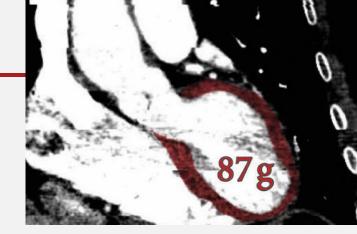
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Cardiovascular remodeling following TEVAR

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Contemporary Long-term Outcomes of Thoracic Endovascular Aortic Repair

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Background

TEVAR is widely used for multiple aortic pathologies, ranging from young, otherwise healthy patients to older individuals with cardiovascular co-morbidities.

There is conflicting evidence on the impact of the stent graft on LV mass and remodeling

- a. TEVAR can worsen aortic distensibility, leading to aortic stiffening and compliance mismatch, increase LV mass and hypertrophy
- b. TEVAR can reverse LV remodeling in patients with TBAD



TEVAR for TBAD

Series of 163 treated with TEVAR for TBAD
Investigate longitudinal changes in LV thickness, diameter, volume, function, and mass
At a mean follow up of 48 months, LV mass and thickness followed a downward trend over time
Interventricular septal thickness at end diastole decreased over time
LV function was not significantly improved
Strict BP control had no influence on LV remodeling.

→TEVAR can reverse LV remodeling and LVH in patients with acute TBAD



Du Y et al. Left ventricular remodeling in patients with acute type B aortic dissection after TEVAR: short and mid-term outcomes. International Journal of 4 Cardiology 274(2019) 283-89

TEVAR and hypertension

Twenty-six patients treated with TEVAR following BTAI with no history of hypertension.

matched with 37 healthy volunteers based on age, sex, and body surface area Comprehensive follow-up: 24-hour ambulatory blood pressure monitoring, and assessment of carotid-femoral pulse wave velocity (cfPWV, a measure of aortic stiffness)

At a mean of 120.2 69.7 months after intervention: 17 patients (65%) presented with HT, 14 (54%) had abnormal nighttime blood pressure dip New-onset HT was related to a more proximal TEVAR landing zone and greater distal oversizing.

Guala A et al. Impact of thoracic endovascular aortic repair following blunt traumatic thoracic aortic injury on blood pressure (J Thorac Cardiovasc Surg 2024;168:1428-37



TEVAR and CV remodeling

20 patients: 11 treated with Gore CTAG, 9 with Medtronic Valiant) for BTAI: office and 24-hr blood pressure (BP) aortic diameters (computed tomography scan)
Left ventricular mass index (echo)

12 patients (55%) developed hypertension post TEVAR Patients treated for more than 3 years show higher LVMI, PWV, and ascending aorta dilatation.



TEVAR and CV remodeling

The impact of this hemodynamic alteration on cardiac function, left ventricular remodeling, and echocardiographic outcomes remains poorly defined.

Single institutional series of patients treated with TEVAR for various pathologies, including

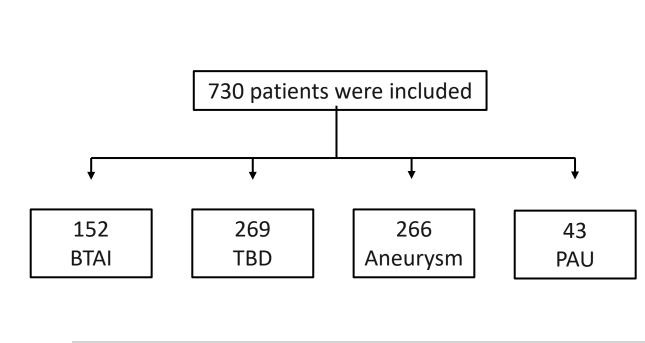
BTAI, TBAD, and TAA

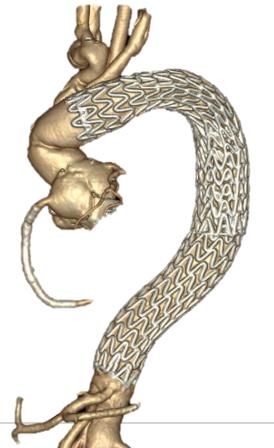
Multispecialty: Vascular Surgery, Cardiac Surgery



Patient characteristics

Patient population





Demographics

	Primary Pathology						
	BTAI	TBD	Aneurysm	PAU	Total	P-value	
	(N=152)	(N=269)	(N=266)	(N=43)	(N=730)		
Age	42.4± 18.4	62.3± 12.9	74.3± 11.2	73.0± 9.1	63.2± 18.0	<0.001	
BMI	29.4± 6.4	30.8± 7.0	27.7± 5.6	27.5± 5.2	29.3± 6.5	<0.001	
Male	112 (73.7%)	174 (64.7%)	138 (51.9%)	17 (39.5%)	441 (60.4%)		
Race							
White	127 (83.6%)	184 (68.4%)	227 (85.3%)	31 (72.1%)	569 (77.9%)	<0.001	
Black	18 (11.8%)	64 (23.8%)	19 (7.1%)	9 (20.9%)	110 (15.1%)		
Other	1 (0.7%)	2 (0.7%)	4 (1.5%)	2 (4.7%)	9 (1.2%)		
Unknown/Declined to answer	6 (3.9%)	19 (7.1%)	16 (6.0%)	1 (2.3%)	42 (5.8%)		
Current Smoker							
No	88 (66.7%)	182 (68.9%)	190 (72.5%)	27 (62.8%)	487 (69.5%)	0.461	
Yes	44 (33.3%)	82 (31.1%)	72 (27.5%)	16 (37.2%)	214 (30.5%)		

Co Morbidities

	BTAI	TBD	Aneurysm	PAU	Total	P-Value
Any Co-morbidities	45 (29.6%)	247 (91.8%)	255 (95.9%)	42 (97.7%)	589 (80.7%)	<0.001
Hypertension	36 (24.8%)	242 (90.3%)	241 (91.6%)	40 (93.0%)	559 (77.7%)	<0.001
Coronary Artery Disease	3 (2.1%)	57 (21.3%)	100 (38.0%)	14 (32.6%)	174 (24.2%)	<0.001
Carotid Disease	1 (0.7%)	7 (2.6%)	22 (8.4%)	5 (11.6%)	35 (4.9%)	<0.001
HLD	22 (15.2%)	103 (38.4%)	144 (54.8%)	27 (62.8%)	296 (41.2%)	<0.001
Peripheral Artery Disease	1 (0.7%)	18 (6.7%)	53 (20.2%)	7 (16.3%)	79 (11.0%)	<0.001
DM	9 (6.2%)	36 (13.4%)	50 (19.0%)	8 (18.6%)	103 (14.3%)	0.004
Chronic Obstructive Pulmonary Disease	9 (6.2%)	47 (17.5%)	98 (37.3%)	16 (37.2%)	170 (23.6%)	<0.001
Active Malignancy	2 (1.4%)	11 (4.1%)	8 (3.0%)	2 (4.7%)	23 (3.2%)	0.462
Arrhythmia	3 (2.1%)	37 (13.8%)	54 (20.5%)	10 (23.3%)	104 (14.5%)	<0.001
CHF	1 (0.7%)	29 (10.8%)	39 (14.8%)	9 (20.9%)	78 (10.8%)	<0.001
ESRD	0 (0.0%)	6 (2.2%)	5 (1.9%)	4 (9.3%)	15 (2.1%)	0.003
History of CABG	2 (1.3%)	17 (6.3%)	45 (16.9%)	3 (7.0%)	67 (9.2%)	<0.001
History of AAA intervention	1 (0.7%)	9 (3.3%)	64 (24.1%)	4 (9.3%)	78 (10.7%)	<0.001
Hx of Arch Repair	0 (0.0%)	62 (23.0%)	24 (9.0%)	2 (4.7%)	88 (12.1%)	<0.001



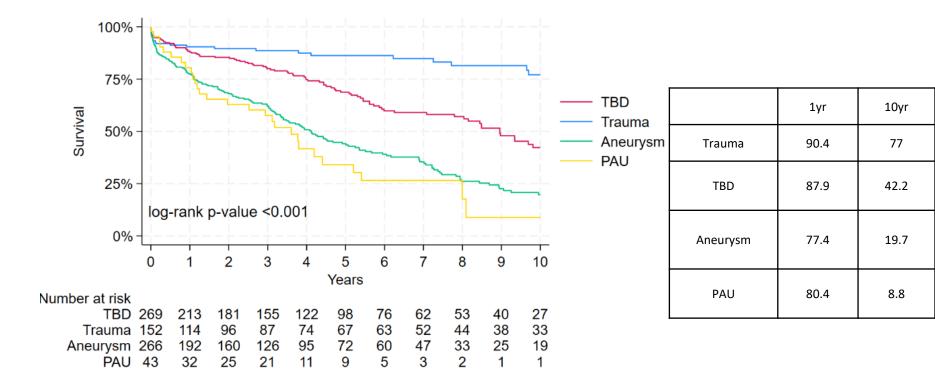
Operative details

	BTAI	TBD	Aneurysm	PAU	Total	P-Value
Operating Team						
Vascular	141 (92.8%)	93 (34.6%)	179 (67.3%)	26 (60.5%)	439 (60.1%)	<0.001
Cardiothoracic	10 (6.6%)	172 (63.9%)	86 (32.3%)	16 (37.2%)	284 (38.9%)	
Both	1 (0.7%)	4 (1.5%)	1 (0.4%)	1 (2.3%)	7 (1.0%)	
Left subclavian artery exclusion						
No	116 (76.3%)	160 (59.5%)	208 (78.5%)	32 (74.4%)	516 (70.8%)	<0.001
Yes, complete	21 (13.8%)	90 (33.5%)	51 (19.2%)	9 (20.9%)	171 (23.5%)	
Yes, partial	15 (9.9%)	19 (7.1%)	6 (2.3%)	2 (4.7%)	42 (5.8%)	
Carotid-subclavian bypass	1 (0.7%)	21 (7.8%)	15 (5.7%)	3 (7.0%)	40 (5.5%)	0.020
Subclavian-carotid transposition	0 (0.0%)	52 (19.3%)	24 (9.1%)	5 (11.6%)	81 (11.1%)	<0.001
Number of Endografts	1 [1 - 1]	2 [1 - 2]	2 [1 - 2]	1 [1 - 1]	2 [1 - 2]	<0.001
Proximal Landing Zone						
0	0 (0.0%)	2 (0.8%)	3 (1.2%)	0 (0.0%)	5 (0.7%)	<0.001
1	0 (0.0%)	4 (1.5%)	9 (3.5%)	0 (0.0%)	13 (1.8%)	
2	33 (22.0%)	99 (38.2%)	51 (19.8%)	12 (28.6%)	195 (27.5%)	
3	113 (75.3%)	134 (51.7%)	133 (51.8%)	20 (47.6%)	400 (56.5%)	
4	3 (2.0%)	17 (6.6%)	52 (20.2%)	9 (21.4%)	81 (11.4%)	
5	1 (0.7%)	3 (1.2%)	9 (3.5%)	1 (2.4%)	14 (2.0%)	
Proximal Diameter	26 [26 - 28]	34 [31 - 36]	34 [32 - 38]	32 [30 - 36]	34 [28 - 36]	<0.001
Conversion to open	0 (0.0%)	4 (1.5%)	3 (1.1%)	1 (2.3%)	8 (1.1%)	0.446
Intra-op death	1 (0.7%)	0 (0.0%)	2 (0.8%)	1 (2.3%)	4 (0.5%)	0.239



Survival

Survival



32

PAU 43

Peri-operative complications

>Stroke (3.84%)

Not significantly associated with pathology or year Increased odds seen associated with Left SCA exclusion (aOR: 4.2; p= 0.001)

➤ Spinal Cord Ischemia (5.21%)

None seen in Trauma

Not significantly associated with year of repair

>Access Injury (5.75%)

(femoral pseudoaneurysms, iliac avulsion/dissection)

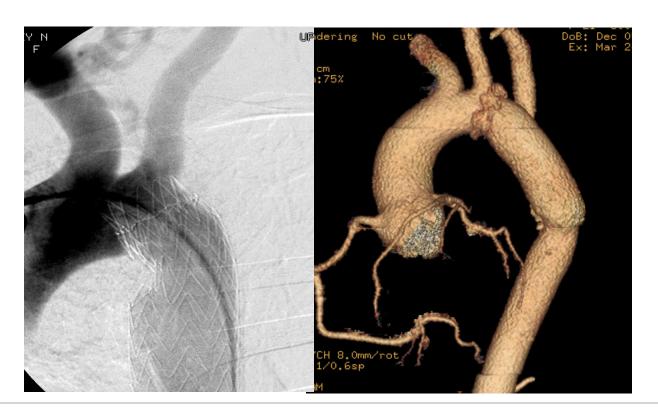
Decreased over time by 8.5% each year.

Not affected by the operating team

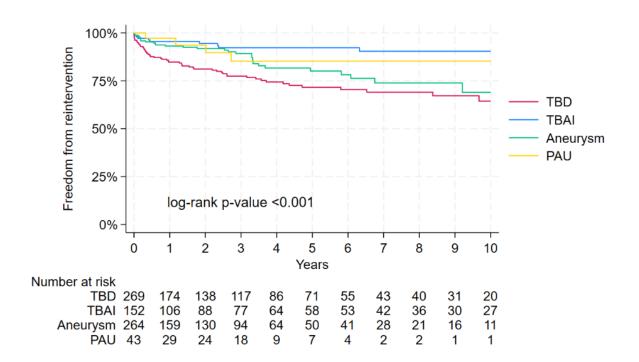
More likely to occur in aneurysm, TBD, and PAU than trauma



Reinterventions

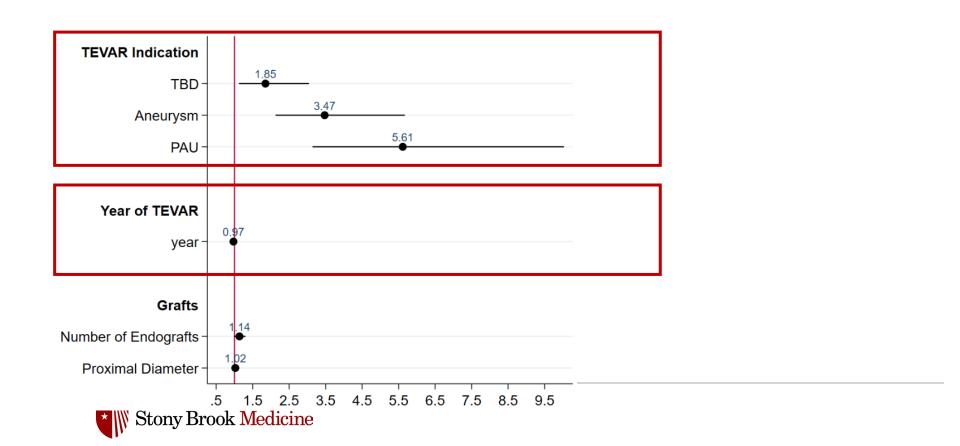


Reinterventions



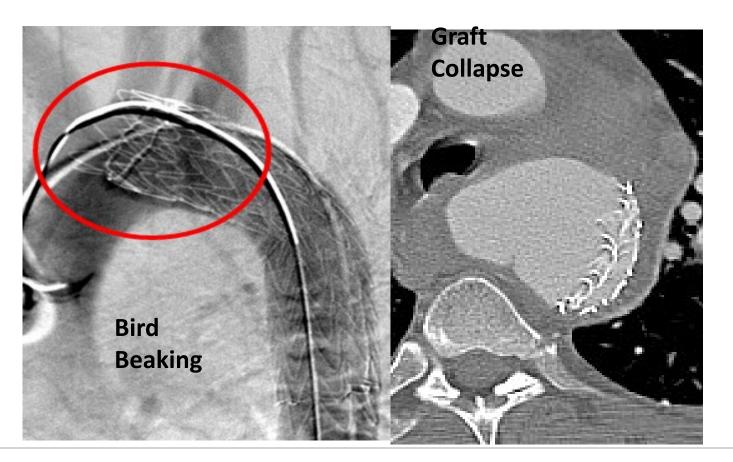
	1yr	10yr
Trauma	95.5	90.4
TBD	84.7	64.3
Aneurys m	93.1	68.9
PAU	97.2	85.2

Cox Regression Post-TEVAR Reinterventions



Indication for Re-interventions

	BTAI	TBD/IMH	Aneurysm	PAU	Total
Endo leak	1 (6.2%)	45 (56.9%)	30 (78.9%)	2 (50.0%)	78 (56.9%)
Graft Collapse*	6 (37.5%)	5 (6.3%)	0 (0.0%)	0 (0.0%)	11 (8.0%)
Graft infection	0 (0.0%)	2 (2.5%)	2 (5.2%)	1 (25.0%)	5 (3.6%)
Graft injury	0 (0.0%)	5 (6.3%)	1 (2.6%)	0 (0.0%)	6 (4.3%)
Residual Dissection	0 (0.0%)	12 (15.1%)	1 (2.6%)	0 (0.0%)	13 (9.5%)
Aorto-esophageal fistula	1 (6.2%)	1 (1.2%)	1 (2.6%)	0 (0.0%)	3 (2.2%)
Embolizing thrombus	2 (12.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (1.5%)
Type A dissection	0 (0.0%)	6 (7.5%)	1 (2.6%)	0 (0.0%)	7 (5.1%)
Impingement on branches	5 (31.2%)	1 (1.2%)	0 (0.0%)	0 (0.0%)	6 (4.3%)
Aortic Rupture	1 (6.2%)	2 (2.5%)	2 (5.2%)	1 (25.0%)	6 (4.3%)





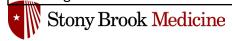
Long-Term cardiovascular outcomes

New-onset Hypertension(HTN)

- A total of 599 (78.61%) had pre-existing HTN
- 172 patients, 38 (22.1%) developed new-onset HTN
- The median time for onset of HTN was 2.55 months (IQR: 0.03 42.6)
- The mean age of onset of HTN was 44.7 ± 18.3 years
- The median follow-up time was 106.8 months (IQR: 52.8 180.5)
- After adjustment: trend for higher risk of HTN with increase in total graft total length/coverage (cm), although this was not statistically significant (aHR:
 - 1.055; 95% CI: 0.99 1.11; p= 0.07)



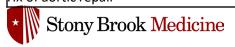
		New Dx of HTN after TEVAR				
	No	Yes	Total	P-value		
	(N=134)	(N=38)	(N=172)			
Age	45.1± 20.1	44.7± 18.3	45.0± 19.7	0.933		
Primary Pathology						
BTAI	93 (69.4%)	24 (63.2%)	117 (68.0%)	0.826		
TBD	21 (15.7%)	6 (15.8%)	27 (15.7%)			
Aneurysm	18 (13.4%)	7 (18.4%)	25 (14.5%)			
PAU	2 (1.5%)	1 (2.6%)	3 (1.7%)			
Male	91 (67.9%)	29 (76.3%)	120 (69.8%)	0.319		
Left subclavian artery exclusion						
No	98 (73.1%)	27 (71.1%)	125 (72.7%)	0.419		
Yes, complete	22 (16.4%)	9 (23.7%)	31 (18.0%)			
Yes, partial	14 (10.4%)	2 (5.3%)	16 (9.3%)			
Number of endografts	1 [1 - 2]	1 [1 - 2]	1 [1 - 2]	0.855		
Proximal Landing Zone						
1	1 (0.8%)	1 (2.7%)	2 (1.2%)	0.786		
2	33 (24.8%)	8 (21.6%)	41 (24.1%)			
3	90 (67.7%)	24 (64.9%)	114 (67.1%)			
4	7 (5.3%)	3 (8.1%)	10 (5.9%)			
5	2 (1.5%)	1 (2.7%)	3 (1.8%)			
First graft proximal diameter (in mm)	28 [26 - 31]	28 [26 - 34]	28 [26 - 31]	0.335		
Total length	100 [100 - 150]	100 [100 - 158]	100 [100 - 150]	0.917		



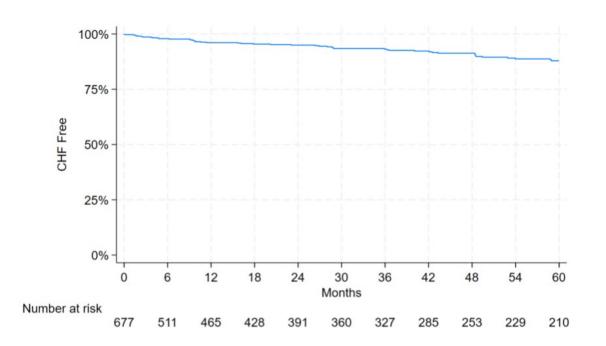
New-Onset Heart Failure (HF)

- Total of 85 (11.5%) had pre-existing HF
- 70 (10.3%) patients developed new-onset HF
- The median time of onset was 36.35 months (IQR: 9.7 73.1)
- The median age of onset of HF was 74.2 (IQR: 63.9 80.7)
- The median follow-up time was 36.6 months (IQR: 8.5 81.0)

	New Dx of heart failure				
	No	Yes	Total	P-value	
	(N=609)	(N=70)	(N=679)		
Age	61.9± 18.6	67.8± 13.6	62.5± 18.2	0.010	
BTAI	150 (24.6%)	4 (5.7%)	154 (22.7%)	0.002	
TBD	223 (36.6%)	32 (45.7%)	255 (37.6%)		
Aneurysm	204 (33.5%)	32 (45.7%)	236 (34.8%)		
PAU	32 (5.3%)	2 (2.9%)	34 (5.0%)		
Male	367 (60.3%)	47 (67.1%)	414 (61.0%)	0.264	
_eft subclavian artery exclusion					
Complete	139 (22.8%)	21 (30.0%)	160 (23.6%)	0.366	
Partial	38 (6.2%)	3 (4.3%)	41 (6.0%)		
Number of endografts	2 [1 - 2]	2 [1 - 2]	2 [1 - 2]	0.441	
Proximal Landing Zone					
0	5 (0.8%)	0 (0.0%)	5 (0.8%)	0.060	
1	10 (1.7%)	1 (1.4%)	11 (1.7%)		
2	158 (26.7%)	24 (34.3%)	182 (27.5%)		
3	344 (58.2%)	30 (42.9%)	374 (56.6%)		
4	64 (10.8%)	11 (15.7%)	75 (11.3%)		
5	10 (1.7%)	4 (5.7%)	14 (2.1%)		
First graft proximal diameter (in mm)	32 [28 - 36]	34 [30 - 37]	32 [28 - 36]	0.094	
Fotal length of graft	186 [100 - 270]	200 [145 - 275]	192 [100 - 270]	0.284	
Hx of aortic repair	0.1 ± 0.3	0.2 ± 0.4	0.1 ± 0.3	0.370	

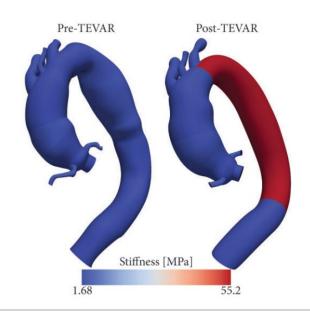


Freedom from HF



Months	New-onset CHF
6	2.1%
12	4%
48	8.7%

Vitrea CT CV remodeling



CTA Imaging

- > A total of 49 patients had Gated CTA scans in both pre- and post-op
- \triangleright N = 49 patients
- The median follow-up time at which a change in LV mass index is calculated was 2.1 years (range 0.3 8.1)

Left ventricular stroke work and mass increase following TEVAR

LV mass = $0.8 (1.04 (LVID + PWT + SWT)^3 - LVID^3) + 0.6$

Stroke work: +269
Mass echo: +269
Mass CTA: + 15%

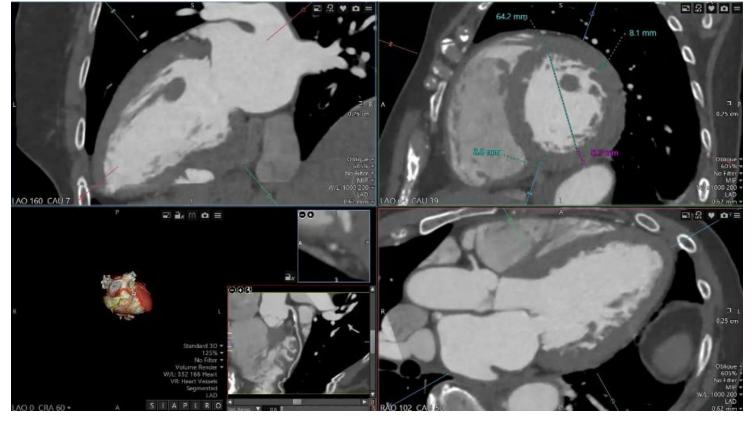
Pre-TEVAR
Post-TEVAR

LV mass Index = LV mass/BSA

LVID=LV internal diameter (mm), PWT=posterior wall thickness (mm), SWT=septal wall thickness (mm), and Body surface area (BSA)



Theodorus M.J. van Bakel et al. Cardiac remodeling following thoracic endovascular aortic repair for descending aortic aneurysms. European Journal of Cardio-Thoracic Surgery 55 (2019) 1061–1070



Short-axis slice at the level of the LV base, with recorded measurements of LVID, PWT, and SWT



	Pre-TEVAR LV mass Index	Post-TEVAR LV mass Index	p-value
All patients (49)	87.8 (70 – 107)	85.7 (72 – 99)	0.9
Prior Arch repair			
Yes (18)	91.1 (70 – 107)	89.4 (74 – 102)	0.7
No (31)	80.3 (66- 110)	82.5 (70 – 98)	0.5
Aortic pathology			
Dissection (38)	93.6 (78 – 119)	89 (75 – 100)	0.4
Aneurysm (8)	64 (62 – 68)	69.9 (64 – 79)	0.015

• No significant change in LV mass index was noted in the dissection group, but there is a 9.2% increase in LV mass index in the aneurysm group.



HTN and LV Mass Index

	Dx of HTN (n=44)	No Dx of HTN (n=5)	P-value
% change in LV mass index	+ 0.6 %	+ 6.4%	0.57
Time from TEVAR to CT (months)	26.5	12.8	0.12

Conclusion

- TEVAR is safe and effective with excellent long-term results.
- Long-term survival worse after treatement for TBAD or TAA
- Reinterventions are more common in patients undergoing TEVAR for aneurysm and dissection compared to trauma patients.
- But reintervention rate has decreased over time.

Conclusion

Hypertension (BTAI) and heart failure (TAA) frequently develop after TEVAR.

New-onset hypertension after TEVAR for BTAI occurs in nearly a quarter previously healthy patients, especially with longer aortic coverage,

Modifiable risk factors, such as the extent of aortic coverage and the number of grafts implanted can impact cardiovascular physiology, suggesting a meaningful biomechanical effect of endograft placement. Need for more compliant devices to reduce the stiffness mismatch with the aorta?

Post TEVAR follow up should include focused evaluation for left ventricular remodeling regardless of patient age Echocardiography, gated CTA chest, hypertension screening



Vascular and Endovascular Surgery Division















