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Original Article / *Özgün Makale*

Repair of residual aortic dissections with frozen elephant trunk technique

Rezidü aort diseksiyonlarının frozen elephant trunk tekniği ile onarımı

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ABSTRACT

Background: In this study, we present our mid-term results of reoperation with the frozen elephant trunk procedure due to patent false lumen-related complications in patients previously undergoing supracoronary aortic repair for acute type A aortic dissection.

Methods: Between January 2013 and September 2018, a total of 23 patients (17 males, 6 females; mean age 51.5±9.7 years; range, 30 to 67 years) who underwent ascending aortic replacement due to type A aortic dissection and, later, frozen elephant trunk procedure for residual distal dissection were included. For diagnostic purposes and follow-up, computed tomography angiography was performed in all patients, and both re-entry and aortic diameters were evaluated. Echocardiography was used to evaluate cardiac function and valve pathologies.

Results: The Ishimaru zone 0 (n=11, 47.8%), Ishimaru zone 1 (n=1, 4.3%), Ishimaru zone 2 (n=4, 17.4%), and Ishimaru zone 3 (n=7, 30.4%) were used for frozen elephant trunk stent graft fixation. The mean duration of cardiopulmonary bypass and antegrade selective cerebral perfusion was 223.9±71.2 min and 88.9±60.3 min, respectively. In-hospital mortality was 13%, while there was one (4.3%) aortic-related death and four (17.4%) re-interventions during follow-up.

Conclusion: Early repair should be considered in the presence of persistent dissections due to alarmingly high mortality rates of reoperations. Reoperation with the frozen elephant trunk procedure has acceptable results and the decision of the procedure to be performed should be based on preoperative risk factors of the patient.

Keywords: Aortic dissection, frozen elephant trunk, hybrid procedure, reoperation.

ÖZ

Amaç: Bu çalışmada, daha önce akut tip A aort diseksiyonu nedeniyle suprakoroner aort onarımı yapılan hastalarda, patent yalancı lümene bağlı komplikasyonlara yönelik frozen elephant trunk ile yapılan tekrar ameliyatların orta dönem sonuçları analiz edildi.

Çalışma planı: Ocak 2013 - Eylül 2018 tarihleri arasında tip A aort diseksiyonu nedeniyle çıkan aorta replasman yapılan ve daha sonra rezidü distal diseksiyon nedeniyle frozen elephant trunk işlemi yapılan toplam 23 hasta (17 erkek, 6 kadın; ort. yaş 51.5±9.7 yıl; dağılım, 30-67 yıl) çalışmaya alındı. Tanı ve takip amaçlı, tüm hastaların bilgisayarlı tomografi anjiyografisi çekildi ve hem reentran hem de aort çapları değerlendirildi. Kalp fonksiyonlarını ve kapakçık patolojilerini değerlendirmek için ekokardiyografi çekildi.

Bulgular: Frozen elephant trunk stent greftini tespit etmek için Ishimaru bölge 0 (n=11, %47.8), Ishimaru bölge 1 (n=1, %4.3), Ishimaru bölge 2 (n=4, %17.4) ve Ishimaru bölge 3 (n=7, %30.4) kullanıldı. Ortalama kardiyopulmoner baypas ve antegrad selektif serebral perfüzyon süresi sırasıyla 223.9±71.2 dk. ve 88.9±60.3 dk. idi. Hastane içi mortalite %13 iken, takip sırasında bir (%4.3) aort ile ilişkili ölüm ve dört (%17.4) yeniden müdahale gözlendi.

Sonuç: Tekrar ameliyatların ölüm oranlarının endişe verici düzeyde yüksek olması nedeniyle, devam eden diseksiyonların varlığında erken onarım düşünülmelidir. Frozen elephant trunk işlemi ile tekrar ameliyatların kabul edilebilir sonuçları olup, uygulanacak işleme hastanın ameliyat öncesi risk faktörlerine göre karar verilmelidir.

Anahtar sözcükler: Aort diseksiyonu, frozen elephant trunk, hibrid girişim, tekrar ameliyat.

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In acute type A aortic dissections, the primary goal in emergency surgery is to prevent complication-related deaths and ensure that the patient survives both the dissection and the operative procedures. The main treatment principle of the conventional supracoronary aortic and/or hemi-arch repair is to resect the intimal tears and provide distal flow of true lumen through graft replacement. Although this treatment protocol has successful results with acceptable early mortality rates, the persistence of the residual false lumen affects the prognosis in the chronic phase.[1-3] Life-threatening complications may emerge in the long-term and reoperations are inevitable, as long as the false lumen is not secured.[4,5]

In this study, we present our mid-term results of reoperation with the frozen elephant trunk (FET) procedure due to patent false lumen-related complications in patients previously undergoing supracoronary aortic repair for acute type A aortic dissection.

PATIENTS AND METHODS

Between January 2013 and September 2018, a total of 303 consecutive patients who had only ascending aortic replacement due to type A aortic dissection were screened from the hospital database and 23 patients (17 males, 6 females; mean age 51.5±9.7 years; range, 30 to 67 years) who underwent FET procedure for residual distal dissection were included in this study. For diagnostic purposes and follow-up, computed tomography angiography (CTA) was performed in all patients, and both reentry and aortic diameters were evaluated. Echocardiography was used to evaluate cardiac function and valve pathologies. Data including demographic and clinical characteristics of the patients were recorded. A written informed consent was obtained from each patient. The study protocol was approved by the Kartal Koşuyolu Yüksek Ihtisas Training and Research Hospital Ethics Committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Early mortality was defined as death occurring within 30 days of operation or at any time during the index hospitalization. Late outcomes included aorta-related deaths, re-interventions, and clinical failure. Indications for reoperation were aortic enlargement (>5.5 cm) or rapid increase in size (>0.5 cm in 6 months) or development of new symptoms (i.e., malperfusion or rupture). Renal failure was defined as the need for hemodialysis, and respiratory failure was defined as the need for re-intubation or tracheostomy postoperatively.

Surgical procedure

In all patients, the central venous catheter, arterial monitorization at the left arm, near-infrared spectroscopy, and cerebrospinal fluid pressure catheter were used routinely. The right subclavian artery for arterial cannulation and right femoral vein for venous drainage were used to initiate cardiopulmonary bypass. After cooling to 30 degrees, sternotomy was done with redo saw and the adhesions in the pericardium were removed. The aortic arch repairs were performed at moderate hypothermia by unilateral selective antegrade cerebral perfusion (flow rate 10 to 15 kg/min). In case of detecting any significant decrease at cerebral pulse oximetry, we switched to bilateral selective antegrade cerebral perfusion by the insertion of an additional

Table 1. Demographic and clinical characteristics of patients

	n	%	Mean±SD
Age (year)			51.5±9.7
Sex			
Male	17	73.9	
Emergency <24 h	4	17.4	
CAD	7	30.4	
Ejection fraction <%50	3	13	
COPD	4	17.4	
Diabetes mellitus	2	8.7	
Creatinine >2 mg/dL	2	8.7	
History of stroke	1	4.3	
Marfan syndrome	3	13	
Severe aortic regurgitation	4	17.4	
Previous operation time (year)			5±3.1
Causes of reoperation			
False lumen aneurysm	10	43.5	
Additional cardiac operation	6	26.1	
Rupture	4	17.4	
Malperfusion	3	13	
Aortic diameters (mm)			
Aortic arch			45.6±9.7
Descending aorta			56.3±14.8
Abdominal aorta			41±9.4
Tear zone			
Zone 0 (Anastomosis line)	9	39.1	
Zone 1	2	8.7	
Zone 2	5	21.7	
Zone 3	7	30.4	

SD: Standard deviation; CAD: Coronary artery disease; COPD: Chronic obstructive pulmonary disease.

arterial cannula into the left carotid artery. In aortic arch repair, the decision to perform re-implantation of aortic arch elements separately or islet shape repair is based on the extent of the disease and location of intimal rupture according to the Ishimaru zones. According to the Ishimaru zone where an intimal rupture was found, aortic arch repair was performed by re-implantation of aortic arch elements separately or islet shape. The E-vita OPEN PLUS (JOTEC GmbH, Hechingen, Germany) prosthesis was used for FET procedure in all cases. The FET prosthesis was introduced and released in an antegrade fashion into the true lumen of the descending aorta over the wire with the guidance of transesophageal echocardiography.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency. The Wilcoxon test was used to compare the mean of the dependent groups. Survival for up to five years in overall survival and follow-up and time without re-treatment were calculated using the Kaplan-Meier analysis. A p value of <0.05 was considered statistically significant.

RESULTS

The median time from the previous operation to reoperation was 5±3.1 (range, 1 to 13) years. Emergency operations were performed for thoracic aortic rupture (n=4, 17.4%), visceral malperfusion (n=2, 13.3), and stroke (n=1, 6.7%). Patient characteristics are shown in Table 1.

The mean total perfusion time was 223.9±71.2 (range, 117 to 419) min. Supraaortic graft replacement was performed in 11 patients (47.8%), while seven patients (30.3%) needed an additional procedure. Operative data and technical details are given in Table 2.

In-hospital mortality was seen in three patients (13%). One of them was urgent operation due to a ruptured thoracic aorta and, following consequent postoperative revisions for bleeding, the patient died on postoperative Day 7 from disseminated intravascular coagulation (DIC). In the other patient, massive blood transfusion for major bleeding resulted in bleeding diathesis and death on the first postoperative day. The reason of death in the third patient was stroke presenting with intracerebral hemorrhage. Spinal cord ischemia (paraplegia and paraparesis) and permanent neurological deficit (stroke or coma) were not observed

Table 2. Operative data

	n	%	Mean±SD	Median	Min-Max
Temperature (°C)			25.6±1.9		
Total perfusion time (min)			223.9±71.2		
ASCP time (min)			88.9±60.3		
Visceral ischemia				72	29-160
Reimplantation of the supra-aortic vessels					
Island	5	21.7			
Separate	16	69.6			
Selective LSA revascularization	2	8.7			
Level of proximal stent-graft anastomosis					
Zone 0	11	47.8			
Zone 1	1	4.3			
Zone 2	4	17.4			
Zone 3	7	30.4			
Supra-aortic graft replacement	11	47.8			
Additional operation					
Aortic valve replacement	3	13			
Coronary artery bypass grafting	1	4.3			
Bentall procedure	3	13			

SD: Standard deviation; Min: Minimum; Max: Maximum; ASCP: Antegrade selective cerebral perfusion; LSA: Left subclavian artery.

in any of the patients. Four patients (17.4%) underwent temporary hemodialysis due to acute renal failure (Table 3).

During the follow-up, aortic-related death occurred due to rupture in only one patient with known aneurysm which was scheduled for secondary intervention (Figure 1). The second patient died from a traffic accident two months after the operation. All patients participated in a median follow-up time of 26.4±20.3 (range, 1 to 61) months (Table 4). Four of the patients underwent secondary distal aortic re-intervention due to stent induced new re-entry (n=1, 4.3%), scheduled thoracic endovascular aortic repair (TEVAR) for post-dissection aneurysm (n=2, 8.7%), and rupture (n=1, 4.3%). The rates of freedom from distal re-intervention and changes in the descending aorta diameters are shown in Figures 2 and 3.

Table 3. Postoperative outcomes

	n	%	Mean±SD
In hospital mortality	3	13	
Pulmonary complication	9	39.1	
Dialysis (Temporary/permanent)	4/0	17.4/0	
Stroke	3	13	
Spinal cord ischemia	0	0	
Low output syndrome	7	30.4	
Extubation time (hour)			28.2±21.7
ICU stay (day)			5.6±3.2
Hospital stay (day)			14.4±4.7
Re-sternotomy			
Bleeding	8	34.8	
Tamponade	1	4.3	

SD: Standard deviation; ICU: Intensive care unit.

Table 4. Follow-up

False lumen status at the follow-up	n	%	Mean±SD
At pulmonary artery			
Thrombosed	16	69.6	
Partially thrombosed	4	17.4	
Patent	1	4.3	
Diaphragm			
Thrombosed	4	17.4	
Partially thrombosed	8	34.8	
Patent	9	39.1	
Follow-up mortality	2	8.7	
Secondary reintervention to distal aorta	4	17.4	
Shrinkage at the stent level			8.3±8.6
Follow-up time/month			26.4±20.3

SD: Standard deviation.

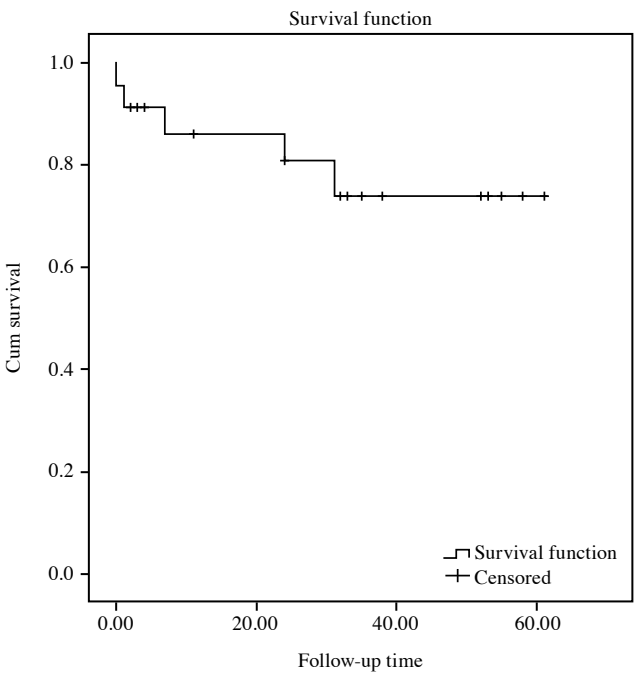

Figure 1. Kaplan-Meier plot showing 78.3% two-year overall survival.

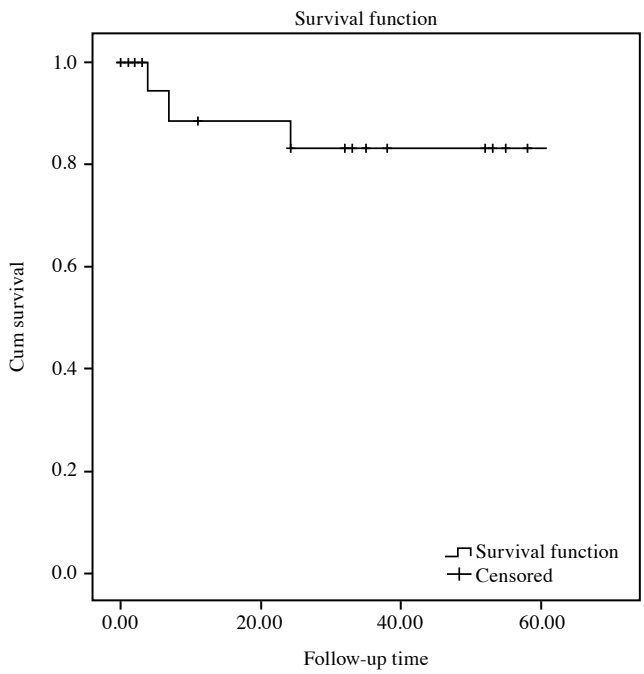

Figure 2. Kaplan-Meier plot showing 82.6% freedom from distal re-intervention rate.

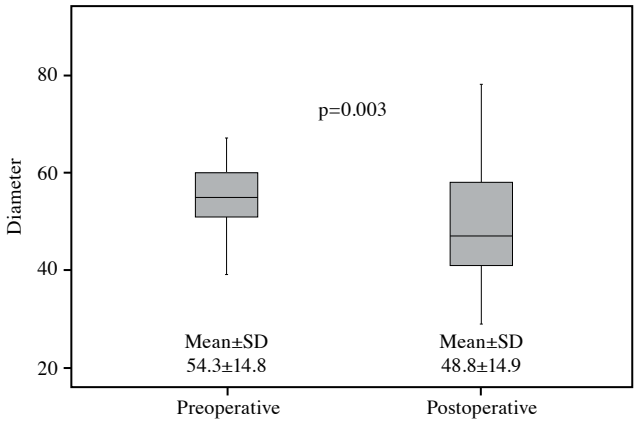

Figure 3. Pre- and postoperative descending aortic diameters (p=0.003).

DISCUSSION

Acute type A aortic dissection is a life-threatening pathology with increasing mortality rates per hour. Supracoronary and hemi-aortic repairs are life-saving standard treatment methods which provide a simple and rapid solution with successful outcomes in the early-term.[1-3] However, in patients undergoing supracoronary aortic repair, if there was an intimal tear at the level of the aortic arch or proximal descending aorta, patent false lumen-related complications such as rupture and malperfusion would necessitate long-term re-interventions and eventually increase mortality.[6] To prevent those complications, as previously described in acute type A aortic dissections, a single-session total arch repair with FET stands as a safe and successful option by ensuring early false lumen thrombosis.[7] The rate of freedom from reoperation at 10-year for distal residual dissection following conventional dissection surgery changes from 30 to 40% and not to be underestimated.[4,5,8] The most frequent indication for reoperations is distal aortic aneurysm development caused by preoperative aortic ecstasies and the lack of false lumen thrombosis due to re-entries and uncontrolled hypertension.[9] Rupture of the sutures in the anastomosis line due to the fragile aorta in the acute phase is one of the common causes of failure of false lumen closure by creating involuntary iatrogenic re-entries.[10] In our study, reoperations were mostly performed for the enlargement of the false lumen and the tears from the anastomosis line (39.1%) were noteworthy as a cause of the patent false lumen.

Hybrid methods have gained popularity with ease of surgical technique and reduction in mortality rates compared to open surgery. In residual type A aortic dissections, the dissection tear mostly starts from the anastomotic suture line and total debranching can be performed by re-sternotomy to use previous supracoronary graft as a suitable landing zone for hybrid arch repair. However, particularly in cases where there are technical restrictions for TEVAR, such as short previous supracoronary graft which does not have sufficient length or sharp-angled and tortuous aorta, FET can be used as an alternative option. The reasons for performing FET to patients in our study were short previous supracoronary graft (n=5), tortuous thoracoabdominal aorta (n=6), sharp-angled aortic arch (n=4), first stage of scheduled post-dissection aneurysm repair (n=2), and additional cardiac surgery with an aortic arch aneurysm (n=6).

Reoperation after previous type A dissection is an independent risk factor in 30-day mortality, as well as emergency surgery, additional cardiac procedures, early reoperation requirement, advanced age, and renal insufficiency.[8,11,12] There are several articles describing early mortality rates of 8.3% and 9% for aortic arch reoperations; however, the proportion of patients who had previous operations for type A aortic dissection was 35% and 32.7%, respectively.[11,13] de la Cruz et al.[14] reported a mean of 11.7% for early mortality in residual type A dissection operations, 10% for hemi-arch repairs, 12.1% for total arch repairs, and 13.7% for total arch repair with an elephant trunk extension, indicating the increase in mortality, as treatment was expanded. In our study, three patients (13%) were lost in the hospital, urgent surgery, additional cardiac surgical procedures, re-sternotomy for postoperative bleeding were observed to increase the mortality. However, the tear zone did not affect the mortality.

Debranching of the cervical vessels brings the risk of cerebrovascular complications as a result of vascular manipulation. Although deep hypothermia is preferred in reoperations in aortic arch surgery, stroke rates are 11 to 15%.[11,12] The presence of pre-existing grafts in residual arch or thoracic aortic dissections and the possibility of debranching without CPB and deep hypothermic circulatory arrest provide advantages for hybrid methods and is promising for future; however, there are no large-series studies showing its safety in reoperations.[15] It is also disadvantageous that wire manipulations increase the stroke rates by 8.8% and unique complications of endovascular repairs such as endoleaks are present.[16] In our study, all operations were performed under moderate hypothermia, and the cervical vessels were bypassed separately during aortic arch repair in 16 patients. No spinal cord ischemia

occurred, although stroke developed in two patients and intracranial hemorrhage occurred in one of these patients.

Kobuch et al.[9] reported that the more aggressive the treatment, the lower the incidence of late reoperations, and no mortality was observed during follow-up. The rate of late operation in reoperation of residual type A aortic dissection was 8.7% at five years; therefore, no distal re-intervention is needed after the tear was removed.[11] However, there was no effect of reoperations on the long-term survival due to residual dissection.[12] After five years of operation, survival rates in various studies are as low as 75%,[11] 77%,[12] 68%,[13] and 73.2%.[14] In the mid-term follow-up of our study, one (4.3%) mortality related to rupture was observed and survival rate was 78.3%. The false lumen at stent-level was completely thrombosed in 69.6% of the patients, and partial thrombosis in remaining patients continued at the diaphragm level with 82.6% freedom from distal re-interventions. Although a decrease was observed in aortic diameters during the follow-up period, it still shows the need of re-intervention for the complications of aortic wall weakness caused by dissection.

Our study has potential limitation due to its retrospective nature. Reoperations after previous cardiac surgery in high-volume studies show a heterogeneous distribution due to both etiological differences and diversity in surgical techniques. Despite the fact that we reported the mid-term results by designing a specific study on the repair of the residual aortic arch and descending aortic dissections with FET procedure, the number of patients determined the limit of our study.

In conclusion, reoperation with the frozen elephant trunk procedure has acceptable results and the decision of the procedure to be performed should be based on preoperative risk factors. To reduce the risk of reoperation due to residual dissection, at the first operation, the aorta of the patient should be thoroughly evaluated and, if necessary, surgical margin should be expanded with more intimal tear resection or additional supraaortic debranching to create a landing zone for a simple endovascular intervention. At least annual computed tomography scans should be performed to compare the previous status of the aorta, and early repairs should be carried out in persistent dissections due to the intimidatingly high mortality rates of reoperation in emergency conditions.

Declaration of conflicting interests

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