13-15). The factors influencing paraplegia are extended length of circulatory arrest (13,14), and level of the distal landing zone beyond

T7 (15). Flores and colleagues identified a distal landing zone of T7 or lower, and a history of previous abdominal aortic aneurysm repair as a predictor of spinal cord injury. This observation suggests an important role of distal inflow to the paraspinous arterial collateral network via the hypogastric arteries (15). The Collateral Network Concept, investigated by Griep's group (10), has been used to explain and understand this phenomenon. The FET technique has the potential to impact both Collateral Network inflow pathways simultaneously: the segmental artery by insertion of the stented part of the hybrid graft into the descending aorta, and the vertebral artery due to lack of perfusion during circulatory arrest. This can explain the increased incidence of spinal cord injury to patients who underwent the FET procedure compared to those who underwent conventional elephant trunk implantation. In the current study, the incidence of spinal cord injury was 21.4%. A core body temperature of 28 °C or higher during circulatory arrest, in combination with circulatory arrest time greater than 45 minutes, was identified as an independent predictor of spinal cord injury. Five out of twelve patients, who suffered ischemic spinal cord injury, had circulatory arrest times greater than 45 minutes during which the core body temperature was 28 °C or warmer. Similar to observations of Pacini *et al.* (12), the core body temperature or duration of circulatory arrest alone do not have a significant impact on the incidence of postoperative spinal cord injury. In the current study we also failed to find a significant correlation between the distal FET landing zone level and the incidence of acute ischemic spinal cord injury. The landing zone of the distal end of the stent-graft was at or even proximal to the T8 level in six of ten patients with postoperative spinal cord injury.

The incidence of PND in patients undergoing aortic arch surgery has been reported to range between 1.1% and 9.8% (8,16,17). Age, acute type A aortic dissection (2), urgent status (7,16), renal insufficiency (16), operation time (16) and, prolonged circulatory arrest (2,16) were factors that influenced the occurrence of PND after surgery. PND was observed in 11.8% of our patients and was nearly twice as high among patients who presented with acute type A aortic dissection.

In conclusion, the FET technique can be performed with a relatively low mortality in patients with extensive pathology of the thoracic aorta. However, this procedure is associated with a significantly increased incidence of postoperative permanent paraplegia due to ischemic spinal cord injury. The independent predictor of paraplegia is

the combination of prolonged circulatory arrest times (≥ 45 minutes) with mild hypothermia (≥ 28 °C). The FET procedure should therefore be performed using deep hypothermia, particularly in patients with prolonged aortic arch surgery, in order to prevent complications due to ischaemic spinal cord injury.

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