ΕΝΩΣΗ ΕΠΙΣΤΗΜΟΝΙΚΟΥ ΠΡΟΣΩΠΙΚΟΥ
Γ.Ν.Α. «Ο ΕΥΑΓΓΕΛΙΣΜΟΣ» (Ε.Ε.Π.Ν.Ε.)

25ο ΕΤΗΣΙΟ ΣΕΜΙΝΑΡΙΟ ΣΥΝΕΧΙΖΟΜΕΝΗΣ ΙΑΤΡΙΚΗΣ ΕΚΠΑΙΔΕΥΣΗΣ Γ.Ν.Α. «Ο ΕΥΑΓΓΕΛΙΣΜΟΣ»

ΥΒΡΙΔΙΚΕΣ ΕΠΕΜΒΑΣΕΙΣ ΤΩΝ ΠΑΘΗΣΕΩΝ ΤΗΣ ΑΟΡΤΗΣ: ΕΙΝΑΙ ΠΑΡΟΝ Ή/ΚΑΙ ΜΕΛΛΟΝ;

Νικόλαος Α. Παπακωνσταντίνου, MD, MSc, PhD

Καρδιοχειρουργός
Χειρουργική Θώρακος - Καρδιάς – Αγγείων,
ΓΝΑ «Ο Ευαγγελισμός»

Αθήνα, 20 Φεβρουαρίου 2020


ΙΟΝΙΚΟΥ ΠΡΟΣΩΠΙΚΟΥ
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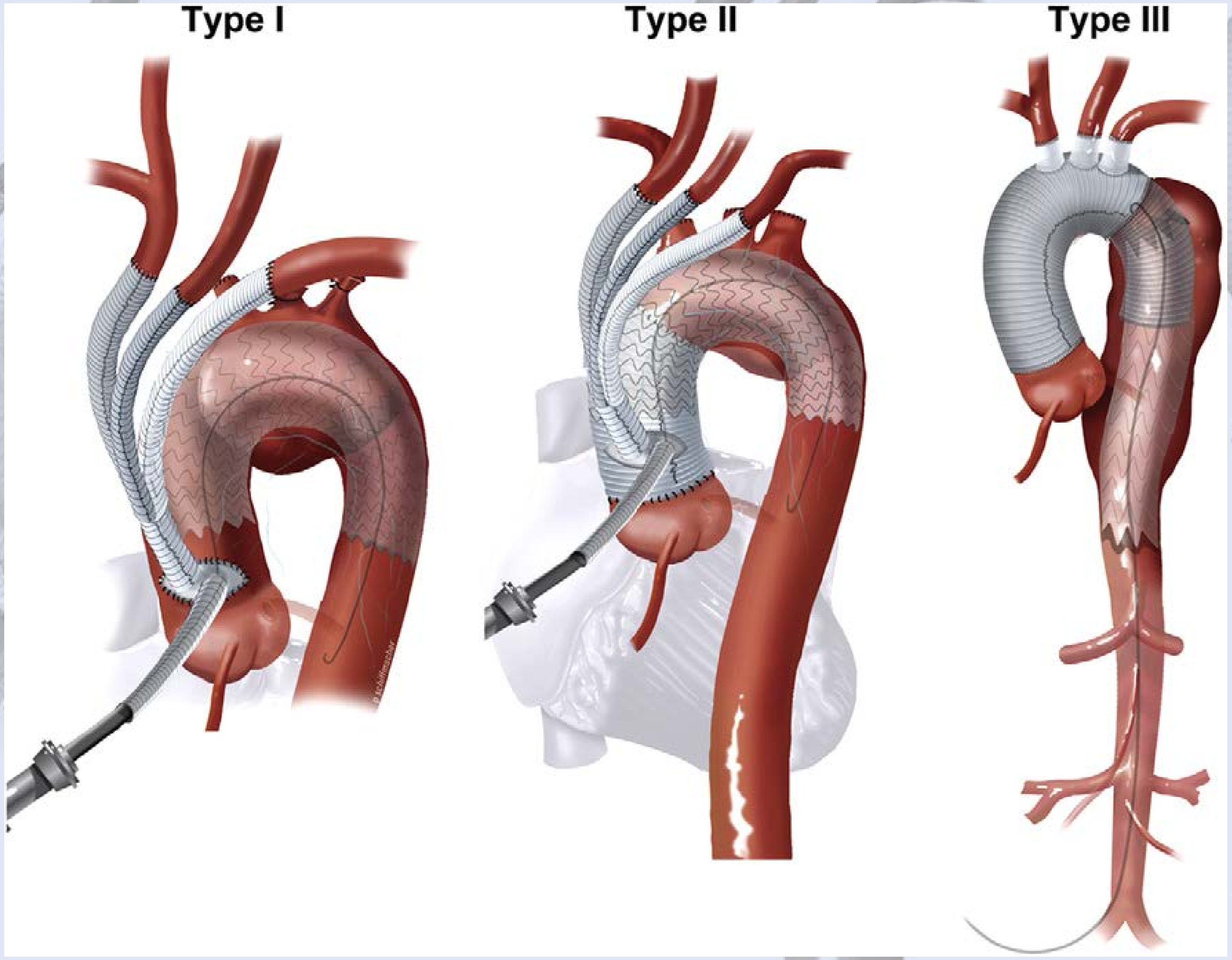

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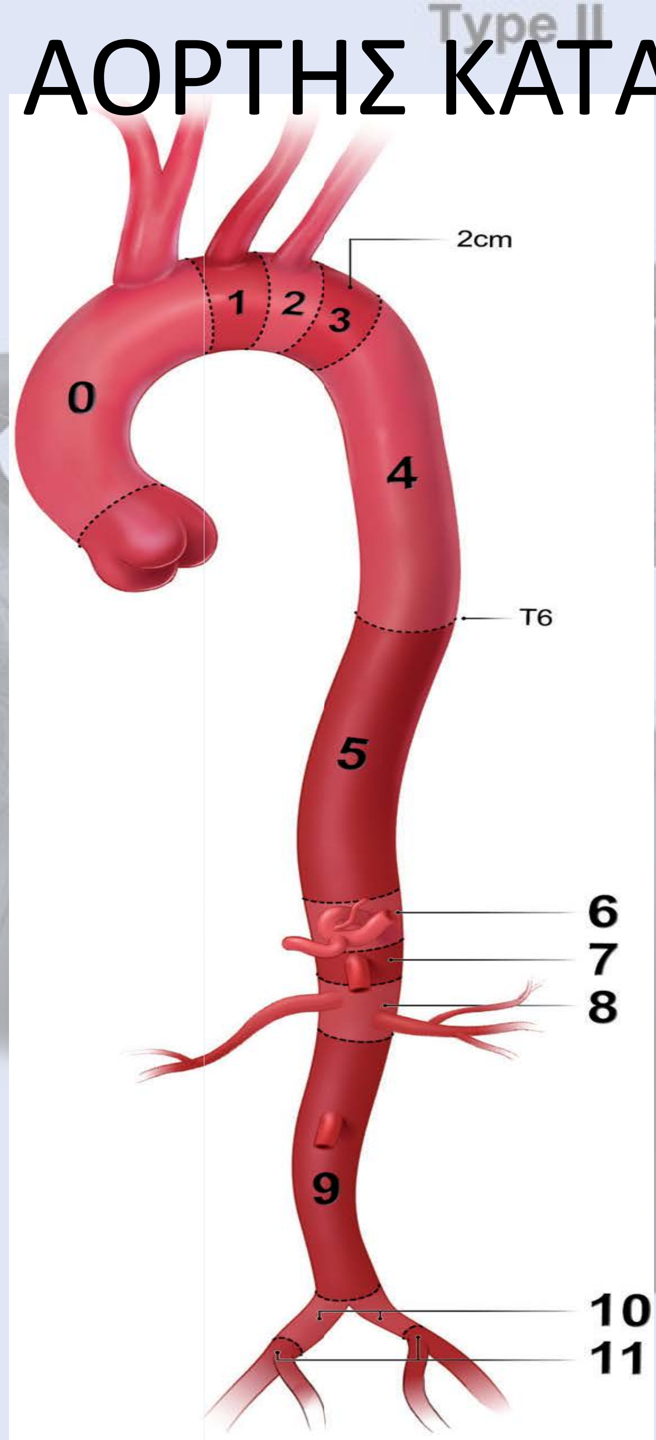
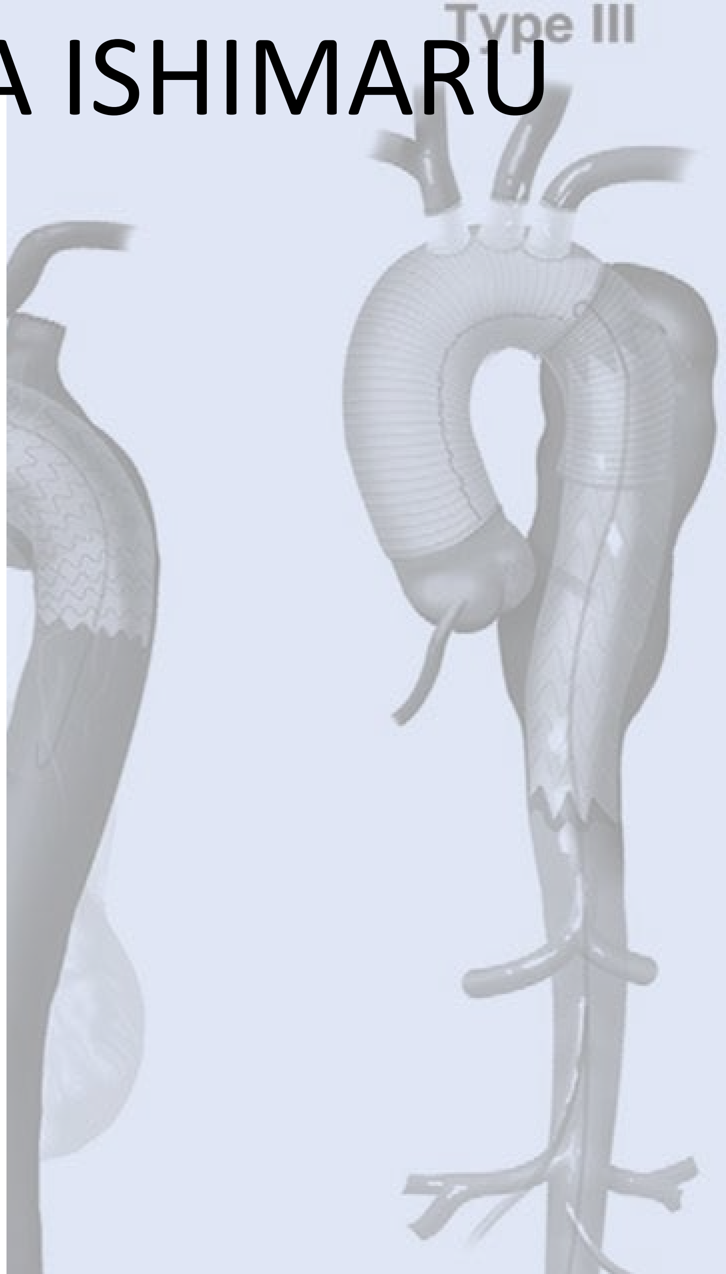
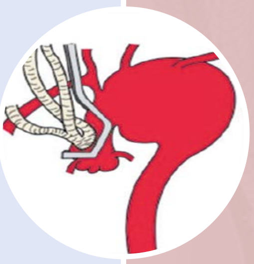
ΖΩΝΕΣ ΑΟΡΤΗΣ ΚΑΤΑ ISHIMARU





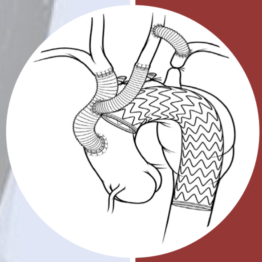
•Czerny M, et al. Current options and recommendations for the treatment of thoracic aorticpathologies involving the aortic arch: an expert consensus document of theEuropean Association for Cardio-Thoracic surgery (EACTS) and the EuropeanSociety for Vascular Surgery (ESVS). Eur J Cardiothorac Surg. 2018;[Epub ahead of print]
•Mitchell RS, Ishimaru S, Ehrlich MP, et al. First International Summit on Thoracic Aortic Endografting: roundtable on thoracic aortic dissection as an indication for endografting. J Endovasc Ther 2002;9 Suppl 2:II98-105.

ΤΥΠΟΣ I: DEBRANCHING



- Total arch debranching
- Partial clamping
- No CPB

- Adequate proximal landing zone (20mm) in zone 0

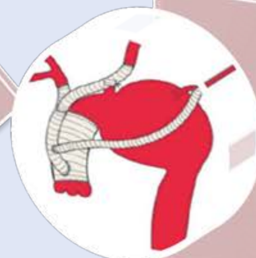


TEVAR graft deployment in native zone 0

•Shirakawa Y[1], et al. The efficacy and short-term results of hybrid thoracic endovascular repair into the ascending aorta for aortic arch pathologies. Eur J Cardiothorac Surg. 2014;45(2):298-304; discussion 304.
•Canaud L[1], et al. Hybrid Aortic Repair of Dissecting Aortic Arch Aneurysm after Surgical Treatment of Acute Type A Dissection. Ann Vasc Surg 2016;30:175-80.
•Vallabhajosyula P, et al. Type II arch hybrid debranching procedure. Ann Cardiothorac Surg 2013;2(3):378-86.
•Kollias VD[1], et al. Single-stage, off-pump hybrid repair of extensive aneurysms of the aortic arch and the descending thoracic aorta. Hellenic J Cardiol 2014;55(5):355-60.

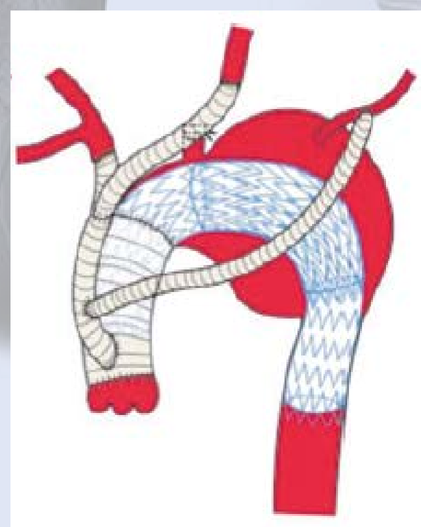
ΤΥΠΟΣ II: DEBRANCHING ΜΑΖΙ ΜΕ ΑΝΤΙΚΑΤΑΣΤΑΣΗ ΑΝΙΟΥΣΗΣ ΑΟΡΤΗΣ

- Unsuitable landing zone
- CPB is required



- Ascending aorta replacement
- Total arch debranching

Artificial landing zone for TEVAR



TEVAR graft deployment in artificial zone 0

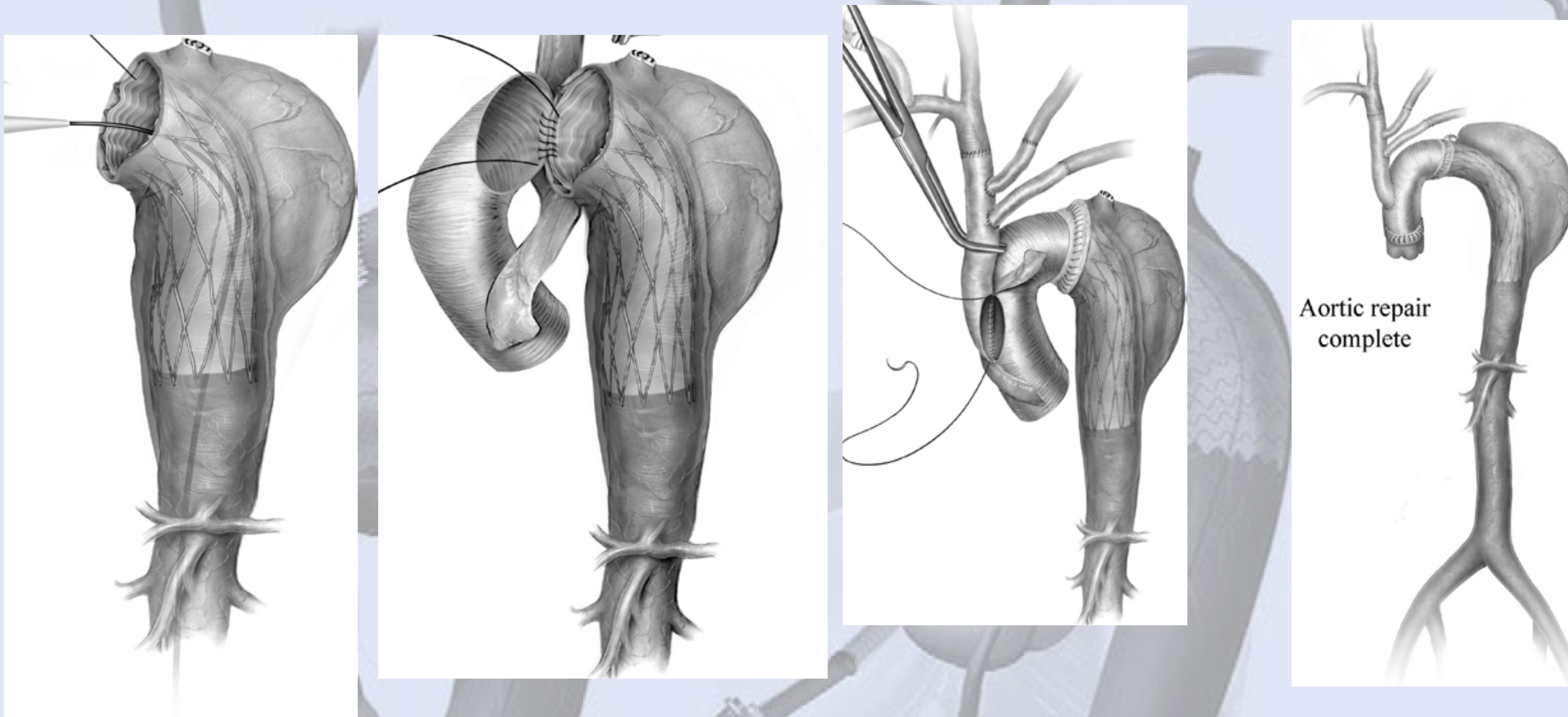
Bavaria J, et al. Hybrid approaches in the treatment of aortic arch aneurysms: postoperative and midterm outcomes. J Thorac Cardiovasc Surg. 2013 Mar;145(3 Suppl):S85-90.

Shirakawa Y[1], et al. The efficacy and short-term results of hybrid thoracic endovascular repair into the ascending aorta for aortic arch pathologies. Eur J Cardiothorac Surg. 2014;45(2):298-304; discussion 304.

Vallabhajosyula P[1], et al. Type I and Type II hybrid aortic arch replacement: postoperative and mid-term outcome analysis. Ann Cardiothorac Surg. 2013;2(3):280-7.

Kent WD[1], et al. Results of type II hybrid arch repair with zone 0 stent graft deployment for complexaortic arch pathology. J Thorac Cardiovasc Surg 2014;148(6):2951-5.

ΤΥΠΟΣ III: FROZEN ELEPHANT TRUNK



- single-stage conventional open aortic arch repair with open endovascular treatment of the descending aorta
- CPB & DHCA
- direct suturing of conventional tube graft, endovascular stent and native aortic wall

•Bavaria J, et al. Hybrid approaches in the treatment of aortic arch aneurysms: postoperative and midterm outcomes. J Thorac Cardiovasc Surg. 2013 Mar;145(3 Suppl):S85-90.
•Vallabhajosyula P[1], et al. Type I and Type II hybrid aortic arch replacement: postoperative and mid-term outcome analysis. Ann Cardiothorac Surg. 2013;2(3):280-7.
•Roselli EE, et al. Frozen Elephant Trunk Procedure. Oper Tech Thorac Cardiovasc Surg 2013;18(2):87-100.
•Karck M, et al. The frozen elephant trunk technique: a new treatment for thoracic aortic aneurysms. J Thorac Cardiovasc Surg 2003;125:1550-1553.

Type I Type II Type III

ΙΣΤΟΡΙΚΑ ΣΤΟΙΧΕΙΑ- ΕΙΣΑΓΩΓΗ

Conventional open total arch repair, “Elephant trunk”, Borst 1983

✓CPB and DHCA
✓2-stage procedure
✓(7-17)% mortality rate
✓(4-12)% neurological injury rate
✓interval mortality
✓not all patients fit for open surgery

Endovascular repair, Volodos, 1991

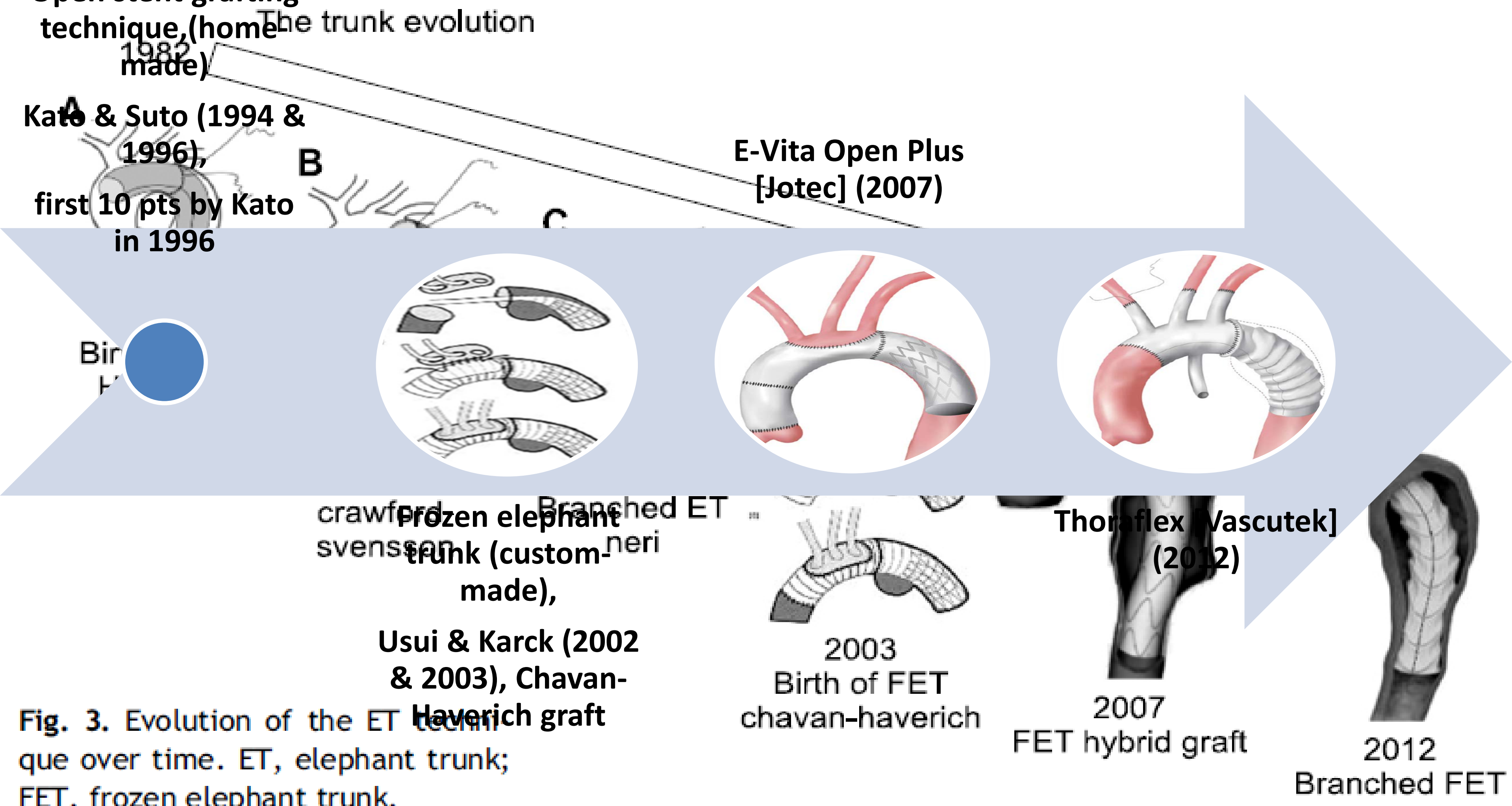
✓but aortic arch anatomy?
✓adequate landing zone?

Hybrid approaches

✓combination of tools
✓extend the envelope
✓high risk patients unfit for open repair
✓acceptable mortality and morbidity rates

•Younes HK[1], et al. Hybrid thoracic endovascular aortic repair: pushing the envelope. J Vasc Surg. 2010;51(1):259-66.
•Moulakakis KG, et al. A systematic review and meta-analysis of hybrid aortic arch replacement. Ann Cardiothorac Surg. 2013;2(3):247-60.
•Borst HG, et al. Extensive aortic replacement using “elephant trunk” prosthesis. Thorac Cardiovasc Surg 1983;31:37-40.
•Bavaria J, et al. Hybrid approaches in the treatment of aortic arch aneurysms: postoperative and midterm outcomes. J Thorac Cardiovasc Surg. 2013 Mar;145(3 Suppl):S85-90.
•Westaby S, et al. Arch and descending aortic aneurysms: influence of perfusion technique on neurological outcome. Eur J Cardiothorac Surg 1999;15:180–5.
•Papakonstantinou NA[1], et al. Cardiac surgery or interventional cardiology? Why not both? Let's go hybrid. J Cardiol. 2017;69(1):46-56.
•Oskowitz AZ[1], et al. Hybrid treatment of aortic arch aneurysms. J CardiovascSurg (Torino). 2015 Oct;56(5):719-28.
•Zerwes S, et al. Clinical outcomes in hybrid repair procedures for pathologies involving the aortic arch. Vascular. 2015 Feb;23(1):9-16.

FET: EACTS Position and Bologna Experience



•Suto Y, Yasuda K, Shiiya N, Murashita T, Kawasaki M, Imamura M et al. Stented elephant trunk procedure for an extensive aneurysm involving distal aortic arch and descending aorta. J Thorac Cardioavsc Surg 1996;112:1389–90.

•Kato M, Ohnishi K, Kaneko M, Ueda T, Kishi D, Mizushima T et al. New graft-implanting method for thoracic aortic aneurysm or dissection with a stented graft. Circulation 1996;94(9 Suppl):II188–93.

•Usui A, Fujimoto K, Ishiguchi T, Yoshikawa M, Akita T, Ueda Y. Cerebrospinal dysfunction after endovascular stent-grafting via a median sternotomy: the frozen elephant trunk. Ann Thorac Surg 2002;74:S1821–32.

•Karck M, Chavan A, Hagl C, Friedrich H, Galanski M, Haverich A. The frozen elephant trunk: a new treatment for thoracic aortic aneurysms. J Thorac Cardiovasc Surg 2003;125:1550–3.

•Karck M, Chavan A, Khaladj N, Friedrich H, Hagl C, Haverich A. The frozen elephant trunk technique for the treatment of extensive thoracic aortic aneurysms: operative results and follow-up. Eur J Cardiothorac Surg 2005;28:286–90.

•Shrestha M, Bachet J, Bavaria J, Carrel TP, De Paulis R, Di Bartolomeo R, et al. Current status and recommendations for use of the frozen elephant trunk technique: a position paper by the Vascular Domain of EACTS. Eur J Cardiothorac Surg 2015;47(5):759-69.

Di Marco L, Pantaleo A, Leone A, Murana G, Di Bartolomeo R, Pacini D. The Frozen Elephant Trunk Technique: European Association for Cardio-Thoracic Surgery Position and Bologna Experience. Korean J Thorac Cardiovasc Surg 2017;50:1-7.

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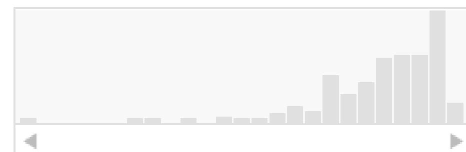

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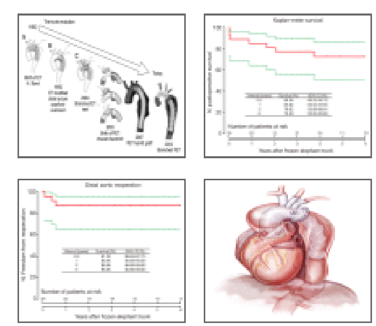

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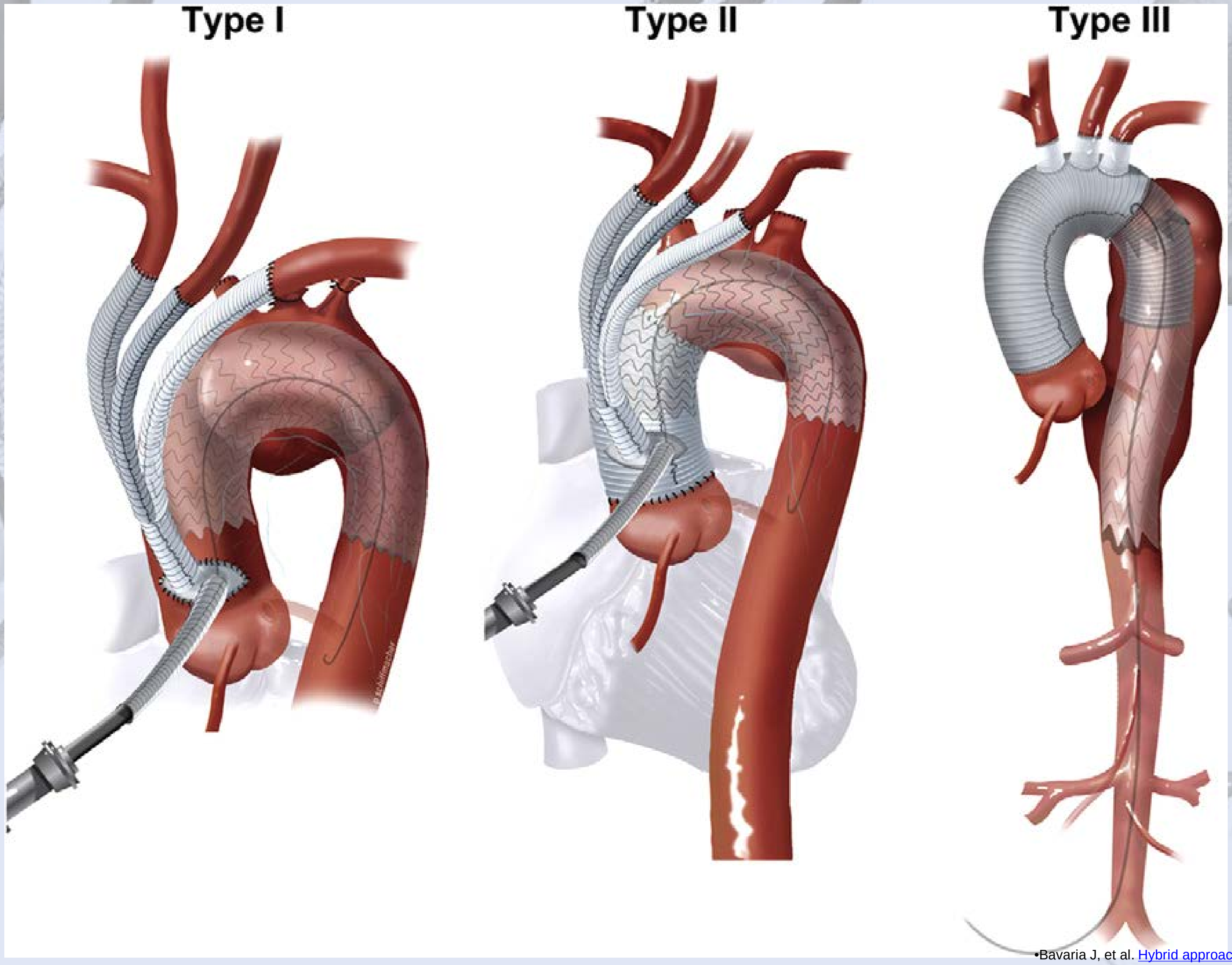

•Bavaria J, et al. Hybrid approaches in the treatment of aortic arch aneurysms: postoperative and midterm outcomes. J Thorac Cardiovasc Surg. 2013 Mar;145(3 Suppl):S85-90.

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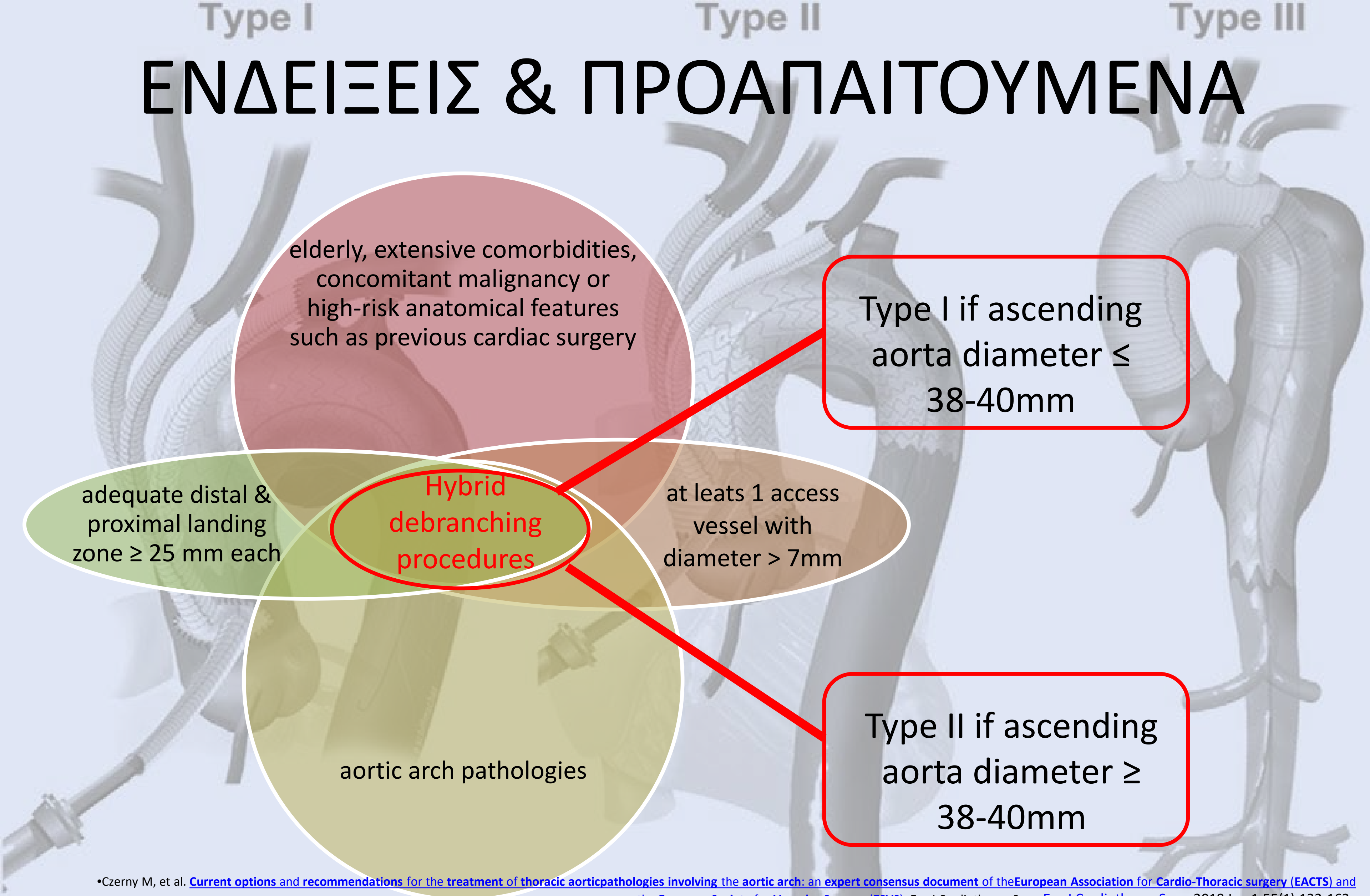
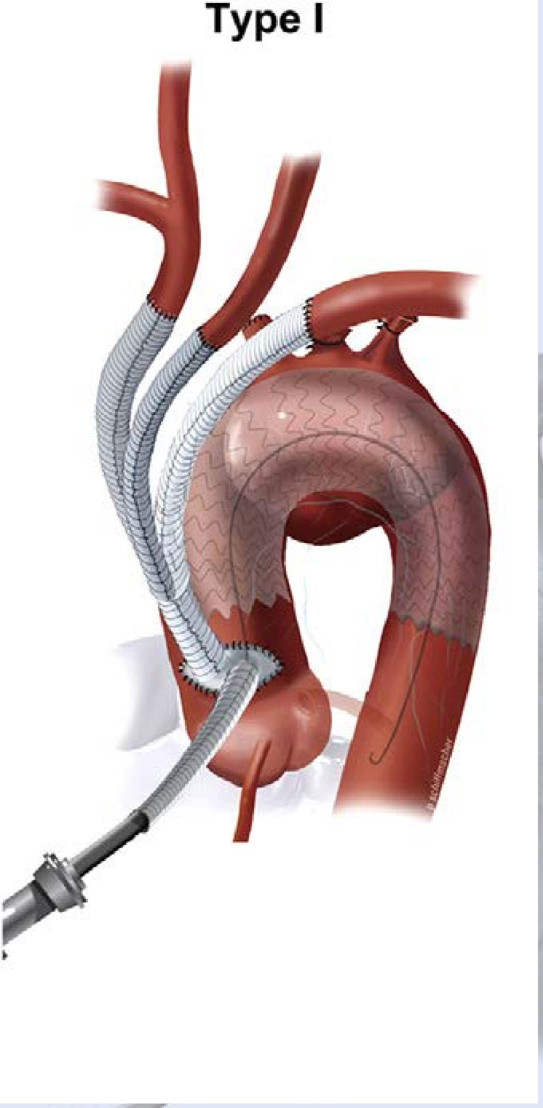


- •Czerny M, et al. Current options and recommendations for the treatment of thoracic aorticpathologies involving the aortic arch: an expert consensus document of theEuropean Association for Cardio-Thoracic surgery (EACTS) and the EuropeanSociety for Vascular Surgery (ESVS). Eur J Cardiothorac Surg. Eur J Cardiothorac Surg. 2019 Jan 1;55(1):133-162.
- •Moulakakis KG, et al. A systematic review and meta-analysis of hybrid aortic arch replacement. Ann Cardiothorac Surg. 2013;2(3):247-60.
- •Bavaria J, et al. Hybrid approaches in the treatment of aortic arch aneurysms: postoperative and midterm outcomes. J Thorac Cardiovasc Surg. 2013 Mar;145(3 Suppl):S85-90.
- •Vallabhajosyula P[1], et al. Type I and Type II hybrid aortic arch replacement: postoperative and mid-term outcome analysis. Ann Cardiothorac Surg. 2013;2(3):280-7.
- •Canaud L[1], et al. Hybrid Aortic Repair of Dissecting Aortic Arch Aneurysm after Surgical Treatment of Acute Type A Dissection. Ann Vasc Surg 2016;30:175-80.
- •Shirakawa Y, et al. The efficacy and short-term results of hybrid thoracic endovascular repair into the ascending aorta for aortic arch pathologies. Eur J Cardiothorac Surg. 2014;45(2):298-304; discussion 304.
- •Vallabhajosyula P, et al. Type II arch hybrid debranching procedure. Ann Cardiothorac Surg 2013;2(3):378-86.
- •Brechtel K[1], et al. Hybrid debranching and TEVAR of the aortic arch off-pump, in re-do patients with complicated chronic type-A aortic dissections: a critical report. J Cardiothorac Surg 2013;8:188.
- •Mizuno T[1], et al. Easy and Safe Total Debranching of Arch Aneurysms Using Axiloaxillary Arterial Bypass. Ann Thorac Surg. 2015;100(4):1476-8.



Pros

- no aortic cross clamping, no cardioplegia
- no DHCA
- no CPB

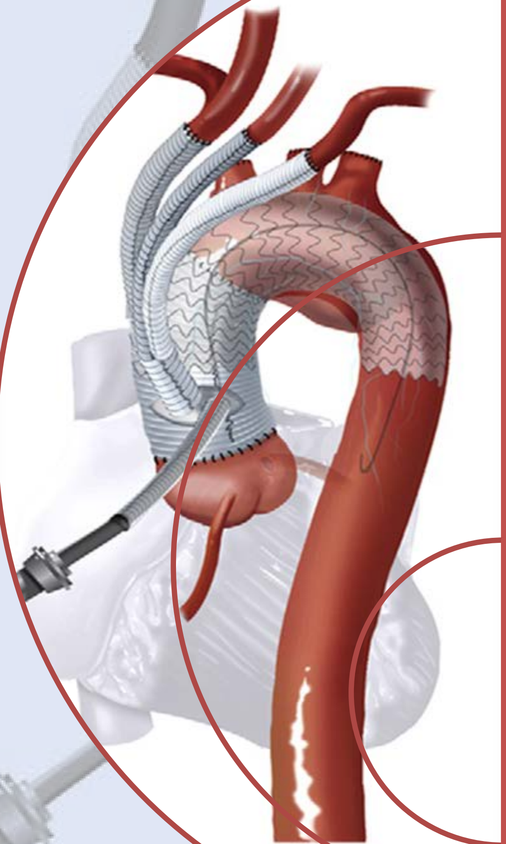
Cons

- retrograde aortic dissection possibility
- no concomitant cardiovascular procedures
- high endoleak rate
- neurologic complications, atheromatous or air embolism

•Younes HK[1], et al. Hybrid thoracic endovascular aortic repair: pushing the envelope. J Vasc Surg. 2010;51(1):259-66.
•Leacche M, et al. Surgical update: hybrid procedures, do they have a role? Circ Cardiovasc Interv. 2010;3(5):511-8.
•Bavaria J, et al. Hybrid approaches in the treatment of aortic arch aneurysms: postoperative and midterm outcomes. J Thorac Cardiovasc Surg. 2013 Mar;145(3 Suppl):S85-90.
•Faulds J, et al. Minimally Invasive Techniques for Total Aortic Arch Reconstruction. Methodist Debakey Cardiovasc J. 2016;12(1):41-4.
•Canaud L[1], et al. Hybrid Aortic Repair of Dissecting Aortic Arch Aneurysm after Surgical Treatment of Acute Type A Dissection. Ann Vasc Surg 2016;30:175-80.
•Kollias VD[1], et al. Single-stage, off-pump hybrid repair of extensive aneurysms of the aortic arch and the descending thoracic aorta. Hellenic J Cardiol 2014;55(5):355-60.

Type I Type II Type III

Type II Hybrid advantages

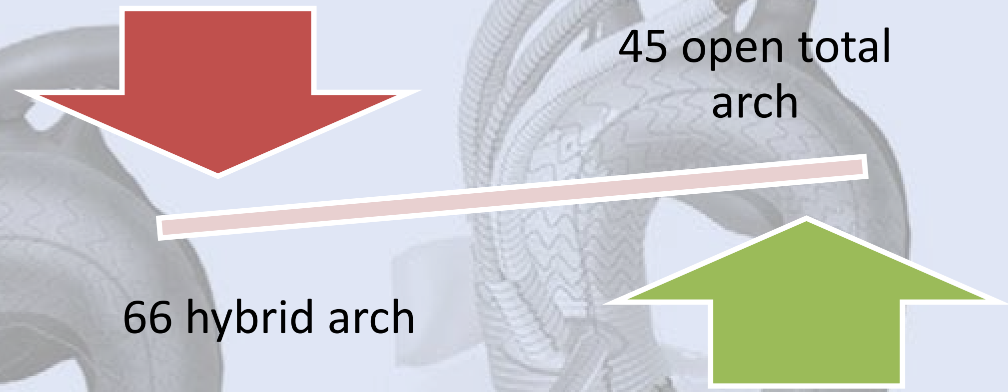


- risks of retrograde type A dissection and endoleak are eliminated
- less invasive than total open arch replacement
- less bleeding

•Kollias VD[1], et al. Single-stage, off-pump hybrid repair of extensive aneurysms of the aortic arch and the descending thoracic aorta. Hellenic J Cardiol 2014;55(5):355-60.
•nt WD[1], et al. Results of type II hybrid arch repair with zone 0 stent graft deployment for complexaortic arch pathology. J Thorac Cardiovasc Surg 2014;148(6):2951-5.
Ke

OPEN TOTAL AORTIC ARCH REPAIR VS HYBRID APPROACH

Cannot be directly compared due to selection bias



- ✓no significant difference in in-hospital mortality (16% open vs 11% hybrid)
- ✓no significant difference in transient neurologic complications (11% both)
- ✓no significant difference in permanent neurologic complications (9% open vs 13% hybrid)

- ✓9% mortality in patient<75 y.o. whereas 36% mortality in patients>75y.o.
- ✓no significant difference in hybrid group
- ✓when >75y.o. 11% mortality in hybrid group vs 36% mortality in open group

Milewski RK, et al. Have hybrid procedures replaced open aortic arch reconstruction in high-risk patients? A comparative study of elective open arch debranching with endovascular stent graft placement and conventional elective open total and distal aortic arch reconstruction. J Thorac Cardiovasc Surg 2010;140:590-7.

General Thoracic and Cardiovascular Surgery
https://doi.org/10.1007/s11748-018-0894-1

Table 3 Predictors of all-cause mortality by multivariate analysis (limited in TAR/d-TEVAR)

Group	Covariate	HR	95% CI	*p* value
TAR	COPD	6.42	1.59–25.9	0.009
	Malignancy	5.28	0.97–28.6	0.05
	Previous cardiac and thoracic aortic surgery	65.9	2.49–1743	0.012
	Perioperative stroke	16.6	2.18–126	0.007
	Postoperative pneumonia	6.72	1.41–32.1	0.017
d-TEVAR	Neurologic dysfunction	2.97	1.23–7.18	0.016
	Perioperative stroke	12.1	1.40–104	0.023

TAR total arch replacement, *d-TEVAR* debranching thoracic endovascular aortic repair, *COPD* chronic obstructive pulmonary disease, *AAA* abdominal aortic aneurysm

Keywords Octogenarians · Aortic arch aneurysm · Total arch replacement · Debranching thoracic endovascular aortic repair

Interactive CardioVascular and Thoracic Surgery (2019) 1–8
doi:10.1093/icvts/ivz027

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Is debranching thoracic endovascular aortic repair acceptable as the

first choice for arch aneurysm in the elderly?[†]

Yoshimas kuda[b], Yo ıra[a],
Sasaki[a] ar

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[b] Department of Rad ka, Japan

[*] Corresponding aut bral and Card 5, Japan.
Tel: +81-6-6833501 I. Matsuda).

Key question

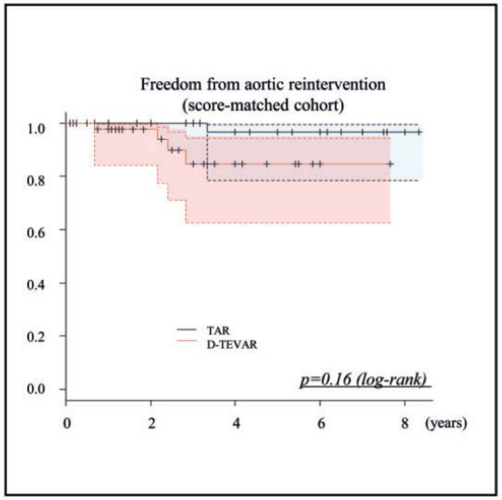
Is debranching thoracic endovascular aortic repair (d-TEVAR) acceptable as the first choice for aortic arch aneurysm in the elderly (>75 years old)?

Key finding(s)

Propensity score matching yielded similar rates of survival (85% in TAR vs 71% in d-TEVAR) and of freedom from reintervention (97% vs 90%) at 4 years.

Take-home message

d-TEVAR is acceptable as the first choice of procedure for repair of aortic arch aneurysm in the elderly (>75 years old).



OBJECTIVES: This outcomes b nching tho-
racic endovascula idity of d-T arch aneu-
rysm in the elderl

METHODS: We r had underg 21 patients
who had underg) between 2 group were
matched based o atient chara

RESULTS: Rates of freedom from all-cause mortality at 2 and 4 years were similar between the 2 groups (88% and 77% in the TAR group vs 82% and 64% in the d-TEVAR group, *P* = 0.11), but rates of freedom from reintervention at 2 and 4 years were significantly higher in the TAR group (100% and 96%) than in the d-TEVAR group (97% and 88%) (*P* = 0.004). Propensity score matching yielded similar survival rates of 88% and 85% for TAR vs 86% and 71% for d-TEVAR (*P* = 0.53) and comparable freedom from reintervention rates (100% and 97% in TAR, 98% and 90% in d-TEVAR, *P* = 0.16) at 2 and 4 years. Cox regression analysis identified previous cerebral infarction [hazard ratio (HR) 3.9; *P* = 0.005 in TAR/HR 3.1; *P* = 0.002 in d-TEVAR] as an independent positive predictor of overall mortality in both groups.

CONCLUSIONS: Midterm outcomes after TAR and d-TEVAR were satisfactory and propensity score matching-based evaluation revealed no significant differences in outcomes, implying that d-TEVAR is an acceptable first-choice procedure for aortic arch aneurysm in patients older than 75 years.

Keywords: Elderly • Aortic arch aneurysm • Total arch replacement • Debranching thoracic endovascular aortic repair • Propensity score matching

TABLE 3. Matched comparison of postoperative data between CTAR and HAR groups

	CTAR (n = 43)	HAR (n = 43)	*P* value

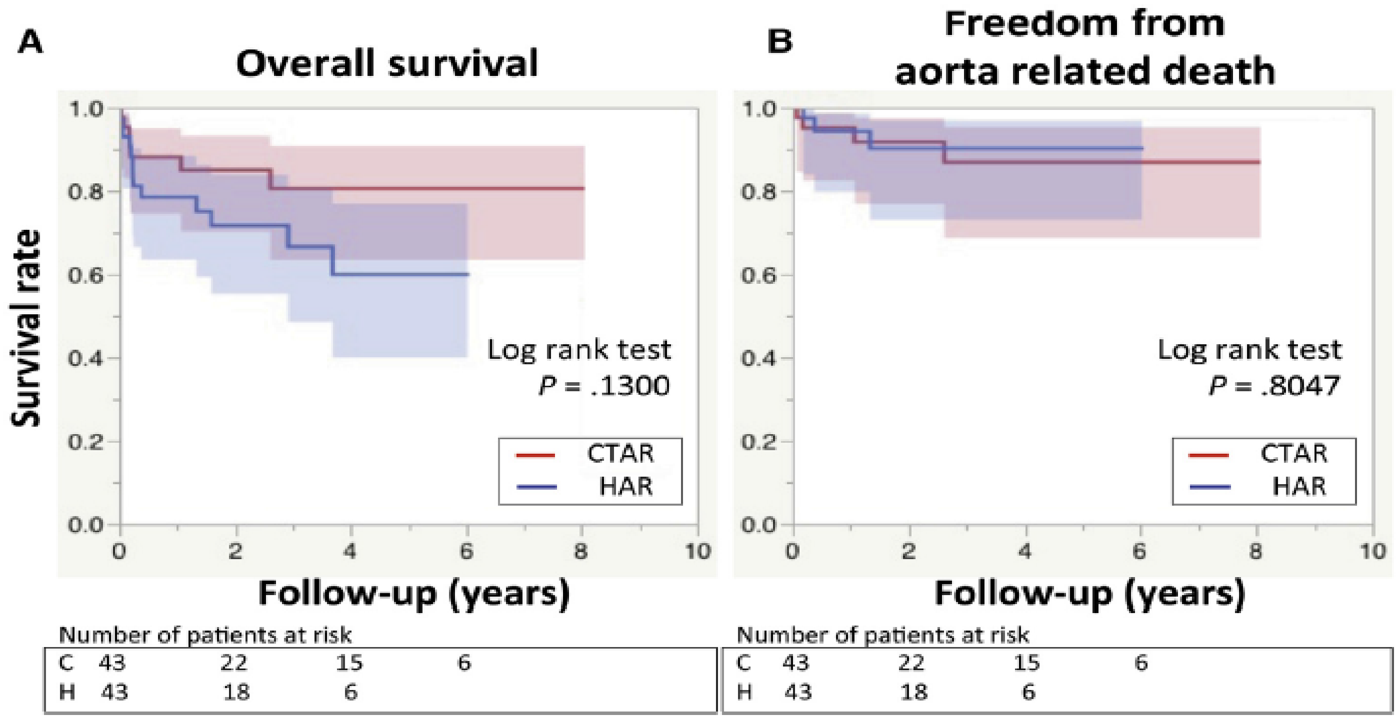


FIGURE 3. A, Matched comparison of midterm overall survival. Between matching pairs of CTAR and HAR groups, there was no significant difference in the survival rate. B, Matching model also showed no significant differences in freedom from aorta-related death between the CTAR and HAR groups. *CTAR*, Conventional total aortic arch repair; *HAR*, hybrid arch repair.

vealed an equivalent 5-year survival rate between the CTAR and HAR groups (80.5% vs 59.9%; *P* = .1300).

Conclusions: Matching analysis revealed a significantly greater incidence of stroke in the HAR group but equivalent midterm outcomes in the hybrid group compared with the CTAR group. (J Thorac Cardiovasc Surg 2017;154:100-6)

tional arch repair group. In a high-risk population, hybrid approaches have the potential to be alternatives to a conventional approach. Further development, however, is required for hybrid repair to become a superior option.

See Editorial Commentary page 107.

See Editorial page 98.

Study	Atrial fibrillation/ cardiac event (%)	Retrograde aortic dissection (%)	Peripheral embolization (%)	Reoperation for bleeding (%)	Endoleak (%)	Late mortality (%)	Cumulative survival at 1-year (%)	Reoperation rate (%)	Follow-up (months)
Vallabhajosyula (2013) (17)	50	nr	Nr	0	0	12.5	87% (at 1 and 3 years)	0 (2pts)	30±21
Kent (2014) (38)	Nr	nr	Nr	25	15 (typeI), 5 (type II)	nr	nr !!!!	10	17.5
Shirakawa (2014)* (15)	0**	0**	10**	0**	10 (type II)**	15	85 (74% at 3 years)	0**	15.4**
Bibiloni Lage (2016)* (47)	20	nr	20	50 (for cardiac tamponade) **	0**	0**	nr	0**	10**

Study	Technical success (%)	30-day/in-hospital mortality (%)	Stroke (%)	Permanent paraplegia (%)	Recurrent nerve palsy (%)	Transient neurologic deficit/ paraplegia (%)	Renal failure/requiring dialysis (%)	Multiorgan failure with respiratory insufficiency/prolonged intubation (%)
Vallabhajosyula (2013) (17)	nr	0	0	0	nr	25	0/0	Nr
Kent (2014) (38)	100	10	5	0	nr	25	0	15
Shirakawa (2014)* (15)	100**	0**	0**	0**	10**	0**	0**	10**
Bibiloni Lage (2016)* (47)	100**	50**	0**	0**	50**	0**	50**	50**

wav: 5.3%

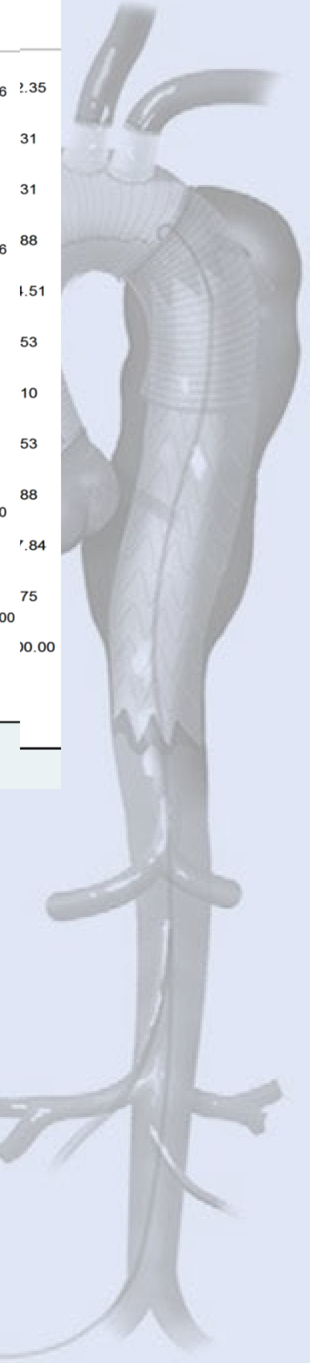
wav: 2.5%

Material and Methods A meta-analysis and detailed review of the literature published from January 2013 until December 2016, concerning hybrid aortic arch debranching procedures was conducted and data for morbidity and mortality rates were extracted.

Results As far as type I hybrid aortic arch reconstruction is concerned, among the 122 patients included, the pooled endoleak rate was 10.78% (95%CI = 1.94–23.40), 30-day or in-hospital mortality was 3.89% (95%CI = 0.324–9.78), stroke rate was 3.79% (95%CI = 0.25–9.77) and weighted permanent paraplegia rate was 2.4%. In terms of type II hybrid approach, among 40 patients, endoleak rate was 12.5%, 30-day or in-hospital mortality rate was 5.3%, stroke rate was 2.5%, no permanent paraplegia was noticed and late mortality rate was 12.5%.

Conclusions Hybrid aortic arch debranching procedures are a safe alternative to open repair with acceptable short- and mid-term results. They extend the envelope of intervention in aortic arch pathologies, particularly in high-risk patients who are suboptimal candidates for open surgery.

Keywords Hybrid • Endovascular • Aortic arch • Debranching • Ascending aorta replacement



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PRACTICE GUIDELINE: FULL TEXT

2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM Guidelines for the Diagnosis and Management of Patients With Thoracic Aortic Disease

9.2.2.2.1. Open Surgery. At present, endovascular stent grafts have not been approved by the US Food and Drug Administration for treatment of aneurysms or other conditions of the aortic arch. For patients with large aneurysms who are not candidates for conventional open operation, experience is accumulating with operative procedures that involve translocation of the brachiocephalic arteries from the aortic arch using branch grafts from the proximal ascending aorta, and placement of an endovascular graft into the distal ascending aorta, the entire aortic arch, and a segment of the adjacent descending thoracic aorta (371,460,461).

European Heart Journal (2014) 35, 2873–2926
doi:10.1093/eurheartj/ehu281

ESC GUIDELINES

2014 ESC Guidelines on the diagnosis and treatment of aortic diseases

Document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult

The Task Force for the Diagnosis and Treatment of Aortic Diseases of the European Society of Cardiology (ESC)

Authors/Task Force members: Raimund Erbel* (Chairperson) (Germany), Victor Aboyans* (Chairperson) (France), Catherine Boileau (France), Eduardo Bossone (Italy), Roberto Di Bartolomeo (Italy), Holger Eggebrecht (Germany), Arturo Evangelista (Spain), Volkmar Falk (Switzerland), Herbert Frank (Austria), Oliver Gaemperli (Switzerland), Martin Grabenwöger (Austria), Axel Haverich (Germany), Bernard Iung (France), Athanasios John Manolis (Greece), Folkert Meijboom (Netherlands), Christoph A. Nienaber (Germany), Marco Roffi (Switzerland), Hervé Rousseau (France), Udo Sechtem (Germany), Per Anton Sirnes (Norway), Regula S. von Allmen (Switzerland), Christiaan J.M. Vrints (Belgium).

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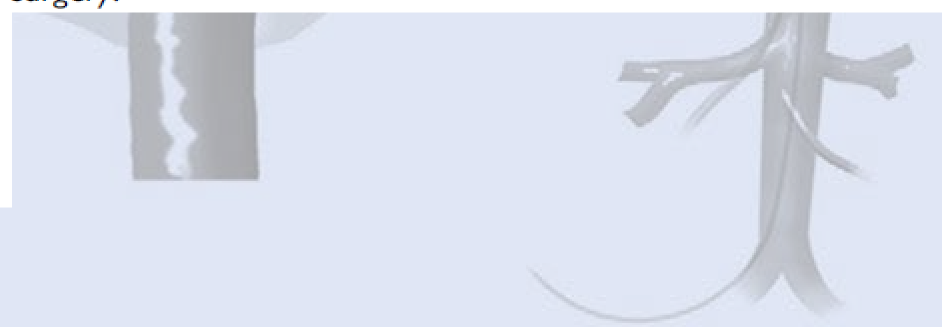
Arch vessel transposition (debranching) and TEVAR might be considered as an alternative to conventional surgery in certain clinical situations, especially when there is reluctance to expose patients to hypothermic circulatory arrest; however, especially after total arch vessel transposition, as well as in patients with the underlying diagnosis of acute Type B AD, the risk of retrograde Type A AD as a direct consequence of the procedure is elevated and should be weighed against the remaining risk of conventional surgery.[105,117,324,325]



European Journal of Cardio-Thoracic Surgery 55 (2019) 133–162
doi:10.1093/ejcts/ezy313 Advance Access publication 12 October 2018

POSITION STATEMENT

Cite this article as: Czerny M, Schmidli J, Adler S, van den Berg JC, Bertoglio L, Carrel T et al. Current options and recommendations for the treatment of thoracic aortic pathologies involving the aortic arch: an expert consensus document of the European Association for Cardio-Thoracic surgery (EACTS) and the European Society for Vascular Surgery (ESVS). Eur J Cardiothorac Surg 2019;55:133–62.

Current options and recommendations for the treatment of thoracic aortic pathologies involving the aortic arch: an expert consensus document of the European Association for Cardio-Thoracic surgery (EACTS) and the European Society for Vascular Surgery (ESVS)

Martin Czerny (EACTS Chairperson)[a,*,†] and Jürg Schmidli (ESVS Chairperson)[b,‡]
Writing Committee: Sabine Adler[c,‡], Jos C. van den Berg[d,e,‡], Luca Bertoglio[f,‡], Thierry Carrel[b,†], Roberto Chiesa[f,‡], Rachel E. Clough[g,‡], Balthasar Eberle[h,†], Christian Etz[i,†], Martin Grabenwöger[j,†], Stephan Haulon[k,‡], Heinz Jakob[l,†], Fabian A. Kari[a,†], Carlos A. Mestres[m,†], Davide Pacini[n,†], Timothy Resch[o,‡], Bartosz Rylski[a,†], Florian Schoenhoff[b,†], Malakh Shrestha[p,†], Hendrik von Tengg-Kobligk[q,‡], Konstantinos Tsagakis[l,†] and Thomas R. Wyss[b,‡]

Recommendation 23: TEVAR in zone 0 after previous debranching may be considered in patients unfit for open repair and suitable anatomy [180, 191].	Class IIB	Level B
Recommendation 24: TEVAR in zones 1 and 2 should be considered in patients with suitable anatomy [4	Class IIA	Level B
Recommendation 25: stent-graft deployment is not recommended in patients with a proximal and/or distal landing zone length less than 25 mm o… 38 mm [4	Class III	Level B
Recommendation 26: zones 0–2 TEVAR are not recommended in patients with connective tissue dis… native ao…	Class III	Level C
Recomm… should be considered in patients with concomitant aortic valve pathology or at high risk for retrograde type A aortic dissection (ascending aorta >38 mm, bicuspid aortic valve, arch abnormalities, lost sinutubular junction, extensive ascending aortic length) [175, 191].	Class IIA	Level B

6.3 Transposition (debranching) of supra-aortic vessels and thoracic endovascular aortic repair and the importance of the subclavian arteries in maintaining the blood supply to the spinal cord

thoracic aortic pathology (zone 0 proximal neck). For patients at a higher risk of stroke, open aortic arch surgery remains the best therapeutic option because extensive manipulation during debranching as well as during TEVAR might cause embolization [178, 180, 181]. Patients presenting with distal arch pathology

Canadian Journal of Cardiology 32 (2016) 703–713

Society Position Statement

Canadian Cardiovascular Society/Canadian Society of Cardiac Surgeons/Canadian Society for Vascular Surgery Joint Position Statement on Open and Endovascular Surgery for Thoracic Aortic Disease

Jehangir J. Appoo, MDCM (Co-chair),[a] John Bozinovski, MD,[b] Michael W.A. Chu, MD,[c] Ismail El-Hamamsy, MD, PhD,[d] Thomas L. Forbes, MD,[e] Michael Moon, MD,[f] Maral Ouzounian, MD, PhD,[g] Mark D. Peterson, MD, PhD,[h] Jacques Tittley, MD,[i] and Munir Boodhwani, MD, MMSc (Co-chair);[j] on behalf of the CCS/CSCS/CSVS Thoracic Aortic Disease Guidelines Committee

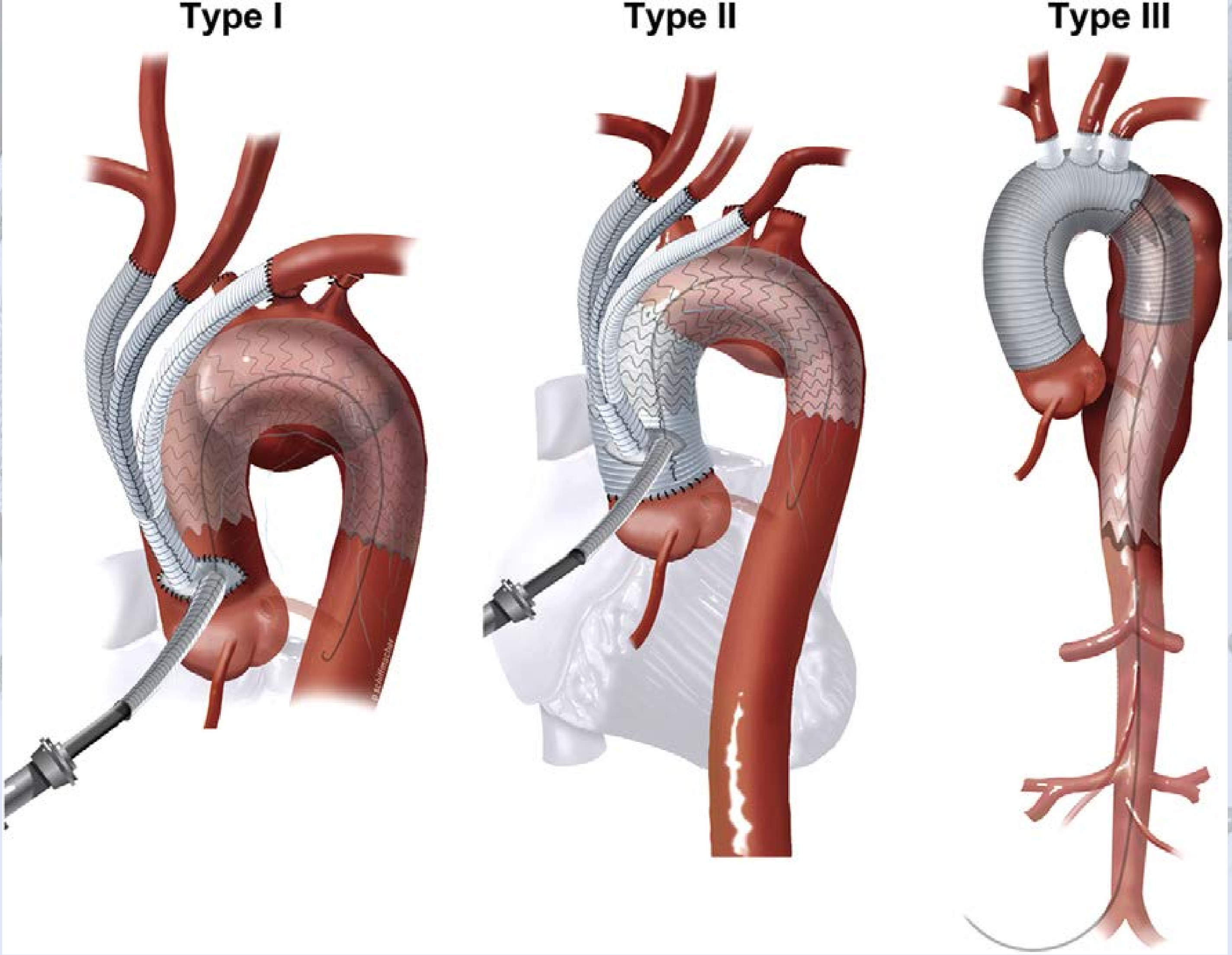
RECOMMENDATION

13. We suggest that hybrid arch repair be considered in patients deemed too high-risk for conventional open repair who meet specific anatomic criteria (Weak Recommendation, Low-Quality Evidence).

Values and preferences. Stroke is a significant risk in conventional and hybrid techniques. Creation of an optimal straight landing zone in Dacron or native aorta is desirable for stent graft technology available today. Ascending aortic diameter ≥ 4 cm is a risk factor for retrograde type A dissection. Hybrid arch repair should be avoided in patients with known or suspected connective tissue disorders unless proximal and distal landing zones are in Dacron replaced aorta.

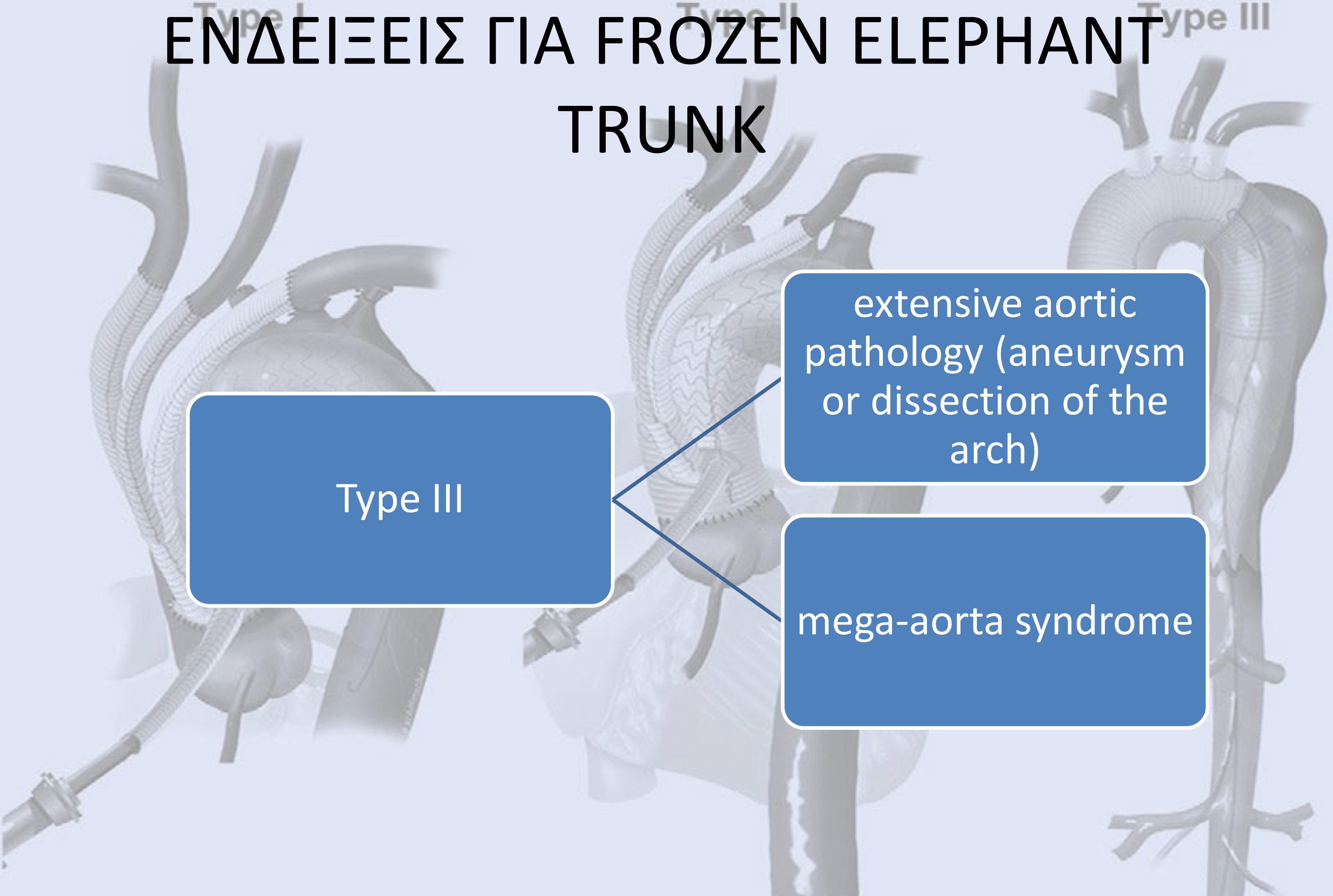
14. We suggest that hybrid arch techniques might be considered for single-stage repair in patients with diffuse aneurysms involving the ascending, arch and descending aorta (mega aorta) (Weak Recommendation, Low-Quality Evidence).

FROZEN ELEPHANT TRUNK



•Bavaria J, et al. Hybrid approaches in the treatment of aortic arch aneurysms: postoperative and midterm outcomes. J Thorac Cardiovasc Surg. 2013 Mar;145(3 Suppl):S85-90.

ΕΝΔΕΙΞΕΙΣ ΓΙΑ FROZEN ELEPHANT TRUNK



- **Type III**
  - extensive aortic pathology (aneurysm or dissection of the arch)
  - mega-aorta syndrome

•Moulakakis KG, et al. A systematic review and meta-analysis of hybrid aortic arch replacement. Ann Cardiothorac Surg. 2013;2(3):247-60.
•Bavaria J, et al. Hybrid approaches in the treatment of aortic arch aneurysms: postoperative and midterm outcomes. J Thorac Cardiovasc Surg. 2013 Mar;145(3 Suppl):S85-90.
•Vallabhajosyula P[1], et al. Type I and Type II hybrid aortic arch replacement: postoperative and mid-term outcome analysis. Ann Cardiothorac Surg. 2013;2(3):280-7.
•Canaud L[1], et al. Hybrid Aortic Repair of Dissecting Aortic Arch Aneurysm after Surgical Treatment of Acute Type A Dissection. Ann Vasc Surg 2016;30:175-80.
•Vallabhajosyula P, et al. Type II arch hybrid debranching procedure. Ann Cardiothorac Surg 2013;2(3):378-86.
•Brechtel K[1], et al. Hybrid debranching and TEVAR of the aortic arch off-pump, in re-do patients with complicated chronic type-A aortic dissections: a critical report. J Cardiothorac Surg 2013;8:188.
•Mizuno T[1], et al. Easy and Safe Total Debranching of Arch Aneurysms Using Axiloaxillary Arterial Bypass. Ann Thorac Surg. 2015;100(4):1476-8.

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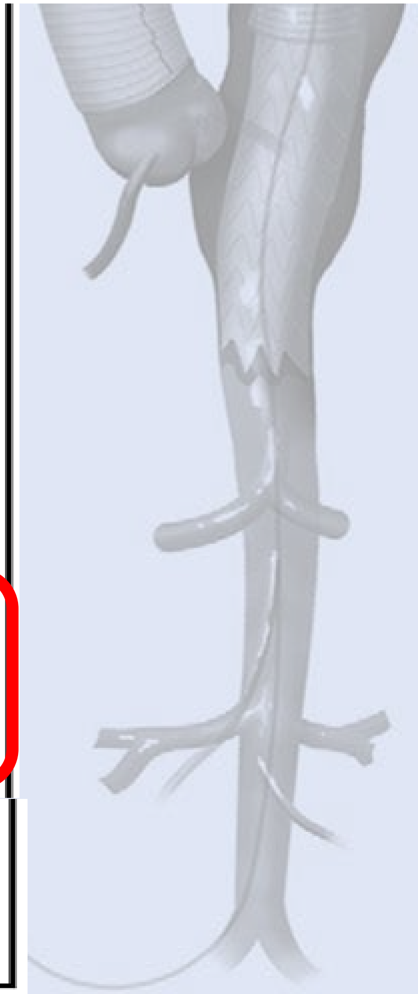
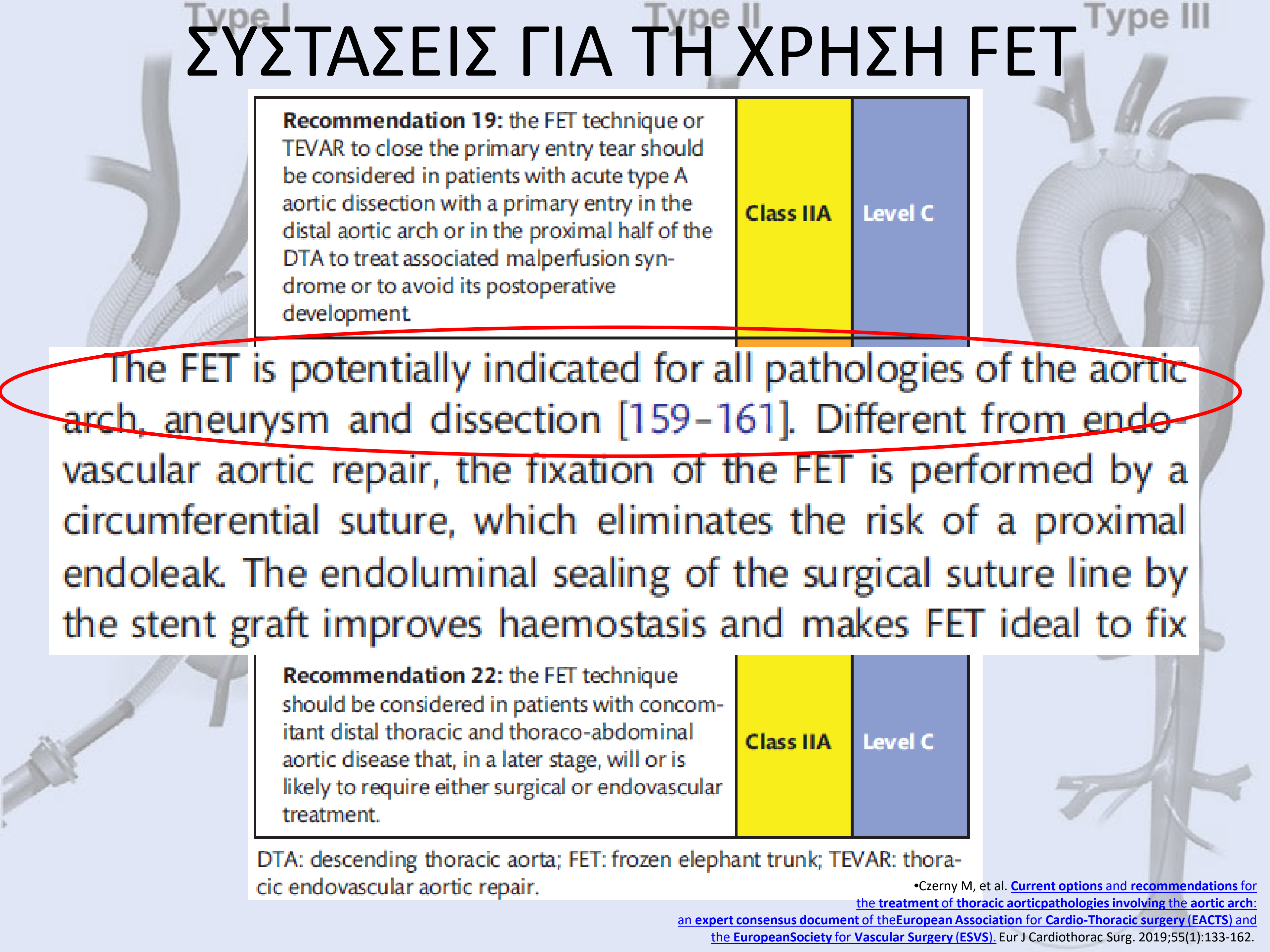
14. We suggest that hybrid arch techniques might be considered for single-stage repair in patients with diffuse aneurysms involving the ascending, arch and descending aorta (mega aorta) (Weak Recommendation, Low-Quality Evidence).

15. We suggest that closed-chest arch reconstructions only be considered for patients at high risk for open or hybrid repair (Weak Recommendation, Low-Quality Evidence).





ΣΥΣΤΑΣΕΙΣ ΓΙΑ ΤΗ ΧΡΗΣΗ FET

Recommendation 19: the FET technique or TEVAR to close the primary entry tear should be considered in patients with acute type A aortic dissection with a primary entry in the distal aortic arch or in the proximal half of the DTA to treat associated malperfusion syndrome or to avoid its postoperative development	**Class IIA**	**Level C**

The FET is potentially indicated for all pathologies of the aortic arch, aneurysm and dissection [159–161]. Different from endovascular aortic repair, the fixation of the FET is performed by a circumferential suture, which eliminates the risk of a proximal endoleak. The endoluminal sealing of the surgical suture line by the stent graft improves haemostasis and makes FET ideal to fix

Recommendation 22: the FET technique should be considered in patients with concomitant distal thoracic and thoraco-abdominal aortic disease that, in a later stage, will or is likely to require either surgical or endovascular treatment.	**Class IIA**	**Level C**

DTA: descending thoracic aorta; FET: frozen elephant trunk; TEVAR: thoracic endovascular aortic repair.

•Czerny M, et al. Current options and recommendations for the treatment of thoracic aorticpathologies involving the aortic arch: an expert consensus document of theEuropean Association for Cardio-Thoracic surgery (EACTS) and the EuropeanSociety for Vascular Surgery (ESVS). Eur J Cardiothorac Surg. 2019;55(1):133-162.

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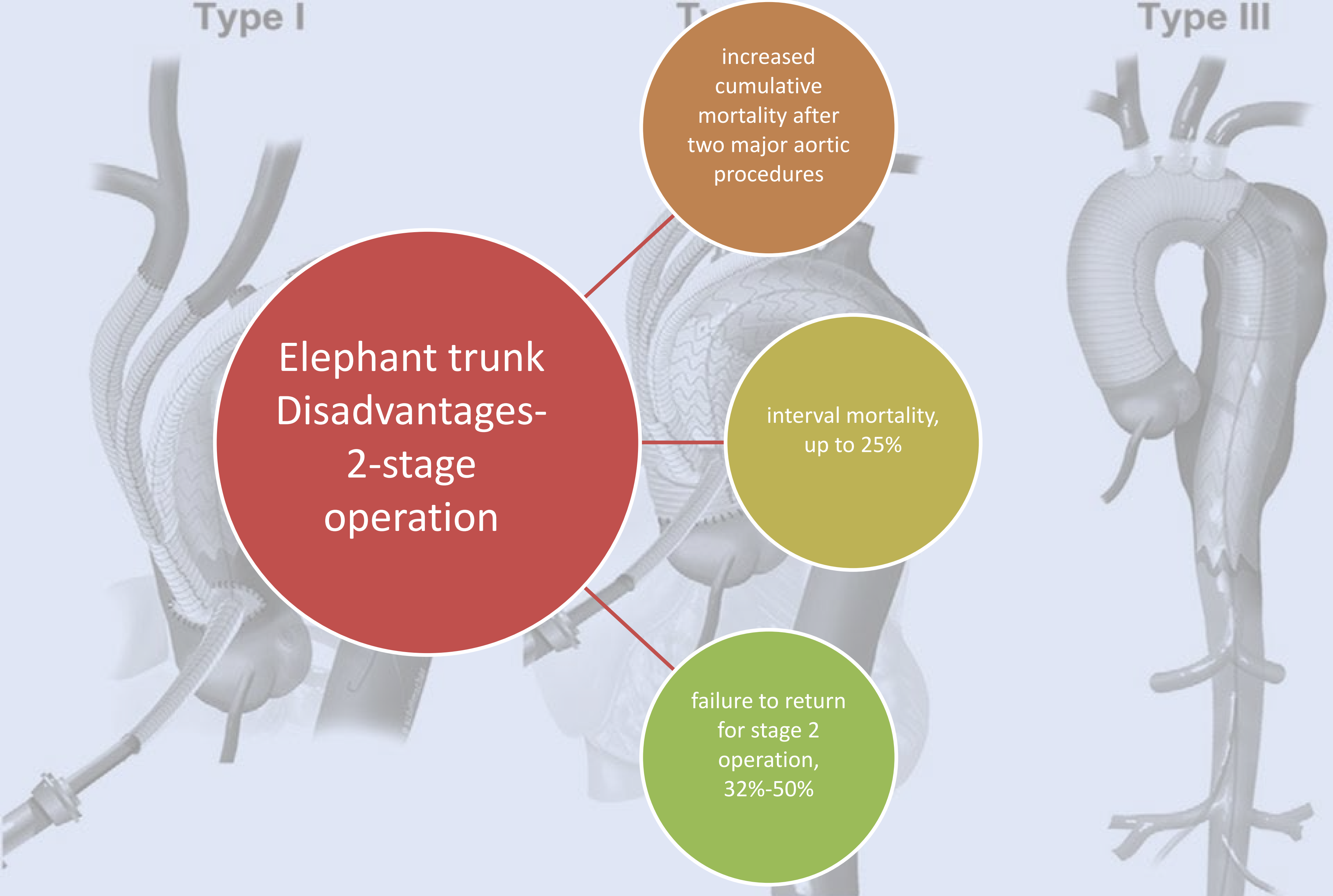
Extensive repair including graft replacement of the ascending aorta and aortic arch and integrated stent grafting of the descending aorta[108] ('frozen elephant trunk') was introduced as a single-stage procedure.[103,105] The 'frozen elephant trunk' is increasingly applied for this disease entity if complete ascending-, arch-, and descending AD are diagnosed in otherwise uncomplicated patients.[113–117] Originally designed for repair of chronic aneurysm, the hybrid approach, consisting of a single graft, is also applied, more often now in the setting of acute dissection (*Web Figures 10 and 11*).[118–121]

Recommendations for treatment of aortic dissection

Recommendations	Class[a]	Level[b]	Ref.[c]
In all patients with AD, medical therapy including pain relief and blood pressure control is recommended.	I	C	
In patients with Type A AD, urgent surgery is recommended.	I	B	1,2
In patients with acute Type A AD and organ malperfusion, a hybrid approach (i.e. ascending aorta and/or arch replacement associated with any percutaneous aortic or branch artery procedure) should be considered.	IIa	B	2,118, 202–204, 227
In uncomplicated Type B AD, medical therapy should always be recommended.	I	C	
In uncomplicated Type B AD, TEVAR should be considered.	IIa	B	218,219
In complicated Type B AD, TEVAR is recommended.	I	C	
In complicated Type B AD, surgery may be considered.	IIb	C	

and peripheral arteries. In particular clinical situations, the 'frozen elephant trunk' technique might also be considered in the treatment of complicated acute Type B AD without a proximal landing zone, as it also eliminates the risk of retrograde Type A AD.[226]



Elephant trunk Disadvantages- 2-stage operation

- increased cumulative mortality after two major aortic procedures
- interval mortality, up to 25%
- failure to return for stage 2 operation, 32%-50%

•Di Bartolomeo R[1], et al. Frozen versus conventional elephant trunk technique: application in clinical practice.Eur J Cardiothorac Surg. 2017 Jan;51(suppl 1):i20-i28.

•Ius F, et al. Elephant trunk procedure 27 years after Borst: what remains and what is new? Eur J Cardiothorac Surg 2011;40:1-11.

•Kollias VD[1], et al. Single-stage, off-pump hybrid repair of extensive aneurysms of the aortic arch and the descending thoracic aorta. Hellenic J Cardiol 2014;55(5):355-60.

•Kent WD, et al. Results of type II hybrid arch repair with zone 0 stent graft deployment for complexaortic arch pathology. J Thorac Cardiovasc Surg 2014;148(6):2951-5.

•Patel HJ, et al. Open arch reconstruction in the endovascular era: analysis of 721 patients over 17 years. J Thorac Cardiovasc Surg 2011;141:1417-23.

•Di Eusanio M, et al. Conventional versus frozen elephant trunk surgery for extensive disease of the thoracic aorta. J Cardiovasc Med (Hagerstown). 2014;15(11):803-9.

Type I Type II Type III

ΠΡΟΒΛΗΜΑΤΑ ΠΟΥ ΑΦΟΡΟΥΝ ΣΤΟ FET

Recommendations for surgical techniques in aortic disease

Recommendations	Class[a]	Level[b]	Ref.[c]
Cerebrospinal fluid drainage is recommended in surgery of the thoraco-abdominal aorta, to reduce the risk of paraplegia.	I	B	126–127
Aortic valve repair, using the re-implantation technique or remodelling with aortic annuloplasty, is recommended in young patients with aortic root dilation and tricuspid aortic valves.	I	C	
For repair of acute Type A AD, an open distal anastomotic technique avoiding aortic clamping (hemiarch/complete arch) is recommended.	I	C	
In patients with connective tissue disorders[d] requiring aortic surgery, the replacement of aortic sinuses is indicated.	I	C	
Selective antegrade cerebral perfusion should be considered in aortic arch surgery, to reduce the risk of stroke.	IIa	B	139,131, 134,141
The axillary artery should be considered as first choice for cannulation for surgery of the aortic arch and in aortic dissection.	IIa	C	
Left heart bypass should be considered during repair of the descending aorta or the thoraco-abdominal aorta, to ensure distal organ perfusion.	IIa	C	

[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.
[d]Ehlers-Danlos IV -, Marfan- or Loeys-Dietz syndromes.

European Heart Journal (2014) 35, 2873–2926
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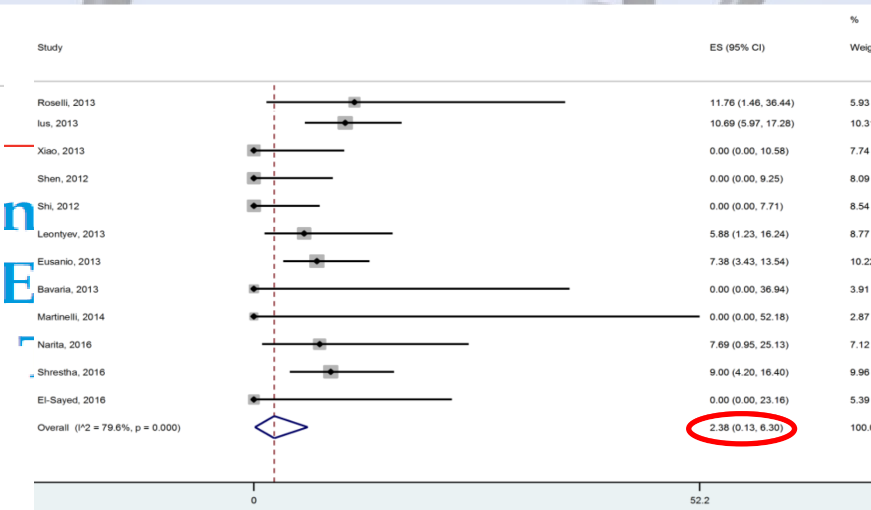
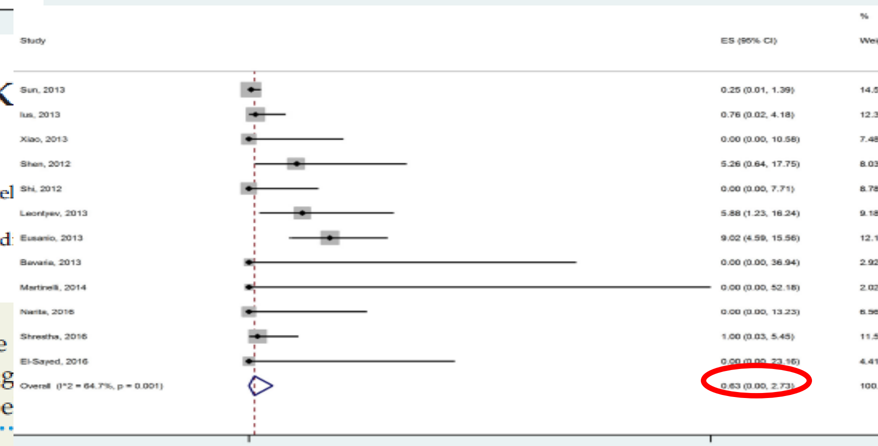
✓distal landing zone of T10 or lower, embolization and postoperative hypotension, abdominal aortic aneurysm repair history and a core body temperature equal to or over 28°C during circulatory arrest combined with circulatory arrest time over 45 minutes are strong predictors of spinal cord injury

•Di Eusanio M. Frozen elephant trunk surgery-the Bologna's experience. Ann Cardiothorac Surg 2013;2:597–605.
al. Impact of clinical factors and surgical techniques on early outcome of patients treated with frozen elephant trunk technique by using EVITA open stent-graft: results of a multicentre study. Eur J Cardiothorac Surg 2016;49:660–6.
S[1], et al. Early- and medium-term results after aortic arch replacement with frozen elephant trunktechniques-a single center study. Ann Cardiothorac Surg. 2013 Sep;2(5):606-11.
, et al. Single-stage, off-pump hybrid repair of extensive aneurysms of the aortic arch and the descending thoracic aorta. Hellenic J Cardiol 2014;55(5):355-60.
•Di Eusanio M[1], et al. Frozen elephant trunk surgery- the Bologna's experience. Ann Cardiothorac Surg 2013;2(5):597-605.
GL, et al. Multibranched Frozen Elephant Trunk with Left Subclavian Artery Cannulation. Aorta (Stamford). 2014 Apr 1;2(2):87-90.

Η ΜΕΤΑ-ΑΝΑΛΥΣΗ ΜΑΣ





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Received 16 March 2018; accepted 17 April 2018; online published-ahead-of-print 11 June 2018

Background Conventional open total arch replacement is the
However, it is a two-stage procedure related to hig
aortic arch reconstruction, the so-called "frozen e

Methods A meta-analysis and detailed review of the literature published from January 2013 until December 2016, concerning frozen elephant trunk hybrid approach was conducted and data for morbidity and mortality rates were extracted.

Results Among 989 patients included, the pooled 30-day or in-hospital mortality rate was 5.04% (95%CI = 1.13–10.74), stroke rate was 2.38% (95%CI = 0.13–6.30), and the irreversible paraplegia due to spinal cord injury rate was 0.63% (95%CI = 0.00–2.73). Finally, the pooled cumulative survival at 1 year was remarkably high (86.7%, 95%CI = 81.08–92.90).

Conclusions Frozen elephant trunk is a safe alternative to conventional elephant trunk repair for extensive aortic arch pathologies with acceptable short- and mid-term results, avoiding the interval mortality hazard.

Keywords Hybrid procedures • Aortic arch • Frozen elephant trunk

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REVIEW

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Frozen versus conventional elephant trunk technique: application in clinical practice

Roberto Di Bartolomeo[†], Giacomo Murana[*,†], Luca Di Marco, Antonio Pantaleo, Jacopo Alfonsi, Alessandro Leone and Davide Pacini

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Summary

Treating complex aortic arch disease with proximal and distal aortic segment involvement is challenging. In recent years, different surgical and endovascular techniques have been applied in a single or multiple-stage approach with the aim to cure and simplify these conditions. The first procedure available for this purpose was the conventional elephant trunk technique. Its recent evolution is the frozen elephant trunk, which treats the descending thoracic aorta using the antegrade release of a self-expandable stent graft. In the following review article, we analyse the advantages and drawbacks of both techniques from clinical and practical perspectives.

Keywords: Aortic arch • Frozen elephant trunk • Elephant trunk • Aortic • Cerebral perfusion

Type I Type II Type III

Conventional elephant trunk

- Not definitive repair (second stage operation is required)
- No need to clamp proximally the LSA (reduced stroke and paraplegia risk, 0.4%-2.8% SCI risk)
- Partial false lumen thrombosis due to reentries
- Kinking, graft occlusion and clot formation around the graft

Table 1: Elephant trunk procedure options for extensive aortic arch and descending thoracic aorta pathologies

Surgical technique	Advantage	Disadvantage
Conventional elephant trunk	• Simplify distal aortic arch anastomosis [10, 20, 49] • Facilitate thoracoabdominal aortic interventions [2, 5, 10, 49]	• Need a II stage procedure [4, 19, 20, 49] • Interval mortality [4, 5, 44]
FET	• Allows single-stage treatment [1, 19, 26, 38] • Facilitates thoracoabdominal aortic interventions [17, 28, 19] • Reduces the risk of additional distal aortic surgery [26, 28, 30, 41]	• Increased risk of spinal cord injury [7, 39, 44, 47] • Technically demanding [31, 37] • Cost of the device [52]

FET

- Allows single-stage treatment (20% risk for secondary reintervention)
- Over than to 10% SCI risk- increased paraplegia risk
- Induce depressurization and false lumen thrombosis and fully opens compressed true lumen
- Prolonged hypothermic circulatory arrest

Neurologic complications after the fro procedure: A meta-analysis of more th

TABLE 4. Summary of clinical outcomes

First author (year)	N	Overall stroke % (95% CI)	Overall SCI/paralysis/paraplegia % (95% CI)	Operative mortalit % (95% CI)
Usui (2002)[14]	24	4.2 (0.0-12.2)	12.5 (0.0-25.7)	0.0 (0.0-0.0)
Flores (2006)[15]	25	16.0 (1.6-30.4)	24.0 (7.3-40.7)	12.0 (0.0-24.7)
Shimamura (2008)[16]	126	5.6 (1.6-9.6)	6.3 (2.1-10.6)	5.6 (1.6-9.6)
Li (2009)[17]	31	3.2 (0.0-9.4)	0.0 (0.0-0.0)	6.5 (0.0-15.1)
Chen (2010)[18]	28	10.7 (0.0-22.2)	0.0 (0.0-0.0)	14.3 (1.3-27.2)
Sun (2010)[19]	19	5.3 (0.0-15.3)	0.0 (0.0-0.0)	5.3 (0.0-15.3)
Lima (2012)[20]	31	12.9 (1.1-24.7)	12.9 (1.1-24.7)	9.7 (0.0-20.1)
Shen (2012)[21]	38	0.0 (0.0-0.0)	5.3 (0.0-12.4)	7.9 (0.0-16.5)
Zhao (2012)[22]	24	4.2 (0.0-12.2)	0.0 (0.0-0.0)	4.2 (0.0-12.2)
Hoffman (2013)[23]	32	0.0 (0.0-0.0)	0.0 (0.0-0.0)	3.1 (0.0-9.2)
Di Marco (2014)[24]	11	9.1 (0.0-26.1)	0.0 (0.0-0.0)	0.0 (0.0-0.0)
Ma (2014)[25]*	456	2.9 (1.3-4.4)	2.4 (1.0-3.8)	8.1 (5.6-10.6)
Ma (2014B)[25]*	347	0.9 (0.0-1.8)	2.3 (0.7-3.9)	4.3 (2.2-6.5)
Nakamura (2014)[26]	51	NR	3.9 (0.0-9.2)	NR
Shi (2014)[27]	84	33.3 (23.3-43.4)	0.0 (0.0-0.0)	6.0 (0.9-11.0)
Xiao (2014)[28]	33	0.0 (0.0-0.0)	0.0 (0.0-0.0)	18.2 (5.0-31.3)
Yang (2014)[29]	86	NR	2.3 (0.0-5.5)	5.8 (0.9-10.8)
Zhang (2014)[30]	88	14.8 (7.4-22.2)	0.0 (0.0-0.0)	5.7 (0.8-10.5)
Dias (2015)[31]	21	4.8 (0.0-13.9)	9.5 (0.0-22.1)	14.3 (0.0-29.3)
Hiraoka (2015)[32]	26	7.7 (0.0-17.9)	11.5 (0.0-23.8)	0.0 (0.0-0.0)
Katayama (2015)[33]	224	2.7 (0.6-4.8)	3.6 (1.1-6.0)	3.6 (1.1-6.0)
Ahmad (2016)[34]	14	14.3 (0.0-32.6)	0.0 (0.0-0.0)	0.0 (0.0-0.0)
Gong (2016)[35]	74	6.8 (1.0-12.5)	6.8 (1.0-12.5)	12.2 (4.7-19.6)
Leontyev (2016)[36]	509	8.1 (5.7-10.4)	7.5 (5.2-9.7)	15.9 (12.7-19.1)
Ma (2016)[37]	99	34.3 (25.0-43.7)	0.0 (0.0-0.0)	17.2 (9.7-24.6)
Shrestha (2016)[38]	100	9.0 (3.4-14.6)	7.0 (2.0-12.0)	7.0 (2.0-12.0)
Aalaei-Andabili (2017)[39]	48	6.3 (0.0-13.1)	4.2 (0.0-9.8)	16.7 (6.1-27.2)
Chen (2017)[40]	20	NR	5.0 (0.0-14.6)	5.0 (0.0-14.6)
Hu (2017)[41]	106	4.7 (0.7-8.8)	0.0 (0.0-0.0)	7.5 (2.5-12.6)
Preventza (2017)[42]	37	5.4 (0.0-12.7)	5.4 (0.0-12.7)	21.6 (8.4-34.9)
Verhoye (2017)[43]	94	9.6 (3.6-15.5)	4.3 (0.2-8.3)	11.7 (5.2-18.2)
Koizumi (2017)[44]	30	10.0 (0.0-20.7)	3.3 (0.0-9.8)	0.0 (0.0-0.0)
Kreibich (2018)[45]	14	14.3 (0.0-32.6)	0.0 (0.0-0.0)	0.0 (0.0-0.0)
Ma (2018)[46]	132	40.9 (32.5-49.3)	0.0 (0.0-0.0)	14.4 (8.4-20.4)
Roselli (2018)[47]	72	2.8 (0.0-6.6)	4.2 (0.0-8.8)	4.2 (0.0-8.8)
All studies (range)	3154	0-40.9	0-24.0	0-21.6

N, Number of patients included in study; *SCI*, spinal cord ischemia; *CI*, confidence interval; *NR*, not reported. *Upper entry, labeled Ma (2014), refers to data from acute ca lower entry, labeled Ma (2014B), refers to data from chronic cases.

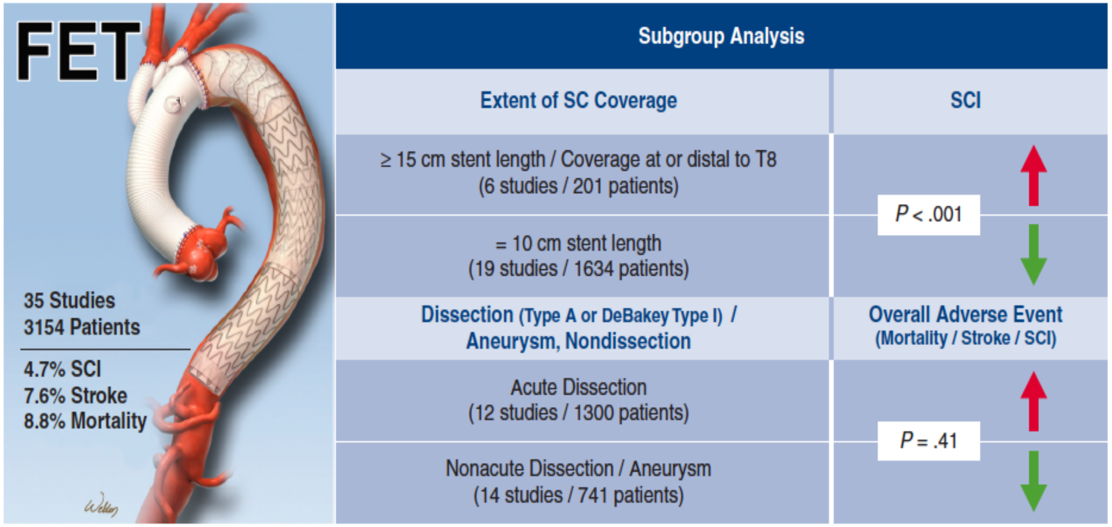

FIGURE 4. A visual summary of the main points of our study. The overall pooled rates of the outcomes of interest were 4.7% for overall SCI, 7.6% for overall stroke, and 8.8% for operative mortality. Additionally, 2 subgroup analyses were performed: One showed that SCI was significantly more frequent in the patients with longer stents or coverage at or beyond T8. The other subgroup analysis found that the FET technique was associated with higher rates of mortality and stroke in patients with acute type A dissection, and the overall adverse event rate (which included mortality, stroke, and SCI) was higher in these patients, too. *FET*, Frozen elephant trunk; *SC*, spinal cord; *SCI*, spinal cord ischemia.

Central Message

In FET, 10-cm stent length is advisable; length 15 cm or greater or coverage to or beyond T8 should be avoided to prevent SCI. FET should be used cautiously for acute type A aortic dissection.

Conclusions: As the frozen elephant trunk procedure becomes more popular, accurate data regarding outcomes are vital. We associated the frozen elephant trunk technique with (nonsignificantly) more adverse events overall in acute type A dissection cases. Stent length of 10 cm was associated with significantly less risk of spinal cord ischemia. Using a stent 15 cm or greater or coverage extending to T8 or farther should be avoided. (J Thorac Cardiovasc Surg 2019;■:1-14)

See Commentary on page XXX.

Total arch repair with frozen elephant trunk using the "zone 0 arch repair" strategy for type A acute aortic dissection

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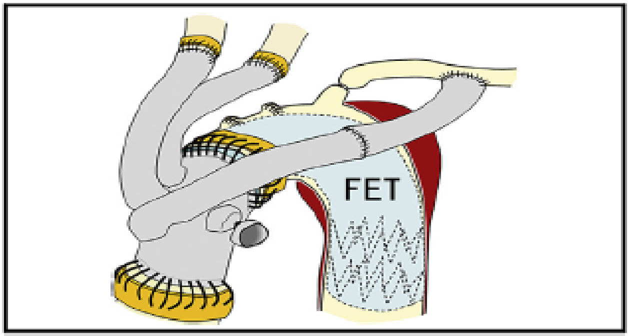
ABSTRACT

Objective: The aim of this study was to investigate the effect of frozen elephant trunk deployment from the zone 0 aorta to the descending aorta on early and midterm postoperative results in patients with acute type A aortic dissection.

Methods: Between October 2014 and April 2018, 108 patients underwent a combined strategy of frozen elephant trunk deployment, ascending aortic replacement, and arch vessel reconstruction ("zone 0 arch repair" strategy) for acute type A aortic dissection (excluding DeBakey type II). Of the 108 patients, 32 (29.6%) had primary tears of the aortic arch or descending aorta.

Results: The 30-day mortality rate was 2.8% (3 patients), and in-hospital mortality rate was 6.5% (7 patients). New-onset permanent neurologic dysfunction and spinal cord injury occurred in 3.7% and 0% of patients, respectively. Five of the 101 survivors underwent thoracic endovascular aortic repair during hospitalization (2 for rapid false lumen enlargement; 3 for true lumen stenosis). The overall survival was 89.8%, 88.1%, and 88.1% at 1, 2, and 3 years, respectively. The cumulative incidence of distal aortic reintervention was 5.8%, 9.1%, and 9.1% at 1, 2, and 3 years, respectively. Two patients underwent thoracic endovascular aortic repair for distal aortic enlargement after discharge.

Conclusions: The use of the "zone 0 arch repair" strategy can eliminate the need for invasive aortic arch resection. It also eliminates the false lumen and produces satisfactory early and midterm postoperative results. Therefore, it can be an alternative to hemiarch and total arch replacements, which are based on a conventional "tear-oriented resection" strategy. (J Thorac Cardiovasc Surg 2019;■:1-10)



FET from the zone 0 aorta, ascending aortic replacement, and arch vessel reconstruction.

Central Message

"Zone 0 arch repair," consisting of FET deployment from the zone 0 aorta, ascending aortic replacement, and arch vessel reconstruction, is straightforward and produces satisfactory late results.

Perspective

TAR, based on a tear-oriented strategy, is more invasive and carries a higher risk of unfavorable early results but less risk of late aortic reintervention than ascending aortic replacement. "Zone 0 arch repair," consisting of FET deployment from the zone 0 aorta, ascending aortic replacement, and arch vessel reconstruction, is straightforward and provides satisfactory late results.

Cardiovascular Surgery

(*Circulation*. 2011;123:971-978.)

Total Arch Replacement Combined With Stented Elephant Trunk Implantation

A New "Standard" Therapy for Type A Dissection Involving Repair of the Aortic Arch?

LiZhong Sun, MD*; RuiDong Qi, MD*; JunMing Zhu, MD; YongMin Liu, MD; Jun Zheng, MD

Table 3. Postoperative Outcomes

	Acute Dissection			Chronic Dissection		
Variable	SET (n=148)	CSR (n=66)	*P*	SET (n=148)	CSR (n=66)	*P*
Injury to recurrent nerves, n (%)	0	0		3 (2.1)	0	0.563
Stroke, n (%)	4 (2.7)	1 (1.5)	1.000	3 (2.1)	0	0.563
Paraplegia, n (%)	2 (1.4)	0	1.000	0	0	
Paraparesis, n (%)	1 (0.7)	1 (1.5)	0.523	4 (2.8)	0	0.577
Acute renal failure, n (%)	1 (0.7)	2 (3.0)	0.226	2 (1.4)	0	1.000
Ventilator support of duration >5 d, n (%)	14 (9.5)	5 (7.6)	0.797	7 (4.9)	1 (1.9)	0.450
Return to operating room for bleeding, n (%)	5 (3.4)	2 (3.0)	1.000	10 (7.0)	5 (9.3)	0.560
Drainage of pericardial sac, n (%)	1 (0.7)	0	1.000	2 (1.4)	1 (1.9)	1.000
In-hospital death, n (%)	7 (4.7)	4 (6.1)	0.741	2 (1.4)	2 (3.7)	0.302

SET indicates stented elephant trunk; CSR, conventional surgical repair.

Table 5. Follow-Up Results

	Acute Dissection			Chronic Dissection		
Variable	SET (n=141)	CSR (n=62)	*P*	SET (n=141)	CSR (n=52)	*P*
Follow-up time (±SD), mo	42±18	49±20	0.007	43±19	46±22	0.408
Out of follow-up, n (%)	6 (4.3)	5 (8.1)	0.316	8 (5.7)	3 (5.8)	1.000
Thrombosis of the false lumen, n (%)	130 (94.2)	7 (14.5)	0.000	126 (92.0)	3 (10.3)	0.000
Secondary surgical intervention, n (%)	1 (0.7)	4 (6.5)	0.031	4 (2.8)	2 (3.8)	0.661
Follow-up death, n (%)	4 (2.8)	2 (3.2)	1.000	6 (4.3)	3 (5.8)	0.704

SET indicates stented elephant trunk; CSR, conventional surgical repair.

Type III

Fate of distal aorta after frozen elephant trunk and total arch replacement for type A aortic dissection in Marfan syndrome

Yu Chen, MD,[a] Wei-Guo Ma, MD,[a,b,c] Ai-Hua Zhi, MD,[b] Lingeng Lu, MD,
Wei Zhang, MD,[a] Yong-Min Liu, MD,[a,b] Jun-Ming Zhu, MD,[a,b] John A. E
Li-Zhong Sun, MD[a,b]

ABSTRACT

Objective: The use of the frozen elephant trunk technique for type A aortic dissection in Marfan syndrome is limited by the lack of imaging evidence for long-term aortic remodeling. We seek to evaluate the changes of the distal aorta and late outcomes after frozen elephant trunk and total arch replacement for type A aortic dissection in patients with Marfan syndrome.

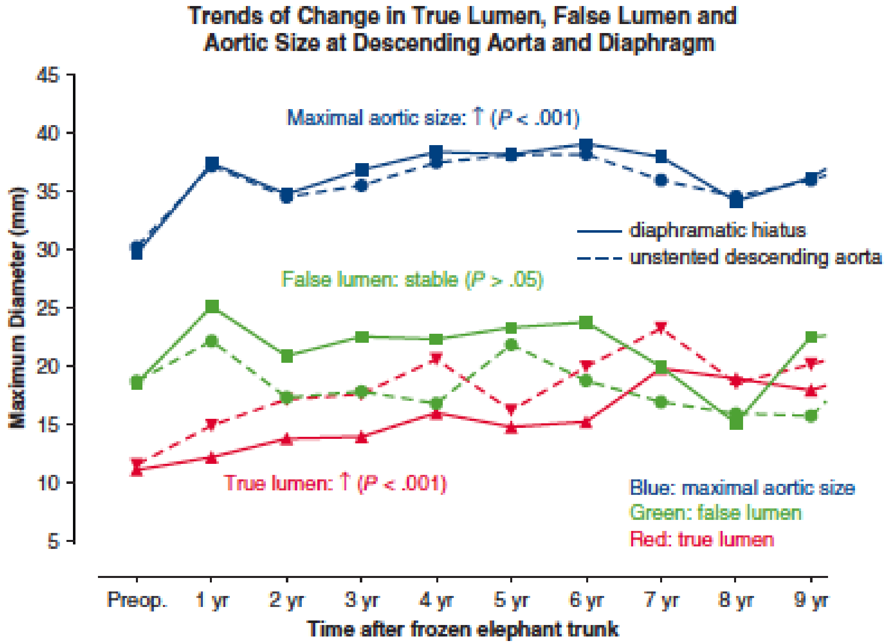
Methods: Between 2003 and 2015, we performed frozen elephant trunk + total arch re... ype A aortic ... s, and 121 w... ow-up was co... itation was de... growth rate of ... raphic angiog... aortic size w...

Result... %, and 21% a... n, and renal a... me at all seg... ephant trunk ... c size was stable at the frozen elephant trunk and renal artery ($P > .05$), but grew at the descending aorta ($P = .001$) and diaphragm ($P < .001$). Respective maximal aortic sizes before discharge were 40.2 mm, 32.1 mm, 31.6 mm, and 26.9 mm, and growth rate was 0.4 mm/year, 2.8 mm/year, 3.6 mm/year, and 2.6 mm/year. By the latest follow-up, distal maximal aortic size was stable in 63.5% (99/156), and complete remodeling down to the mid-descending aorta occurred in 28.8% (45/156). There were 22 late deaths and 23 distal reoperations. Eight-year incidence of death was 15%, reoperation rate was 20%, and event-free survival was 65%. Preoperative distal maximal aortic size (mm) predicted dilatation (hazard ratio, 1.11; $P < .001$) and reoperation (hazard ratio, 1.07; $P < .001$). A patent false lumen in the descending aorta predicted dilatation (hazard ratio, 3.88; $P < .001$), reoper-

Conclusions: The frozen elephant trunk technique can expand the true lumen across the aorta, decrease or stabilize the false lumen, and stabilize the distal aorta

Central Message

In 172 patients with Marfan syndrome suffering from type A aortic dissection, the frozen elephant trunk technique induced true lumen expansion across the aorta, stabilized the distal aorta in 63.5%, and achieved a 65% event-free survival at 8 years.



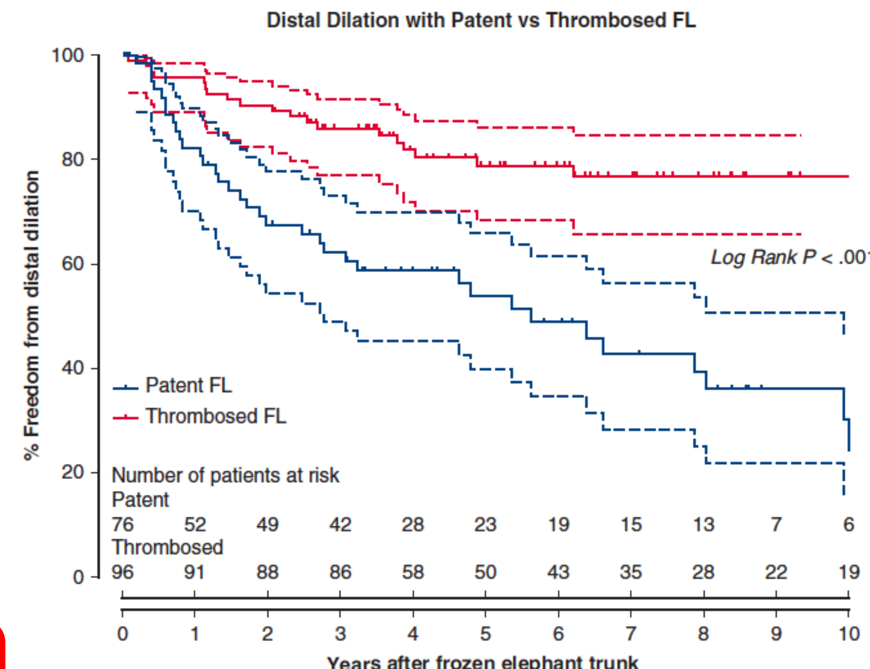


FIGURE 3. Distal aortic dilation in patent versus thrombosed FL. *FL*, False lumen.

Type I Type II Type III

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ORIGINAL ARTICLE

Experience with the conventional and frozen elephant trunk techniques: a single-centre study†

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Table 4: Postoperative clinical characteristics for cET vs FET patients and for patients with and without Type A aortic dissection

	Total *n* = 171	cET *n* = 125	FET *n* = 46	*P*
Postoperative outcome				
PND	26 (15.2)	20 (16.0)	6 (13.0)	0.6
TND	27 (15.8)	23 (18.4)	4 (8.7)	0.1
Paraplegia	15 (8.8)	5 (4.0)	10 (21.7)	<0.001
Respiratory failure	76 (44.4)	57 (45.6)	19 (41.3)	0.6
Renal failure	34 (19.9)	23 (18.4)	11 (23.9)	0.4
Reoperation for bleeding	30 (17.5)	24 (19.2)	6 (13.0)	0.3
30-day mortality	28 (16.4)	24 (19.2)	4 (8.7)	0.1
In-hospital mortality	31 (18.1)	27 (21.6)	4 (8.7)	0.053

The elephant trunk is freezing: The Hannover experience

TABLE 3. Postoperative data

	Total			Aneurysm			Acute dissection			Chronic dissection		
	Group A (ET)	Group B (FET)	*P*	Group A (ET)	Group B (FET)	*P*	Group A (ET)	Group B (FET)	*P*	Group A (ET)	Group B (FET)	*P*
Patients	97	180		43	62		47	67		7	51	
Ventilation (d [range])	0.91 (0.58-2.7)	1.2 (0.58-4.4)	.13	0.63 (0.50-1.0)	0.87 (0.51-3.2)	.055	2.1 (0.84-5.8)	2.0 (0.70-5.6)	.79	0.76 (0.40-0.96)	1.2 (0.54-4.6)	.29
Hospital stay (d [range])	12 (7.5-20)	15 (9.0-23)	**.037**	12 (9.0-18)	15 (9.0-22)	.31	14 (5.0-22)	13 (8.0-21)	1.00	11 (8.0-12)	17 (12-30)	**.0049**
Rethoracotomy for bleeding	23 (24)	30 (17)	.20	6 (14)	8 (13)	1.00	15 (32)	12 (18)	.12	2 (29)	10 (20)	.62
Stroke	12 (12)	24 (13)	1.00	2 (5)	6 (10)	.47	10 (21)	11 (16)	.62	0 (0)	6 (12)	1.00
Prolonged ventilation	27 (28)	44 (24)	.57	4 (9)	8 (13)	.76	13 (28)	10 (15)	.10	1 (14)	14 (28)	.66
Paraparesis	5 (5)	9 (5)	1.00	0	2 (3)	.51	5 (11)	6 (9)	.76	0 (0)	1 (2)	1.00
Recurrent nerve palsy	15 (16)	36 (20)	.42	8 (19)	10 (16)	.80	5 (11)	13 (19)	.30	1 (14)	9 (18)	1.00
Renal failure; dialysis	12 (12)	25 (14)	.85	2 (5)	7 (11)	.30	10 (21)	9 (13)	.31	0 (0)	9 (18)	.58
30-d mortality	24 (25)	22 (12)	**.011**	4 (9)	9 (15)	.55	19 (40)	10 (15)	**.004**	1 (14)	4 (8)	.42

Boldface indicate *P* < .005. Values are n, or n (%), unless otherwise indicated. *ET*, Elephant trunk; *FET*, frozen elephant trunk.

proximal descending aorta, the FET approach potentially allows for single-stage therapy, whereas a second-stage operation is inevitable with the classic ET approach. Moreover, owing to the availability of prefabricated, easy-to-use, FET, hybrid prostheses that result in significantly better outcomes in patients who have acute aortic dissection, type A, and if necessary, and provide an ideal "landing zone" for future endovascular completion, the classic ET procedure is "freezing," in the sense that it is being replaced by the FET approach. (J Thorac Cardiovasc Surg 2015;149:1286-93)

Original article

Conventional versus frozen elephant trunk surgery for extensive disease of the thoracic aorta

Marco Di Eusanio[a], Michael Borger[b], Francesco D. Petridis[a], Sergey Leontyev[b], Antonio Pantaleo[a], Monica Moz[b], Friedrich Mohr[b] and Roberto Di Bartolomeo[a]

Objective To compare early and mid-term outcomes after repair of extensive aneurysm of the thoracic aorta using the conventional elephant trunk or frozen elephant trunk (FET) procedures.

Methods Fifty-seven patients with extensive thoracic aneurysmal disease were treated using elephant trunk ($n = 36$) or FET ($n = 21$) procedures. Patients with aortic dissection, descending thoracic aorta (DTA) diameter less than 40 mm, and thoracoabdominal aneurysms were excluded from the analysis, as were those who did not undergo antegrade selective cerebral perfusion during circulatory arrest. Short-term and mid-term outcomes were compared according to elephant trunk/FET surgical management.

Results Preoperative and intraoperative variables were similar in the two groups, except for a higher incidence of female sex, coronary artery disease and associated procedures in elephant trunk patients. Hospital mortality (elephant trunk: 13.9% versus FET: 4.8%; $P = 0.2$), permanent neurologic dysfunction (elephant trunk: 5.7% versus FET: 9.5%; $P = 0.4$) and paraplegia (elephant trunk: 2.9% versus FET: 4.8%; $P = 0.6$) rates were similar in the two groups. Follow-up was 100% complete. In the elephant trunk group, 68.4% of patients did not undergo a second-stage procedure during follow-up for a variety of reasons. Of these patients, the DTA diameter was greater than 51 mm in 72.2% and two (6.7%) died due to aortic rupture while awaiting stage-two intervention. Endovascular second-stage procedures were successfully performed in all FET patients with residual DTA aneurysmal disease ($n = 3$), whereas nine of 11 elephant trunk patients who returned for second-stage procedures required conventional surgical replacement through a lateral thoracotomy. Kaplan–Meier estimate of 4-year survival was 75.8 ± 7.6 and 72.8 ± 10.6 in elephant trunk and FET patients, respectively (log-rank $P = 0.8$).

Conclusion In patients with extensive aneurysmal disease of thoracic aorta, elephant trunk and FET procedures seem to be associated with similar satisfactory early and mid-term outcomes. The FET approach leads to single-stage treatment of all aortic disease in most patients, and facilitates endovascular second-stage treatment in patients with residual DTA disease. The elephant trunk staged-approach appears to leave a considerable percentage of patients at risk for adverse aortic events.

J Cardiovasc Med 2014, 15:803–809

Keywords: aneurysm, aorta, great vessels, hybrid

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	Conventional elephant trunk	FET
Number of patients	36	21
In-hospital mortality	5	1 (p=0.272)
Potential candidates for stage-two operation	31/31	3/20
Underwent stag operation		
Endovascular stage-two operation	2/11	3/3
Mean interval in months	24.2±11.2	2.9±1.1
Interval mortality	2	0

similar satisfactory early and mid-term outcomes. The FET approach leads to single-stage treatment of all aortic disease in most patients, and facilitates endovascular second-stage treatment in patients with residual DTA disease. The elephant trunk staged-approach appears to leave a considerable percentage of patients at risk for adverse aortic events.

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Is the frozen elephant trunk procedure superior to the conventional elephant trunk procedure for completion of the second stage?[†]

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Abstract

OBJECTIVES: Our goal was to compare the results and outcomes of second-stage completion in patients who had previously undergone the elephant trunk (ET) or the frozen elephant trunk (FET) procedure for the treatment of complex aortic arch and descending aortic disease.

METHODS: Between August 2001 and December 2014, 53 patients [mean age 61 ± 13 years, 64% (*n* = 34) male] underwent a second-stage completion procedure. Of these patients, 32% (*n* = 17) had a previous ET procedure and 68% (*n* = 36) a previous FET procedure as a first-stage procedure.

RESULTS: The median times to the second-stage procedure were 7 (0–78) months in the ET group and 8 (0–66) months in the FET group. The second-stage procedure included thoracic endovascular aortic repair in 53% (*n* = 28) of patients and open surgical repair in 47% (*n* = 25). More endovascular interventions were performed in FET patients (61%, *n* = 22) than in the ET group (35%, *n* = 6, *P* = 0.117). The in-hospital mortality rate was significantly lower in the FET (8%, *n* = 3) group compared with the ET group (29%, *n* = 5, *P* = 0.045). The median follow-up time after the second-stage operation for the entire cohort was 4.6 (0.4–10.4) years. The 5-year survival rate was 76% in the ET patients versus 89% in the FET patients (log-rank: *P* = 0.11).

CONCLUSIONS: We observed a significantly lower in-hospital mortality rate in the FET group compared to the ET group. This result might be explained by the higher rate of endovascular completion in the FET group. We assume that the FET procedure offers the benefit of a more ideal landing zone, thus facilitating endovascular completion.

Keywords: Frozen elephant trunk • Aortic arch replacement • Second-stage aortic repair

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ORIGINAL ARTICLE

AORTIC SURGERY

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Single-centre experience with the frozen elephant trunk technique in 251 patients over 15 years†

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Abstract

OBJECTIVES: Our goal was to present our 15-year experience (2001–2015) with the frozen elephant trunk (FET) technique.

METHODS: A total of 251 patients (82 with aortic aneurysms, 96 with acute aortic dissection type A, 4 with acute type B dissections, 52 with chronic aortic dissection type A, 17 with chronic type B dissection and 67 redo cases) underwent FET implantation with either the custom-made Chavan–Haverich (n = 66), the Jotec E-vita (n = 31) or the Vascutek Thoraflex hybrid (n = 154) prosthesis. The cases were assigned to an early period (2001–2011) and a contemporary period (2012–present).

RESULTS: Mean cardiopulmonary bypass time, aortic cross-clamp time, circulatory arrest time and selective antegrade cerebral perfusion time were 241 ± 72, 125 ± 59, 56 ± 30 and 81 ± 34 min, respectively. Incidence of rethoracotomy for bleeding, stroke, spinal cord injury, prolonged ventilatory support (>96 h) and long-term dialysis were 18, 14, 2, 24 and 2%, respectively. The in-hospital mortality rate was 11% (in acute aortic dissection type A, 12%). Of the 2 patients with graft infections, 1 died and the other had a protracted hospital stay. There were 49 second-stage procedures in the downstream aorta: either open surgical [n = 25 (thoraco-abdominal, n = 15; descending, n = 6; infrarenal, n = 4)] or transfemoral endovascular (n = 23). Elective thoracic endovascular aneurysm repair R implantation was successful in all 23 cases.

CONCLUSIONS: FET results are comparable with those of the published results of the conventional elephant trunk technique. FET is an ideal landing zone for subsequent transfemoral endovascular completion. Patients with graft infections may have dismal results.

Keywords: Frozen elephant trunk • Aortic surgery • Aneurysm • Aortic dissection

Semin Thorac Cardiovasc Surg. 2019 Winter;31(4):679-685. doi: 10.1053/j.semtcvs.2019.05.038. Epub 2019 Jul 4.

Which Frozen Elephant Trunk Offers the Optimal Solution? Reflections From Essen Group.

Tsagakis K[1], Jakob H[2].

⊕ Author information

Abstract

Frozen Elephant Trunk (FET) combines the advantages of open and endovascular surgery for the treatment of complex aortic arch pathologies extending into the descending aorta. At University Hospital Essen, operative skills were developed to make FET surgery safer including guidance and control of FET deployment into the descending aorta by angioscopy and facilitation of arch repair by moving the distal anastomosis to Zone 2 and more proximally. Selective whole body perfusion during the arch repair was used to improve organ protection under moderate hypothermia. Our results demonstrate acceptable mortality in this high risk patient population and reduction of postoperative morbidity in the last years. With regard to the rate of exclusion of aneurysms in the distal arch and the false lumen in acute aortic dissection, FET should be the treatment of choice in both. In chronic aortic dissection and extensive descending aortic aneurysms, FET represents a safe first stage procedure and provides an ideal docking place in the mid-descending aorta for a second endovascular or open thoracoabdominal aortic repair, if required.

Type I

Type III

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doi:10.1016/j.jacc.2010.02.015

PRACTICE GUIDELINE: FULL TEXT

2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM Guidelines for the Diagnosis and Management of Patients With Thoracic Aortic Disease

Elephant trunk, 2010

9.2.2.2. RECOMMENDATIONS FOR AORTIC ARCH ANEURYSMS

CLASS IIa

1. For thoracic aortic aneurysms also involving the proximal ... together with ascending ... inflow and ... 449,450) ... for acute ... there is extensive ... aortic ... leakage (222,450) (Level of Evidence ...)

3. Replac... for aneurysms ... the arch is enlar... involve the proxim... the elephant trunk p...

...Disease: Aorta

The elephant trunk is freezing: The Hannover experience

...Malakh Shrestha, MBBS, Erik Beckmann, MD, Heike Krueger, RN, Felix Fleissner, MD, ...feld, MD, Nurbol Koigeldiyev, MD, Julia Umminger, MD, Fabio Ius, MD, Axel Haverich, MD

PRACTICE GUIDELINE: FULL TEXT
2010 ACCF/AHA/AATS/A...
Guidelines for the Diagnosis an...
With Thoracic Aortic Disease

6.1 Open aortic arch replacement

Open aortic arch replacement involving all 3 supra-aortic branches without the adjunct of either elephant trunk (ET) repair or in combination with the FET technique has become rare [147, 148] (Figs 4 and 5). The ET technique should be applied when the FET technique remains debatable. For instance, in large aneurysmal formations involving several TA segments and in very small true lumina with the risk of inducing pseudocoarctation), a FET procedure is not recommended.

Interactive CardioVascular and Thoracic Surgery 26 (2018) 183–189
doi:10.1093/icvts/ivx283 Advance Access publication 11 September 2017

ORIGINAL ARTICLE

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VASCULAR

Table 3: Early outcomes

	Total cohort (*n* = 168)			Propensity-matched cohort (*n* = 52)		
	FET (*n* = 132)	Arch debranching (*n* = 36)	*P*-value	FET (*n* = 26)	Arch debranching (*n* = 26)	*P*-value
30-day mortality (%)	19 (14.4)	2 (5.6)	0.254	6 (23.1)	2 (7.7)	0.248
Stroke (%)	7 (5.3)	2 (5.6)	>0.999	1 (3.8)	2 (7.7)	>0.999
TND (%)	47 (35.6)	10 (27.8)	0.379	7(26.9)	7 (26.9)	>0.999
ARD (%)	20 (15.2)	3 (8.3)	0.414	3 (11.5)	2 (7.7)	>0.999
Pulmonary infection (%)	44 (33.3)	8 (22.2)	0.201	6 (23.1)	5 (19.2)	0.734
Tracheotomy (%)	26 (19.7)	5 (13.9)	0.426	-	-	-
Reoperation (%)	9 (6.8)	3 (8.3)	0.754	-	-	-
ICU time (days)						
Mean ± SD	7.6 ± 4.4	6.1 ± 5.6	0.079	7.2 ± 4.1	6.5 ± 6.2	0.375
Median (IQR)	7.1 (4.8–9.6)	4.8 (2.6–8.4)		7.0 (4.6–9.7)	5.3 (2.7–8.0)	
Ventilation time (h)						
Mean ± SD	126.1 ± 90.5	96.2 ± 91.5	0.033	124.4 ± 84.0	100.5 ± 89.0	0.140
Median (IQR)	112 (49.3–159.5)	62.5 (16.8–148.3)		115 (49.8–180.0)	69.0 (23.5–148.3)	
Total drainage (l)						
Mean ± SD	4.2 ± 2.3	3.6 ± 2.7	0.080	3.8 ± 2.0	3.4 ± 2.6	0.132
Median (IQR)	4.2 (2.5–5.3)	2.9 (1.5–5.3)		4.1 (2.4–4.2)	2.7 (1.0–5.6)	
Time in hospital (days)						
Mean ± SD	23.4 ± 13.7	28.5 ± 19.8	0.076	20.4 ± 10.8	25.1 ± 14.9	0.693
Median (IQR)	23 (14–30)	24.5 (17.3–35.3)		21.5 (11.2–29.3)	21.5 (14.3–31.8)	

Values are represented as median (interquartile range) or *n* (%).
ARD: acute renal dysfunction; FET: frozen elephant trunk; ICU: intensive care unit; IQR: interquartile range; SD: standard deviation; TND: transient neurologic dysfunction.

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Abstract

OBJECTIVE ... pro-
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Perioperative data and mid-term follow-up results were assessed.

RESULTS: In the FET and the debranching groups, the 30-day mortality rates were 14.4% and 5.6% ($P = 0.254$) and the incidence of stroke was 5.3% and 5.6% ($P > 0.999$). Cardiopulmonary bypass time was significantly shortened, and the circulatory arrest was exempted in the debranching group. Cardiopulmonary bypass time was identified as a predictor for 30-day mortality ($P = 0.027$, odds ratio 1.01). Body mass index ≥25 kg/m^2 was associated with multiorgan dysfunction syndrome ($P = 0.016$, odds ratio 3.51). Surgical modality did not significantly affect early outcomes. The 3-year survival rate was 76.1% (95% confidence interval, 63.0–81.9%) in the FET group and 82.5% (95% confidence interval, 65.2–91.8%) in the debranching group ($P = 0.330$).

CONCLUSIONS: The hybrid aortic arch procedure without circulatory arrest can be safely performed on patients with acute Type I aortic dissection. Irrespective of cost-effectiveness, arch debranching was a promising alternative for patients who were unfit for the FET procedure.

Keywords: Aortic arch • Aortic dissection • Endovascular procedures • Propensity matching

Hybrid and frozen elephant trunk for total arch replacement in DeBakey type I dissection

… Sun, MD,[b] Juntao Qiu, MD,[b]

TABLE 4. Early outcomes for total and propensity-matched cohorts

Variable	Total cohort (n = 937) FET (n = 815)	Total cohort (n = 937) Hybrid (n = 122)	Total cohort (n = 937) *P* value	Propensity-matched cohort (n = 218) FET (n = 109)	Propensity-matched cohort (n = 218) Hybrid (n = 109)	Propensity-matched cohort (n = 218) *P* value
Early postoperative death	10.7% (87)	9% (11)	.5767	17.4% (19)	9.2% (10)	.0727
Composite rate of complications	20.2% (165)	15.6% (19)	.2257	25.7% (28)	15.6% (17)	.0657
Infection	27.9% (227)	19.7% (24)	.0571	36.7% (40)	18.3% (20)	.0024
Renal insufficiency	32.3% (263)	23% (28)	.0380	38.5% (42)	22.9% (25)	.0126
Dialysis	9.6% (78)	9.8% (12)	.9260	16.5% (18)	10.1% (11)	.1627
Hepatic insufficiency	31.4% (256)	22.1% (27)	.0373	33.9% (37)	20.2% (22)	.0222
Stroke	4.4% (36)	0% (0)	.0099	2.8% (3)	0% (0)	.2465
Paraplegia	4.4% (36)	0% (0)	.0099	6.4% (7)	0% (0)	.0141
SCI	6.9% (56)	2.5% (3)	.0704	8.3% (9)	2.8% (3)	.1348
Transient mental dysfunction	14.1% (115)	13.1% (16)	.7674	21.1% (23)	12.8% (14)	.1044
Cardiac dysfunction	2.3% (19)	3.3% (4)	.5268	4.6% (5)	3.7% (4)	1.0000
Gastrointestinal dysfunction	12.8% (104)	11.5% (14)	.6898	15.6% (17)	11% (12)	.3187
Reoperation for bleeding	3.7% (30)	5.7% (7)	.2766	2.8% (3)	4.6% (5)	.4712
Blood loss during operation (mL)	947.2 ± 773.02	872.38 ± 543.34	.3818	964.31 ± 516.55	866.79 ± 541.79	.0617
Blood product use						
Red cell (U)	6.83 ± 8.85	6.04 ± 5.44	.4658	8.93 ± 8.74	5.94 ± 5.57	.0201
FFP (mL)	873.97 ± 1024.34	677.87 ± 861.63	.0075	920.56 ± 934.53	672.48 ± 864.51	.0182
Platelet (U)	2.45 ± 2.62	1.87 ± 1.56	.0011	2.73 ± 2.52	1.9 ± 1.61	.0016
ICU stay (h)	69.59 ± 63.08	85.36 ± 63.45	.0047	79.48 ± 65.67	85.89 ± 65.18	.5663
Hospital stay (d)	16.45 ± 11.28	16.7 ± 7.55	.0141	17.7 ± 12.25	17.06 ± 7.69	.2161
Endoleaks (type Ia)	0% (0)	7.4% (9)	<.0001	0% (0)	7.3% (8)	<.0001

FET, Frozen elephant trunk; *SCI*, spinal cord ischemia; *FFP*, fresh-frozen plasma; *ICU*, intensive care unit.

Results: Early mortality and complication rates were lower in the hybrid group, but the difference was not statistically significant (9.2% vs 17.4%, *P* = .073; 15.6% vs 25.7%, *P* = .066). The rates of postoperative renal insufficiency was significantly lower in the hybrid group than in the frozen elephant trunk group (22.9% vs 38.5%, *P* = .013); liver insufficiency and paraplegia were significantly lower in the hybrid group than in the frozen elephant trunk group (20.2% vs 33.9%, *P* = .022; 0% vs 6.4%, *P* = .014). After matched, the 1-year, 3-year, and 5-year survivals were 87.6%, 86.3%, and 82.2%, respectively, in the hybrid group and 80.7%, 76.5%, and 74.6% (*P* = .071), respectively, in the frozen elephant trunk group.

Conclusions: Hybrid aortic arch repair is a viable alternative treatment for patients with DeBakey type I aortic dissection, which improves outcomes and promotes remodeling of the dissected thoracic aorta. (J Thorac Cardiovasc Surg 2019;[redacted]:1-8)

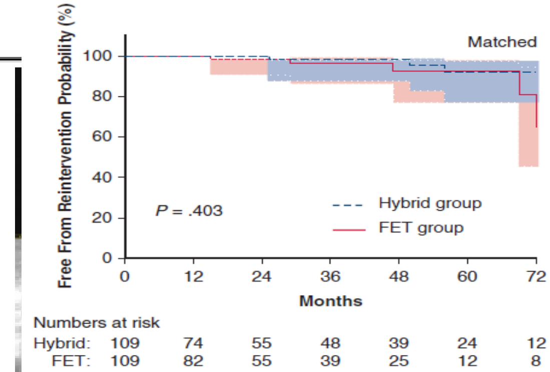


FIGURE 2. Free from reintervention rates for all patients after propensity matching. Free from reintervention rates at 1 year, 3 years, and 5 years were 100%, 98.1%, and 92.2%, respectively, in the hybrid group and 100%, 96.5%, and 92.6% (*P* = .403), respectively, in the FET group. *FET*, Frozen elephant trunk.

Central Message

Hybrid repair of DeBakey type I aortic dissection can reduce postoperative complications and increase aortic remodeling compared with conventional TAR.

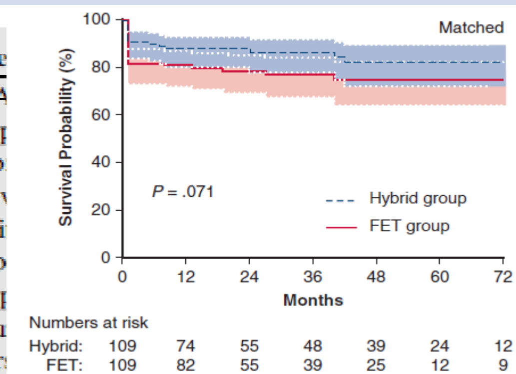


FIGURE 1. Kaplan–Meier survival curves for all patients after propensity matching. The 1-, 3-, and 5-year survivals were 87.6%, 86.3%, and 82.2%, respectively, in the hybrid group and 80.7%, 76.5%, and 74.6% (*P* = .071), respectively, in the FET group. *FET*, Frozen elephant trunk.

Table 4
Postoperative Early-Term Morbidity

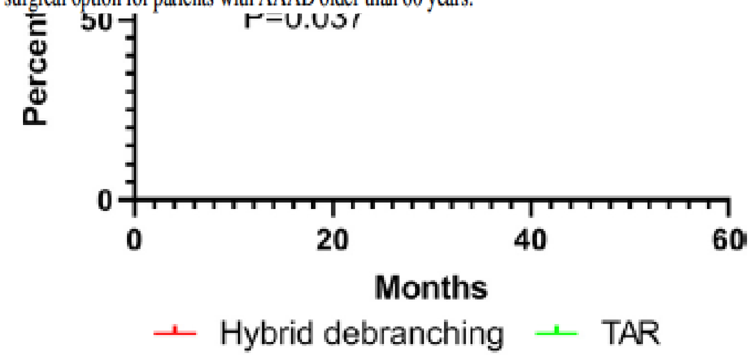
	Older-Than-60-Years Group						Younger-Than-60-Years Group					
	Total Cohort (n = 142)			Propensity-Matched Cohort (n = 88)			Total Cohort (n = 167)			Propensity-Matched Cohort (n = 60)		
Parameters	Debranching (n = 58)	TAR (n = 84)	p Value	Debranching (n = 44)	TAR (n = 44)	p Value	Debranching (n = 39)	TAR (n = 128)	p Value	Debranching (n = 30)	TAR (n = 30)	p Value
Transfusion	6 (10.3)	25 (29.8)	0.006	5 (11.4)	13 (29.5)	0.034	3 (7.7)	22 (17.2)	0.146	2 (6.7)	5 (16.7)	0.421
Renal failure (n)	3 (5.2)	20 (23.8)	0.003	2 (4.5)	10 (22.7)	0.013	1 (2.6)	13 (10.2)	0.243	1 (3.3)	3 (10.0)	0.605
Neurologic dysfunction (n)	3 (5.2)	14 (16.7)	0.038	2 (4.5)	8 (18.2)	0.044	2 (5.1)	6 (4.7)	0.752	2 (6.7)	1 (3.3)	>0.999
Lung infection (n)	2 (3.4)	18 (21.4)	0.002	1 (2.3)	8 (18.2)	0.035	1 (2.6)	11 (8.6)	0.356	1 (3.3)	3 (10.0)	0.605
Pleural effusion (n)	0 (0.0)	3 (3.6)	-	0 (0.0)	1 (2.3)	-	0 (0.0)	1 (0.8)	-	0 (0.0)	1 (3.3)	-
Wound infection (n)	0 (0.0)	4 (3.6)	-	0 (0.0)	2 (4.5)	-	0 (0.0)	0 (0.0)	-	0 (0.0)	0 (0.0)	-
Internal leakage (n)	0 (0.0)	0 (0.0)	-	0 (0.0)	0 (0.0)	-	0 (0.0)	0 (0.0)	-	0 (0.0)	0 (0.0)	-

NOTE. Values are expressed a:

Conclusion: In the treatment of AAAD, patients older than 60 years undergoing hybrid debranching surgery had shorter hospital lengths of stay, lower rates of neurologic events and renal insufficiency, and a higher mid-term survival rate compared with the TAR procedure, whereas there was no statistical difference in hybrid debranching versus TAR in patients younger than age 60. Irrespective of reintervention, hybrid debranching can be a promising surgical option for patients with AAAD older than 60 years.

hybrid de| ... rch replacement

Fig 3. Procedure details of hybrid debranc| ... l arch replacement. The aorta was opened lon- left common carotid artery, and left subclavia| ... ommon carotid artery and the left subclavian limbs of the 4-branch artificial vessels. The d| ... fusion was resumed through the perfusion limb vessel was anastomosed to the aortic arch be| ... sel, and the proximal ends of the stented graft and the left common carotid artery, and the pr| ... sed together to a 4-branched artificial vessel. was anastomosed to the junction of the aortic| ... y and brachiocephalic trunk were anastomosed grafts were released through the femoral arte| ... vessel individually. chiocephalic trunk.



postoperative survival rate

Fig 5. Kaplan-Meier plots of overall survival by group TAR versus hybrid debranching in patients older than 60 years. The 2-year survival rate of the patients older than 60 years in the debranching group was higher than that of patients in the TAR group ($p < 0.05$). TAR, total arch replacement.

Measurements and Main Resu| ... outcomes between the 2 inter- ventions. In the hybrid versu| ... .6 ± 5.0 ($p < 0.001$) for those ≥60 years and 18.6 ± 1.8 *v* | ... % *v* 16.7% ($p = 0.038$) of those ≥60 years and in 5.1% *v* 4.7| ... of those ≥60 years and 2.6% *v* 10.2% ($p = 0.243$) of those <6| ... 0% *v* 100% ($p > 0.999$) of those <60 years; and a reinterventi| ... se <60 years.

Conclusion: In the treatment| ... shorter hospital lengths of stay, lower rates of neurologic eve| ... TAR procedure, whereas there was no statistical difference i| ... eintervention, hybrid debranch- ing can be a promising surgic

Key Words: type A acute aortic d

Interactive CardioVascular and Thoracic Surgery 26 (2018) 183–189
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ORIGINAL ARTICLE

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Acute Type I aortic dissection: a propensity-matched comparison of elephant trunk and arch debranching repairs

Mingjia Ma, Xin Feng, Jing Wang, Yiming Dong, Taiqiang Chen, Ligang Liu and Xiang Wei*

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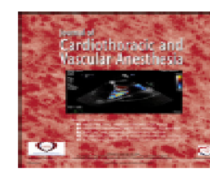

Original Article

Acute Aortic Dissection Surgery: Hybrid Debranching Versus Total Arch Replacement

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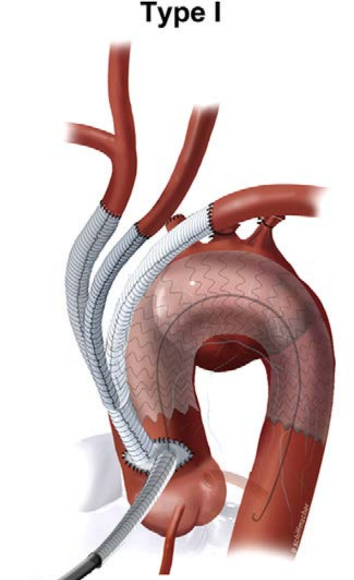
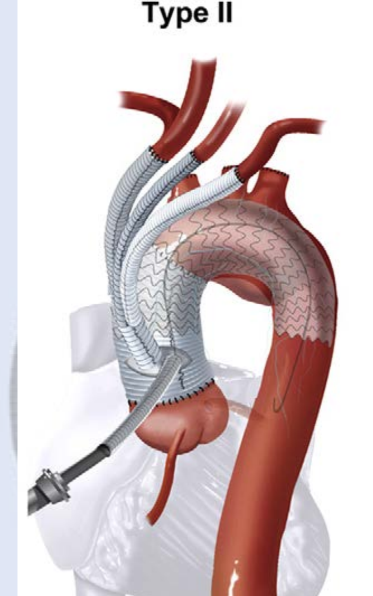
Department of Cardiovascular Surgery, Renmin Hospital of Wuhan University, Wuhan, Hubei, China





- Υψηλού κινδύνου/ ηλικιωμένοι ασθενείς
- Ακατάλληλοι για ανοιχτή επέμβαση
- Μήκος landing zones > 25 mm & διάμετρος αορτής < 38 mm
- Αποφυγή ασθενών με νόσο συνδετικού ιστού, αορτική βαλβιδοπάθεια, υψηλό κίνδυνο εγκεφαλικού επεισοδίου
- Αποδεκτά βραχυπρόθεσμα και μακροπρόθεσμα αποτελέσματα

- Εκτεταμένη αορτική παθολογία (ανεύρυσμα ή διαχωρισμός)
- Επέμβαση ενός σταδίου
- Διευκολύνει πιθανή επακόλουθη ενδαγγειακή θεραπεία
- Προάγει θρόμβωση ψευδούς αυλού
- Κίνδυνος SCI/ παραπληγίας
- Αποδεκτά βραχυ-, μακροπρόθεσμα αποτελέσματα

Swans Reflecting Elephants (1937) - Salvador Dali