Total Endovascular Arch replacement for a Non-A, Non-B Aortic Dissection

Konstantinos Tzimkas-Dakis[1], Konstantinos Spanos[1], George Kouvelos[1], George Volakakis[1], Metaxia Bareka[2], Grigorios Giamouzis[3], Eleni Arnaoutoglou[2], Miltiadis Matsagkas[1]

[1] Department of Vascular Surgery, Faculty of Medicine, School of Health Sciences, University of Thessaly, Larissa, Greece
[2] Department of Anesthesiology, Faculty of Medicine, School of Health Sciences, University of Thessaly, Larissa, Greece
[3] Department of Cardiology, Faculty of Medicine, School of Health Sciences, University of Thessaly, Larissa, Greece

Abstract:

Introduction: Branched Thoracic Endovascular Repair of the Aortic Arch (bTEVAR) is a feasible alternative to conventional open surgical repair or endovascular debranching techniques in unfit for open repair patients, allowing for complete endovascular repair of thoracic aortic pathologies involving the aortic arch, such as Non-A, Non-B dissections.[1]

Case Report/Technique: We present the case of a 64-year-old male patient who was transferred to our department with an acute Non-A, Non-B aortic dissection, extending from the innominate artery to the aortic bifurcation. Following initial conservative management, the patient presented aortic diameter enlargement and was treated with a custom-made arch-branch device [Bolton Medical, Inc. (Terumo Aortic, US)], incorporating three directional branches for the innominate, left carotid and left subclavian artery, respectively. Postoperative 6-month follow-up shows nice graft deployment resulting in partial false lumen thrombosis with complete branch patency and no signs of type Ia endoleak or bird-peak formation.

Conclusion: Branched TEVAR appears to be feasible and safe as a treatment alternative for aortic pathologies involving the aortic arch, such as Non-A, Non-B dissections, while long-term postoperative surveillance is warranted.

INTRODUCTION

TEVAR has fundamentally changed the management of thoracic aortic syndromes, allowing for treatment of high-risk patients, unfit for traditional surgical repair.[2] Aortic lesions including descending thoracic aortic aneurysms, chronic Type B (Standford Classification) dissections, intramural hematomas and penetrating aortic ulcers can be successfully treated with endovascular solutions, largely decreasing the high mortality and complication rates of open surgical repair, in both intact and emergent lesions.[3,4]

Aortic pathologies involving the aortic arch require a more complex management, as standard TEVAR fails to provide a suffice proximal landing zone. Non-A, non-B aortic dissections, either limited to the aortic arch or evolving as a retrograde dissection with an entry point at the descending thoracic aorta institute complex lesions, unable to be treated with conventional TEVAR. Moreover, conventional open surgical repair as well as hybrid techniques including endovascular repair in addition to debranching of the aortic arch have been associated with increased morbidity and mortality, excluding high-risk patients.[5,6] Fenestrated and branched (fTEVAR, bTEVAR) have been extensively used in the last decade as alternatives, allowing for proximal landing zone on the ascending aorta (Zone 0), while incorporating fenestrations or directional branches for implementation of the innominate, left carotid and left subclavian artery.[7]

Author for correspondence:

Tzimkas-Dakis Konstantinos

Vascular Surgery Trainee, University of Thessaly, Mezourlo, 41110, Larissa, Greece
Tel: +302413501739
E-mail: kostasdakis1994@gmail.com
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CASE REPORT/TECHNIQUE

We present the case of a 64-year-old male patient, with no prior medical history or under any medication, who was transferred to our hospital following an acute non-A, non-B dissection. The patient presented with acute chest pain, radiating to his back, and uncontrolled systolic arterial pressure (~190mmHg). Initial management at a district hospital included aggressive arterial pressure and pulse management at a High Dependency Unit. The patient underwent a complete diagnostic work-up, including a Computed Tomography Angiography (CTA) of the aorta, detecting a non-A, non-B aortic dissection, alongside a descending thoracic aortic aneurysm (maximum diameter ~5.4cm). The dissection extended from proximally to Zone 1 and distally to Zone 10, with the initial entry point detected distally to the left subclavian artery (B_{1-10}), based on the reporting standards for type B aortic dissections.[8] Following vital signs and clinical status stabilization, the patient was transferred to our department for further diagnostic and therapeutic management. During initial assessment, the patient was hemodynamically stable, with palpable upper and lower limb radial, brachial, femoral, popliteal, posterior tibial, and dorsalis pedis arteries. Follow-up CTA revealed no further retrograde or antegrade dissection. **(Figure 1)**

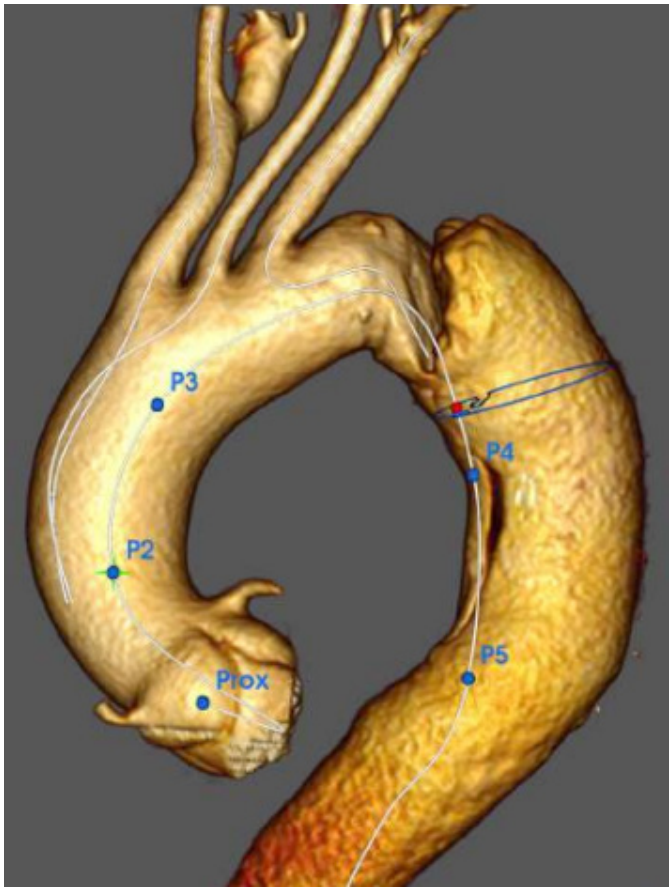

Figure 1. Preoperative aortic non-A, non-B dissection (3D Reconstruction)

Periaortic hematoma extended to the level of the innominate artery. **(**Figure 2**)** Reno-visceral arteries (celiac trunk, superior mesenteric artery, left renal artery) arose from the true aortic lumen besides the right renal artery which arose from the false lumen, with complete patency of all renovisceral vessels and no signs of dissection extension. Cardiothoracic evaluation was negative for open surgical repair. After thorough CTA examination and patient briefing, a total endovascular repair via branched TEVAR was decided, utilizing a custom-made device (CMD) [Bolton Medical, (Terumo Aortic, US]. The patient was discharged with antihypertensive and beta-blockers medication until further notice following device manufacturing.

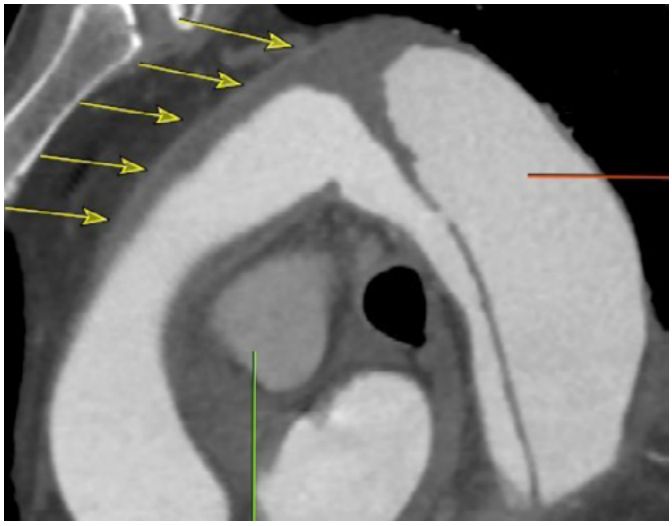

Figure 2. Hematoma extension to Zone 0.

Footnote: Yellow arrows depicting hematoma.

Branched Endograft Characteristics

A branched thoracic CMD endograft was designed and manufactured, including 3 branches, two for the incorporation of the innominate and left carotid (LCCA) and one retrograde branch for the left subclavian (LSA) artery. Proximal and distal endografts diameters were 46mm and 28mm, aiming for an approximately 25% proximal and 20% distal overlap at Zone 0 and 4, respectively. Total graft length was 270mm, while the implemented, inner directional branches were 12mm for the innominate and 10mm wide for the LCCA and LSA, respectively. All branches were 40mm in length, while the innominate and LCCA branches, cranially oriented, originated 60mm from the proximal end of the CMD and the LSA branch, caudally oriented, originating 125mm from the proximal end of the CMD. **(**Figure 3**)**

Additionally, a custom-made straight-tube endograft for bridging of the innominate artery was manufactured, with a 13-11mm, and 103mm proximal, distal diameter and length, respectively. Total manufacturing time from CMD design to delivery was 2 months. Bridging of the LCCA and the LSA was scheduled to be implemented through self-expanding and balloon-expandable covered stentgrafts (Viabahn and VBX, Gore & Associates, Newark, 555 Paper Mill Road, USA).

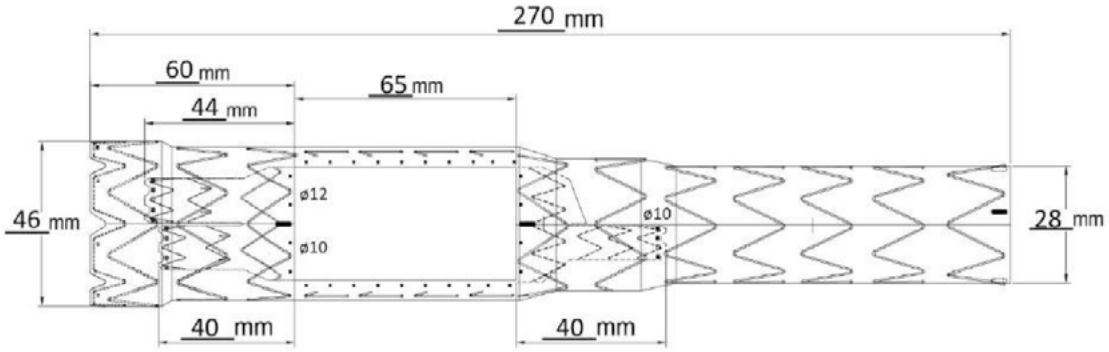

Figure 3. Custom-Made Arch Branch Device [Bolton Medical, (Terumo Aortic, US]

Intraoperative Details/Procedure

Following general anesthesia induction, surgical cutdown of the common carotid arteries and the right common femoral artery was undertaken. Percutaneous vascular access of the right brachial artery was achieved for diagnostic angiography and the left common femoral vein for cardiac rapid ventricular pacing during device deployment, respectively. Following vascular access completion, per protocol 5000 IU of unfractionated heparin were administered for an ACT of >250 seconds, with 30-minute time interval ACT measurements and additional heparin infusions, when necessary. Prior to CMD introduction, carbon dioxide flushing of the device was thoroughly undertaken, for air embolization protection.[9] A diagnostic angiography catheter was introduced via the right brachial artery, to the ascending aorta, later retracted during endograft deployment. The device was introduced, oriented, and deployed under rapid ventricular cardiac pacing of ~180 beats per minute (bpm) for approximately 30 seconds, eliminating aortic pulse pressure, for precise stentgraft deployment. Following successful device deployment, catheterization of the LCCA branch was initially achieved, and a VBX 11*59mm balloon-expandable covered stentgraft with a Viabahn 8*50mm self-expanding covered stentgraft were implanted, with a complete sealing of the branch. The innominate artery branch was later catheterized through the right CCA, introduction and deployment of the custom-made straight-tube 13-11*103mm endograft was successfully undertaken. Finally, through the right common femoral artery, the LSA branch and consequently the LSA were catheterized, a 11*100mm Viabahn self-expanding covered stentgraft was deployed successfully. Final angiogram confirmed precise CMD deployment from the coronary arteries, and complete branch patency, with no signs of endoleak. **(Figure 4)**

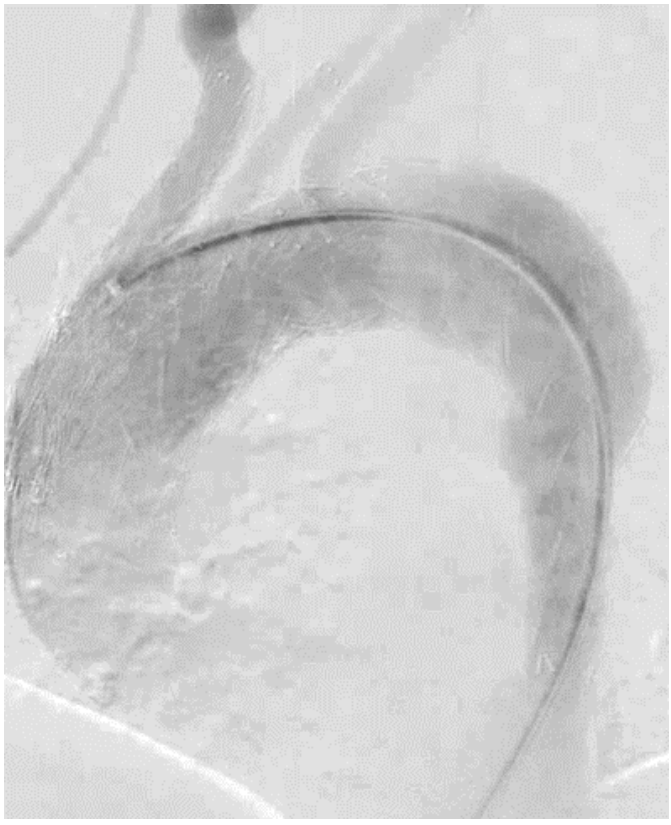

Figure 4. Intraoperative confirmation angiography

Following standard arterial suture closing, the patient was extubated with no signs of cerebral events and was transferred to the Vascular Surgery Ward under close monitoring. Total radiation time exposure and contrast media administration was 8.570 cGy/cm^2 and 120mls, respectively. No blood or blood products were transfused.

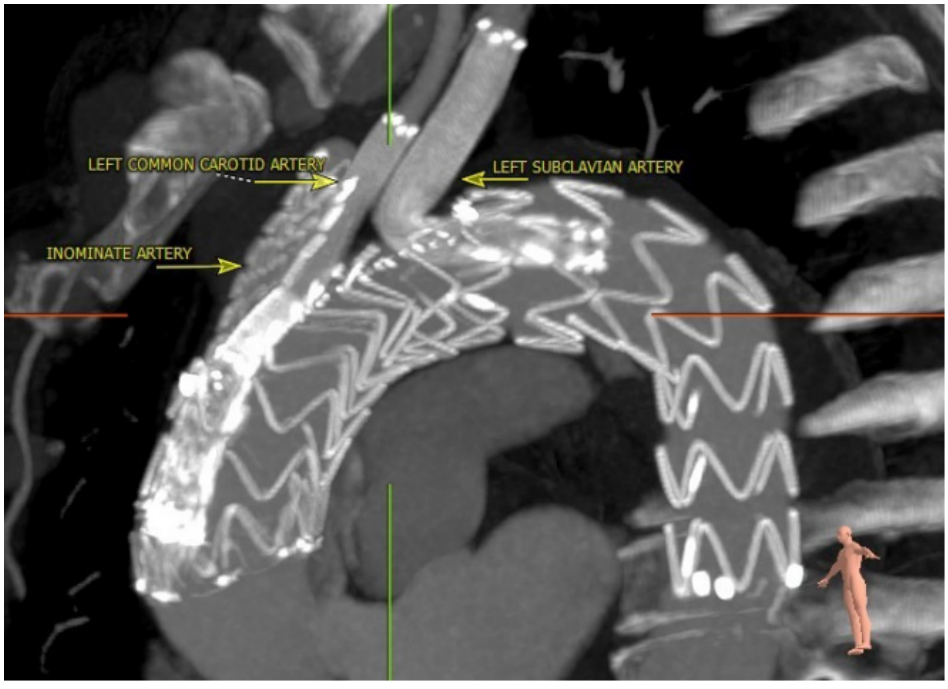

Figure 5. Postoperative 6-month arch-branch device configuration.

The patient received single antiplatelet therapy (Acetylsalicylic Acid, 100mg, OD) upon ward transfer, and dual antiplatelet therapy (Clopidogrel, 75mg OD) was administered on the 1st postoperative day. , and , The patient underwent a complete CTA scan the 2nd post-operative day, showing successful device implementation, total branch patency and no signs of endoleak or bird-peak formation. Postoperative recovery was uneventful and the patient was discharged on the 4th post-operative day. During follow-up, the patient has been well, with adequate blood-pressure and cardiac rhythm medication control. The 6-month postoperative CTA scan showed patency of all supra-aortic vessels and their branches resulting in partial false lumen thrombosis, due to distal entry points, with gradual aortic remodeling, with a maximum diameter of 5.2cm **(Figure 5)**

DISCUSSION

Non-A, non-B dissections are high-risk manifestations of TAD, often not amendable to standard TEVAR, nonetheless associated with intramural hematomas and retrograde dissections.[10] Excluding cases requiring urgent open thoracic aortic repair through open conventional surgical total arch reconstruction or hybrid solutions involving arch debranching, complex endovascular repair of such lesions has proven to be feasible, with acceptable outcomes, including all-cause and aorta-related mortality, as well as complication and reintervention rates.[7]

Open surgical repair of thoracic aortic dissections involving the arch requires, total arch reconstruction with open sternotomy, cardiopulmonary bypass, and hypothermic circulatory arrest in most cases, and it is still recommended by guidelines as the gold standard. Such interventions have been traditionally associated to high morbidity and complication rates and prolonged ICU stay, rendering them restrictive for high-risk patients.[3] Multidisciplinary evaluation is mandatory in all TAD cases, with complete patient vital sign, laboratory values and aorta CTA assessment, as open surgical repair could be the only available solution.

Branched and fenestrated thoracic aortic repair of TAD involving the arch and its branches requires diligent planning and sizing, and specific pre-, intra- and postoperative protocols for successful implementation in high-risk patients unfit for traditional repair.[11] Main entry point coverage with total endovascular incorporation of supra-aortic target vessels are essential parts for first management. Moreover, these technical characteristics are crucial for future aortic remodeling. In clinically stable patients or in chronic aortic dissection, with uncomplicated TAD, custom-made devices allow for design of “tailor-made” endografts, with no compromise regarding technical and clinical success. Fenestrated arch devices have been studied, albeit data is still scarce regarding branched devices.[12] Emergent endovascular approaches, including the hybrid procedures, chimney technique or in situ fenestrations, although extremely valuable, present high risk of gutter endoleaks, cerebral events and scarce long-term outcomes.[13,14]

Careful preoperative CTA scan evaluation is of outmost importance prior to CMD design and production. Branched-TEVAR for arch lesions requires most of the time proximal seal at Zone 0. Misaligned deployment of an arch branch device could lead to catastrophic events, from coverage of the ostiums of coronary arteries, to misalignment of branches or fenestrations in regard to the ostiums of the supra-aortic vessels.[11] An important factor for successful deployment is the diameter of the ascending aorta. While data is limited, an oversize of approximately 20% on the proximal landing zone, in addition to most arch branch devices manufactured with a proximal stentgraft diameter of 45-50mm, restricts the use of arch branch devices in patients with ascending aorta diameter less than 40mm. Also, minimal tapering of the proximal landing zone is important in satisfactory proximal sealing of the endograft. Another important factor is aortic angulation at the sealing zone, with aortic angulations over 60° associated with higher risk of type Ia endoleaks.[11,15]

Cerebral event protection has been and remains crucial during endovascular arch repair, especially when proximal seal occurs in Zone 0. Endovascular solutions involving the chimney technique, as well as hybrid arch reconstruction (applying the frozen elephant trunk technique) have been associated with risk of stroke over 10 and 16%, respectfully.[16,17] Reports on total endovascular aortic arch repair suggest considerable stroke rates as high as 14%, further highlighting the need for vigilant measures of cerebral protection.[18] Careful CMD flushing using carbon dioxide prior to introduction and deployment, rapid ventricular pacing, as well as meticulous sheath and wire flushing and exchange contribute towards successful subsequent CMD deployment and limitation of cerebral events.[9,19] Data on short-term outcomes of branched total endovascular arch repair are associated with high technical success rates over 95% and no mortality during the initial 30-day postoperative period.[7]

CONCLUSION

Branched stentgraft device is a feasible procedure for totally endovascular repair of aortic lesions involving the arch. Longer follow up is needed to prove its durability and efficacy.

REFERENCES

1 Zhang L, Qingsheng L, Zhu H, Jing Z. Branch stent-grafting for endovascular repair of chronic aortic arch dissection. *J Thorac Cardiovasc Surg.* 2021;162(1):12-22.e1. DOI: 10.1016/j.jtcvs.2019.10.184.

2 Kamman AV, de Beaufort HWL, van Bogerijen GHW, Nauta FJH, Heijmen RH, Moll FL, et al. Contemporary Management Strategies for Chronic Type B Aortic Dissections: A Systematic Review. *PLoS One.* 2016, 4;11(5). DOI: 10.1371/journal.pone.0154930

3 Cheng D, Martin J, Shennib H, Dunning J, Muneretto C, Schueler S, et al. Endovascular aortic repair versus open surgical repair for descending thoracic aortic disease a systematic review and meta-analysis of comparative studies. *J Am Coll Cardiol.* 2010, 9;55(10):986-1001. DOI: 10.1016/j.jacc.2009.11.047.

4 Jonker FHW, Verhagen HJM, Lin PH, Heijmen RH, Tri-

marchi S, Lee WA, et al. Open surgery versus endovascular repair of ruptured thoracic aortic aneurysm. *J Vasc Surg.* 2011;53(5):1210-6. DOI: 10.1016/j.jvs.2010.10.135.

5 Konstantinou N, Debus ES, Vermeulen CFW, Wipper S, Diener H, Larena-Avellandea A, et al. Cervical Debranching in the Endovascular Era: A Single Center Experience. *Eur J Vasc Endovasc Surg*. 2019;58(1):34-40. DOI: 10.1016/j.ejvs.2018.12.010.

6 Matsagkas M, Kyrou I, Kouvelos G, Arnaoutoglou, Papakostas JC, Katsouras CS, et al. Follow-up papers - aortic and aneurismal stenting of the descending thoracic aorta: A six-year single-center experience. *Interact Cardiovasc Thorac Surg.* 2011;12(5): 789-93. DOI: 10.1510/icvts.2010.262584.

7 Tsilimparis N, Debus ES, von Kodolitsch Y, Wipper S, Rohlffs F, Detter C, et al. Branched versus fenestrated endografts for endovascular repair of aortic arch lesions. *J Vasc Surg.* 2016;64(3):592-9. DOI: 10.1016/j.jvs.2016.03.410.

8 Lombardi JV, Hughes GC, Appoo JJ, Bavaria JE, Beck AW, Cambria RP, et al. Society for Vascular Surgery (SVS) and Society of Thoracic Surgeons (STS) reporting standards for type B aortic dissections. *J Vasc Surg*. 2020;71(3):723-747. DOI: 10.1016/j.jvs.2019.11.013.

9 Kölbel T, Rohlffs F, Wipper S, Carpenter SW, Debud ES, Tsilimparis N. Carbon Dioxide Flushing Technique to Prevent Cerebral Arterial Embolism and Stroke During TEVAR. *J Endovasc Ther.* 2016;23(2):393-5. DOI: 10.1177/1526602816633705.

10 Howard C, Ponnapalli A, Shaikh S, Idhress M, Bashir M. Non-A non-B aortic dissection: A literature review. *J Card Surg.* 2021;36(5):1806-1813. DOI: 10.1111/jocs.15349.

11 Spanos K, Panuccio G, Rohlfss F, Heidemann F, Tsilimparis N, Kölbel T. Technical Aspects of Branched Thoracic Arch Graft Implantation of Aortic Arch Pathologies. *J Endovasc Ther.* 2020;27(5):792-800. DOI: 10.1177/1526602820925443

12 Melo RGE, Prendes CE, Khanafer A, Wanhainen A, Mani K, Rouhani G, et al. Common designs of Custom-Made Fenestrated Arch Devices and Applicability of an Off-the-Shelf Design. *J Endovasc Ther.* 2023;9. DOI: 10.1177/15266028231179593.

13 Zhao Y, Fenk J, Yan X, Zhu G, Zhou J, Li Z, et al. Outcomes of the Chimney Technique for Endovascular Repair of Aortic Dissection Involving the Arch Branches. *Ann Vasc Surg.* 2019;58(238-247). DOI: 10.1016/j.avsg.2018.10.041.

14 Glorion M, Coscas R, McWilliams RG, Javerliat I, Brissonnieer OG, Coggia M. A comprehensive Review of In Situ Fenestration of Aortic Endografts. *Eur J Vasc Endovasc Surg. 2016;52(6):787-800.* DOI: 10.1016/j.ejvs.2016.10.001

15 Rudarakanchana N, Jenkins MP. HP. Hbrid and total endovascular repair of the aortic arch. *Br J Surg.* 2018;105(4):315-327. DOI: 10.1002/bjs.10713.

16 Berger T, Kreibich M, Mueller F, Breurer-Kellner L, Rylski B, Kondov H, et al. Risk factos for stroke after total aortic arch replacement using the frozen elephant trunk technique. *Interact Cardiovasc Thorac Surg.* 2022;34(5):865-871. DOI: 10.1093/icvts/ivac013.

17 Mangialardi N, Serrao E, Kasemi H, Alberti V, Fazzini S, Ronchey S. Chimney technique for aortic arch pathologies: an 11-year single-center experience. *J Endovasc Ther.* 2014;21(2)312-23. DOI: 10.1583/13-4526MR.1

18 Bash AM, Moore RD, Rommens KL, Herget EJ, McClure RS. A Systematic Review of Total Endovascular Aortic Arch Repair: A Promising Technology. *Can J Cardiol.* 2023;39(1):39-56.

19 Joseph G, Thomson VS, Kota A. Rapid Ventricular Pacing During Endograft Deployment in the Arch and Ascending Aorta: A Simple, Reliable, and Sage Technique Using a Stabilizing Buddy Wire System. *Eur J Vasc Endovasc Surg.* 2021;2(61):338-339. DOI: 10.1016/j.ejvs.2020.10.019