

Article

Key Factor to Prevent Aortic Root and Descending Thoracic Aorta Enlargement after Aortic Valve and Ascending Aorta Combined Surgery

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Abstract: Objective: aortic root enlargement (ARE) and descending thoracic aorta dilatation (DTAD) in combined aortic valve and ascending aorta replacement surgery (AV+AAR) are postoperative concerning issues. This retrospective observational analysis studies surgical factors which could determine those complications. **Methods:** 236 patients underwent AV+AAR. Mean-time follow-up by trans-thoracic echocardiography (TTE) and computer tomography (CT) was 44.7 ± 21.2 and 38.2 ± 18.4 months respectively. In long-term follow-up, outcome variables are: ARE equal/more than 10% of the preoperative TTE data and DTAD equal more than 5% of preoperative CT measurement at the same thoracic vertebrae axial slice. **Results:** ARE and DTAD appear strictly related to the discrepancy between prosthetic valve and straight vascular prosthesis diameters ($p = 0.024$), while there is not significant difference ($\log\text{-rank} = 0.917$) related to aortic valve surgery type (replacement or repair). Considering diameter difference (DD) between vascular and aortic valve prosthesis, patients were subsequently grouped into two sections: L5 group, in which DD was less/equal than 5 mm, and M5, in which DD was more/equal than 5 mm. ARE was found in 30.8 % of L5 patients and only in 14.7 % among M5 patients ($\log\text{-rank} = 0.026$). We have also observed descending thoracic aorta dilatation in 34.2 % of L5 and in 12.1 % of M5 ($\log\text{-rank} = 0.023$). **Conclusions:** According with our data, difference between vascular prosthesis and aortic valve prosthesis equal/more than 5 mm is a protective factor against ARE and DATD.

Keywords: Aortic Root Dilatation; Aortic Aneurysm; Descending Thoracic Aneurysm; Shear Stress; Vascular Prosthesis

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1. Introduction

Post operative aortic root enlargement (ARE) and descending thoracic aorta dilatation (DTAD) in concomitant aortic valve and ascending aorta replacement surgery (AV+AAR) are both main concern in the long-term follow-up. When the sino-tubular junction (STJ) can be preserved, ascending aorta is replaced using vascular prosthesis, and native aortic valve undergoes to repair or replacement as appropriate [1, 2]. Although AV+AAR treats ascending aortic aneurysm and aortic valve disease with a concomitant benefit on cardiac function, a following ARE and DTAD are both important concern in long-term follow-up (FU) because they can lead to rupture or dissection [3, 4]. The present analysis aimed to identify possible predictors of post-operative ARE and DTAD overtime.

2. Methods

From May 2016 to May 2023, 236 patients, 164 males and 72 females, underwent AV+AA. A general informed consent for personal data collection, treatment, post processing analysis, and publishing was collected and signed by each patient, whose demographics are summarized in Table 1. To analyse ARE and DTAD trans-thoracic echocardiography and computer tomography have been respectively used as per guidelines protocol [5]. The mean trans-thoracic echocardiographic (TTE) follow-up was 44.7 ± 21.2 months, while mean computer tomography scan (CT) follow up was 38.2 ± 18.4 months. For the long term follow up, the considered outcome variables were: an aortic root diameter equal/more than 10% of the preoperative TTE data and a descending thoracic aorta diameter equal more than 5% of the preoperative CT measurement which was performed at the same thoracic vertebrae axial slice. Student-t or chi-square test was used depending on the case. Kaplan-Meier curve and log-rank p-value were calculated to perform the survival analysis, while Cox's regression model was used to check predictive value of variables overtime. A p-value < 0.05 was significant. Aortic valve surgery technique was replacement for 202 patients and repair for the other 34 patients. A biological prosthetic model was implanted in 172 patients (85%). Concomitant one or more coronary artery bypass graft was performed in 12 patients. No minimally invasive access was used in this series. In Table 2 are presented the main intraoperative surgical data.

Table 1. Patients' demography

	N (%)		Mean \pm SD
Female	72 (30)	Mean echocardiography follow up (months)	44.7 ± 21.2
Male	164 (70)	Mean computer tomography follow up (months)	38.2 ± 18.4
Hypertension	178 (75)	Age (year)	69.8 ± 8.2
Dyslipidemia	148 (63)	EuroScore II	3.2 ± 0.7
Diabetes	124 (52)	Ejection Fraction (%)	56.1 ± 4.9
COPD	120 (51)	Descending thoracic aorta diameter (mm)	28 ± 4.2
Psychiatric disorders	58 (25)	Aortic root diameter (mm)	40.4 ± 5.2
Aortic stenosis	98 (41)	Sino-tubular junction (STJ) diameter (mm)	32.9 ± 5.3

Table 2. Intra-operative data

Aortic vascular prosthesis size (mm)	n	Aortic valve prosthesis size (mm)	n
22	1	19	4
24	4	21	37
26	6	23	64
28	96	25	79
30	92	27	16
32	20	29	2
34	17	----	----
CPB time (min)	78.1 ± 10.8	Biological Aortic valve prosthesis (n)	172
X clamp time (min)	58.4 ± 8.4	Mechanical Aortic valve prosthesis (n)	30
Other surgical procedures (n)	12	Aortic valve repair (n)	34

3. Results

In our series, there is a not significant difference related to the aortic valve surgical technique (replacement compared to aortic valve repair had log-rank = 0.917), in fact ARE has been detected in 12 patients (35.3%), who received aortic valve repair and in 48 patients (23.8 %,) who have had the replacement, as it is represented in Figure 1 and resumed in Table 3. This difference was found not significant through the Cox's regression analysis. In our series, the DTAD, with a rate more than 5% from the baseline CT measurement, occurred in the 25% of patients, as it is reported in Table 4. Among patients who received valve replacement, ARE and DTAD were both related to DD between valve and vascular prosthesis. Considering the diameter difference (DD) between straight vascular prosthesis and aortic valve prosthesis, patients were subsequently grouped into two sections: Less 5 mm (L5), in which DD was ≤ 5 mm, and More 5 mm (M5), in which DD > 5 mm. ARE was found in 32.8 % of L5 patients and only in 14.2 % among M5 patients (log-rank = 0.026) as it is shown in Figure 2. We have also observed descending thoracic aorta dilatation in 34.2 % of L5 and in 12.1 % of M5 (log-rank = 0.023). The predictive validity of this observation was estimated using Cox's regression model. Analysis demonstrated that DD was ≤ 5 mm between valve and vascular prosthesis is strictly related to higher risk of post-operative ARE and DTAD overtime (p = 0.033), and same significance appears if data are adjusted for sex and age (p = 0.042). Schoenfeld residuals test was used to estimate the assumption of proportional hazards. It showed Chi-square 1.93 (3-freedom-degree) with p < 0.05. The statistics was confirmed through graphic test, as reported in Figure 3 and Figure 4. The overlapped predicted and observed survival functions are presented in Figure 5.

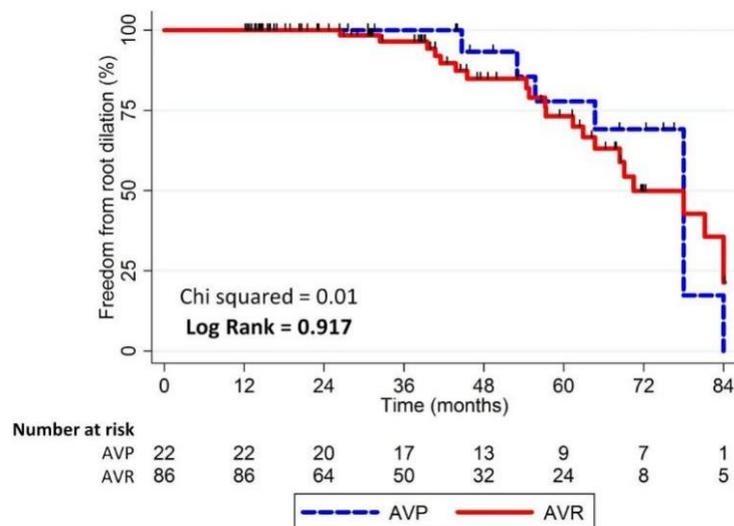


Figure 1. Kaplan Meier curves show no significant aortic root enlargement in aortic valve repair vs. replacement.

Table 3. Postoperative diameters of aortic root and sino-tubular junction compared with pre-operative value.

	Mean ± SD
AR post (mm)	46.4 ± 5.8
STJ post (mm)	40.2 ± 5.3
AR variation (mm)	9.8 ± 11.6
STJ variation (mm)	3.2 ± 4.9
AR variation > 10% (n)	48

AR, aortic root; STJ, sino-tubular junction.

Table 4. Postoperative diameters of descending thoracic aorta compared with preoperative value.

	Mean ± SD
DTA post (mm)	34.4 ± 2.2
DTA variation (mm)	10.1 ± 0.9
DTA variation > 5% (n)	59

DTA descending thoracic aorta.

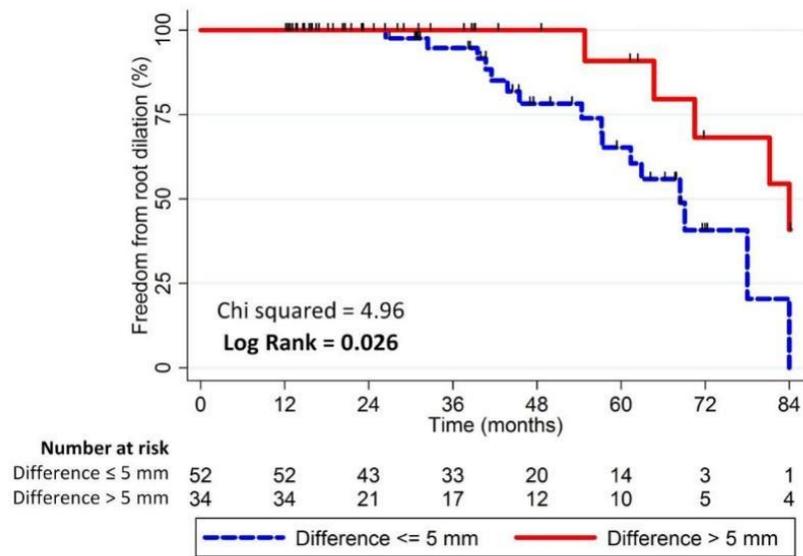


Figure 2. Kaplan Meier curves show significant aortic root dilatation in L5 group compared to M5 group (log-rank = 0.026).

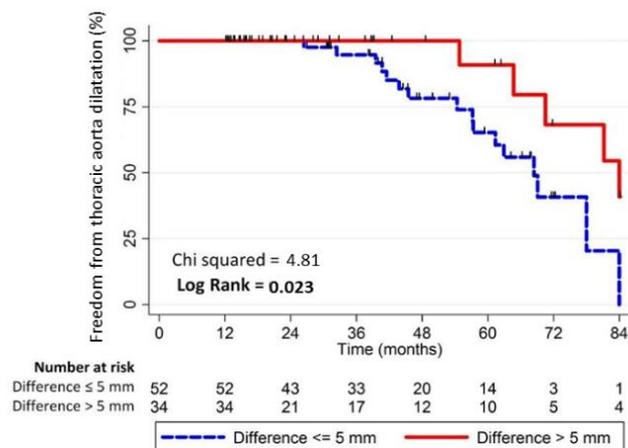


Figure 3. Kaplan Meier curves show significant descending thoracic aorta dilatation in L5 group compared to M5 group (log-rank = 0.023).

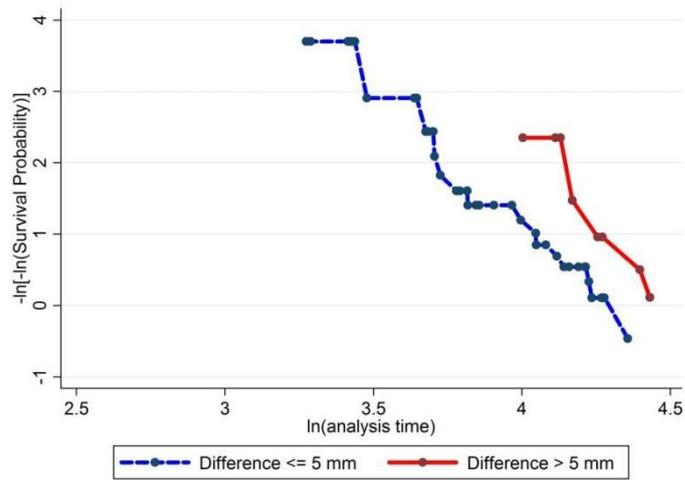


Figure 4. Log-log plot evaluation.

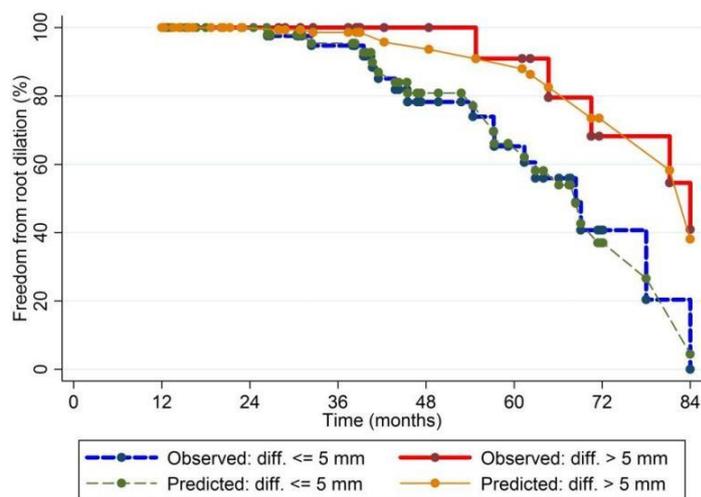


Figure 5. Kaplan Meier vs. survival probability plot.

4. Discussion

Dacron® vascular graft, used to replace the aortic wall in AAR do not have biomechanical properties of the native vascular tissue [6-10]. Compliance (increase in volume for an increased in pressure) of a vascular prosthesis is 4-time lower than the aorta, and this mismatch between graft and aorta causes flow turbulence with serious clinical issues overtime. Reduction of elastic properties induces retrograde effects, which reverberate on the aortic root, while the antegrade repercussions affect the descending thoracic aorta. In fact, the compliance mismatch produces significant modifications in the biomechanical properties of aortic root [11-14], as well as in the descending aorta. It is well documented, that vascular graft in replacement of the ascending aorta aneurysm increases the circumferential strain of the descending aorta, particularly in patients with cystic medial necrosis and other collagen disorders. Grafts augment energy transfer to the distal aorta, which is potential mechanism for progressive distal aortic dilation and/or dissection overtime [3, 4]. This retrospective observational study shows that $DD > 5$ mm between valve and vascular prosthesis, due to minor jump in caliber between vascular graft and the AR, lowers the risk of ARE in the long-term follow up. For the same geometrical reason

of reduced-turbulence in reduced-caliber jump, the DTAD rate is contemporary lowered overtime. Conversely, if the DD between prosthetic valve and vascular graft is less than 5 mm, as it is shown in L5 group, the Valsalva sinuses have more shear-stress due to the barrier-effect as it is schematized in Figure 6. Based on our data, difference between straight vascular prosthesis and aortic valve prosthesis equal/more than 5 mm is a protective factor against ARE and DATD, while a discrepancy less than 5 mm in our series is the only cause of ARE and DTAD over time. The best choice appears to choose a size of aortic valve prosthesis as larger as possible, also resorting to techniques of aortic annulus enlargement (for example Nicks or modified Manouguian) in case of a small aortic annulus, and or using sutureless aortic prosthesis, for their less bulky characteristics [15].

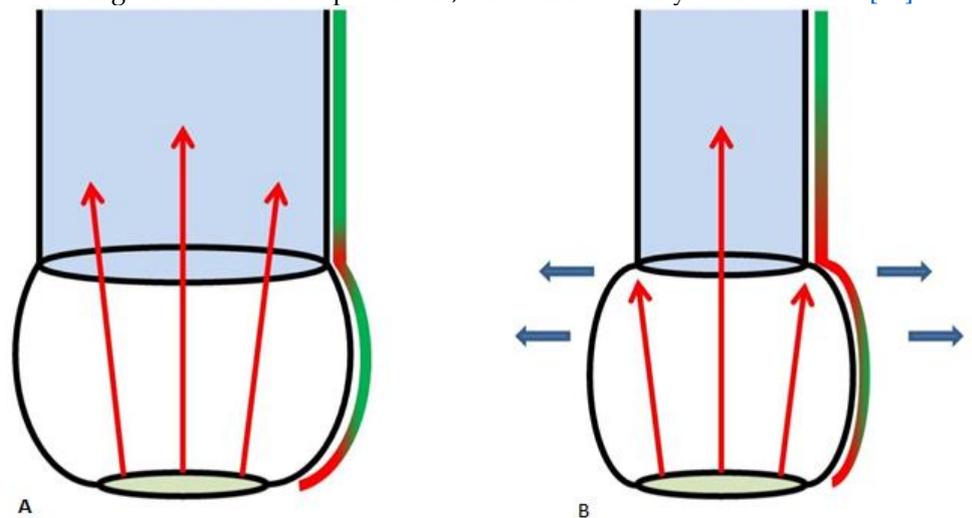


Figure 6. Schematic representation of AV+AAR in the L5 group (A) and M5 group (B). Red arrows indicate blood flow direction. Green indicates less shear stress and turbulence. Red highlights greater shear stress and turbulence in the region where a jump of caliber is present.

5. Conclusion

Based on our findings, in our series, $DD > 5$ mm between vascular prosthesis and aortic valve prosthesis is itself as protective factor against ARE and DATD, while $DD \leq 5$ mm between valve and vascular devices is the only variable which is significant related to ARE and DTAD overtime. Further researches with wide sample and prospective collected data are mandatory to provide more detailed information regarding post operative ARE and DTAD after ascending aortic replacement surgery.

Compliance with Ethical Standards: this study compliances with Ethical Standards; a general informed consent for personal data collection, treatment, post processing analysis, and publishing purposes was collected and signed by each patient as per institutional internal ethical committee.

Conflict of Interest: no conflict of interest to be declared by Authors.

References

- [1] Ellauzi H, Zafar MA, Wu J, Papanikolaou D, Buntin J, Ziganshin BA et al. Fate of Preserved Aortic Root Following Acute Type A Aortic Dissection Repair. *Semin Thorac Cardiovasc Surg.* 2022;34(2):419-427.
- [2] Lenz A, Warncke M, Wright F, Weinrich JM, Schoennagel BP, Henes FO et al. Longitudinal follow-up by MR angiography reveals progressive dilatation of the distal aorta after aortic root replacement in Marfan syndrome. *Eur Radiol.* 2023 May 9.
- [3] Morgant MC, Miteran J, Lin S, Laubriet A, Cochet A, Lalande A et al. Impact of ascending aorta replacement by graft on elastic properties of descending thoracic aorta evaluated by cardiac magnetic resonance imaging. *MAGMA.* 2020;33(5):641-647.

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- [4] Rong LQ, Palumbo MC, Rahouma M, Meineri M, Arguelles GR, Kim J et al. Immediate Impact of Prosthetic Graft Replacement of the Ascending Aorta on Circumferential Strain in the Descending Aorta. *Eur J Vasc Endovasc Surg.* 2019;58(4):521-528.
- [5] Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Carr VF, Casey DE Jr et al. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM Guidelines for the diagnosis and management of patients with thoracic aortic disease. A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. *J Am Coll Cardiol.* 2010; 55:e27–e129.
- [6] Kiema M, Sarin JK, Kauhanen SP, Torniaainen J, Matikka H, Luoto ES et al. Wall Shear Stress Predicts Media Degeneration and Biomechanical Changes in Thoracic Aorta. *Front Physiol.* 2022;13:934941.
- [7] Dagum P, Green P, Nistal FJ, Daughters GT, Timek TA, Foppiano LE et al. Deformational dynamics of aortic root: modes and physiologic determinants. *Circulation* 1999;100 (suppl II):1154-62.
- [8] Iddawela S, Ravendren A, Harky A. Bio-chemo-mechanics of the thoracic aorta. *Vasc Biol.* 2021;3:R25-R33.
- [9] Tai NR, Salacinski HJ, Edwards A, Hamilton G, Seifalian AM. Compliance properties of conduits used in vascular reconstruction. *Br J Surg* 2000;87(11):1516-24.
- [10] Bollache E, Fedak PWM, van Ooij P, Rahman O, Malaisrie SC, McCarthy PM et al. Perioperative evaluation of regional aortic wall shear stress patterns in patients undergoing aortic valve and/or proximal thoracic aortic replacement. *J Thorac Cardiovasc Surg.* 2018;155(6):2277-2286.e2.
- [11] Palumbo MC, Redaelli A, Wingo M, Tak KA, Leonard JR, Kim J et al. Impact of ascending aortic prosthetic grafts on early postoperative descending aortic biomechanics on cardiac magnetic resonance imaging. *Eur J Cardiothorac Surg.* 2022; 61(4):860-868.
- [12] Okamoto RJ, Xu H, Kouchoukos NT, Moon MR, Sundt TM 3rd. The influence of mechanical properties on wall stress and distensibility of the dilated ascending aorta. *J Thorac Cardiovasc Surg.* 2003;126(3):842-50.
- [13] Zhang C, Li Y, Chakraborty A, Li Y, Rebello KR, Ren P et al. Aortic Stress Activates an Adaptive Program in Thoracic Aortic Smooth Muscle Cells That Maintains Aortic Strength and Protects Against Aneurysm and Dissection in Mice. *Arterioscler Thromb Vasc Biol.* 2023;43(2):234-252.
- [14] Scharfschwerdt M, Leonhard M, Lehmann J, Richardt D, Goldmann H, Sievers HH. In vitro investigation of a novel elastic vascular prosthesis for valve-sparing aortic root and ascending aorta replacement. *Eur J Cardiothorac Surg.* 2016;49(5):1370-3.
- [15] Kulik A. Aortic root enlargement: worth the effort? *Ann Thorac Surg* 2010 Sep;90(3):703-5.