TJVS Turkish Journal of Vascular Surgery

Turk J Vasc Surg.2026;35(1): 23-31
DOI: 10.9739/tjvs.2025.09.052

Available online at www.turkishjournalofvascularsurgery.org

Original Article

Short-term outcome of aortic arch repair: Debranching and thoracic endovascular aortic repair

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Received: September 17, 2025 Accepted: December 02, 2025 Published online: March 04, 2026

Abstract

Aim: Open repair for aortic arch pathologies remains the gold standard, despite its association with significant neurological and cardiovascular risks due to the need for cardiopulmonary bypass and deep hypothermic circulatory arrest. Hybrid techniques, combining supra-aortic trunk debranching with thoracic endovascular aortic repair (TEVAR), have emerged as promising alternatives for high-risk patients and they are still a viable alternative in face of recently intervening extremely expensive branched and fenestrated stents of total endovascular techniques in unaffordable situations. Our study aimed to evaluate the short-term outcomes of hybrid arch repair using debranching and TEVAR from our tertiary center experience prospectively.

Material and Methods: This is a prospective analytical observational study that included 60 patients who underwent supra-aortic debranching and TEVAR. Those with occlusive carotid disease, proximal landing zones of <20 mm, concomitant aortic or mitral valve replacement, or coronary artery bypass grafting were excluded. Surgical techniques included both partial and total debranching based on the Ishimaru zone classification and anatomical considerations. Primary outcomes: evaluation of post operative neurological complications like stroke and cerebral infarction. Secondary outcomes: the morbidity/mortality rate and the complications/ re-interventions' rate, endoleak rate, intensive care unit (ICU) stay duration, Hospital length of stay and early procedural success (defined as absence of mortality, conversion to open surgery, or major complication).

Results: Of the 60 patients, 47 (78.3%) were male and 13 (21.7%) were female, with a mean age of 65.2±8.6 years. Aortic aneurysm was the most common indication (51.7%), followed by aortic dissection (31.7%) and penetrating ulcers/intramural hematoma (16.7%). The mean aortic arch diameter was 3.32±0.5 cm. Three patients (5%) had Endo leak. Six patients (10%) experienced postoperative stroke, most associated with debranching from left common carotid artery and left subclavian artery to the innominate artery (p=0.008). The 30-days mortality was 2 (3.3%), one attributed to sudden cardiac arrest on postoperative day 1 in the ICU (mostly due to development of retro A dissection and mostly ruptured), the other patient died on day 15 postoperative due to stroke complicated by chest infection and sepsis and no reported intraoperative mortality.

Conclusion: Hybrid aortic arch repair with debranching and TEVAR is safe and effective, offering acceptable early neurological outcomes and low rates of endoleak. Careful patient selection, surgical experience, and technique refinement are essential.

Keywords: Aorta, thoracic, endovascular aneurysm repair, stroke, surgical procedures, operative

INTRODUCTION

Diseases of the aortic arch, including aneurysms, dissections, and penetrating ulcers, represent a formidable surgical challenge due to their anatomical complexity and proximity to vital supra-aortic branches. Traditional open aortic arch repair requires cardiopulmonary bypass and deep hypothermic circulatory arrest, which are associated with significant perioperative risks, including stroke, coagulopathy, and prolonged recovery times [1-3].

Over the past decade, thoracic endovascular aortic repair (TEVAR) has emerged as a less invasive alternative, particularly in high-risk surgical candidates. However, achieving an

CITATION

Abdelaziz OD, Badr SA, Sayed HFA, Abdelwahab AHA, Elnaggar IM. Short-term outcome of aortic arch repair: Debranching and thoracic endovascular aortic repair. Turk J Vasc Surg.2026;35(1):23-31.

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adequate proximal landing zone for endograft deployment often necessitates surgical debranching of the supra-aortic vessels [4,5]. This hybrid approach—combining surgical debranching with TEVAR—has shown promise in reducing operative morbidity while maintaining durable aortic repair, especially in elderly or comorbid patients [6].

Despite the growing adoption of the technique, data regarding the early outcomes of hybrid aortic arch repair remain limited and inconclusive, particularly on Middle Eastern populations. This prospective study was conducted to evaluate the short-term neurological and technical outcomes of arch debranching with TEVAR in patients presenting with complex aortic arch pathologies.

The aim of the study was to evaluate the short term (30 day follow up) outcomes of arch repair with debranching techniques and TEVAR as a good surgical option for patients with aortic arch pathologies prospectively from our center experience in terms of neurological outcomes, morbidity and mortality, and surgically related complications as reintervention.

The study objectives were to observe prospectively patient demographics, comorbidities, disease characteristics, and arch anatomy and relate them statistically to our observations of postoperative neurological sequelae, operative and 30-day mortality, surgically related early complications or re-intervention and other postoperative complications or morbidities.

Hypothesis

We hypothesized that arch repair with debranching and TEVAR would have good short-term outcomes through 30-day follow up.

Potential risks and problems

Neurological complications, surgical bleeding, blood transfusion, surgical wound infection, re-intervention, morbidity and mortality.

MATERIAL AND METHODS

Study Design and Setting

This was a prospective observational analytical study that was conducted at the Cardiothoracic Surgery Department of Cairo University Hospitals (Kasr Al-Ainy Hospitals), from March 1, 2022 to September 1, 2024.

Ethics Committee

The study received institutional ethical committee approval of the Faculty of Medicine, Cairo University, Egypt (MD-90-2023), and written informed consent was obtained from all participants. and conducted per the Declaration of Helsinki.

Inclusion and Exclusion Criteria

A total of 60 consecutive patients aged >18 years with aortic arch pathology, involving aneurysm, dissection (Figure 1), intramural hematoma, or penetrating aortic ulcer and candidates for supra-aortic debranching followed by TEVAR with feasible anatomical landing zones. Criteria for exclusion from our study were as follows: Carotid artery occlusive disease requiring separate revascularization, proximal descending aorta with <20 mm landing zone, concomitant surgical need for aortic valve replacement, mitral valve replacement, or coronary artery bypass grafting, and finally ascending aortic pathology necessitating open repair.

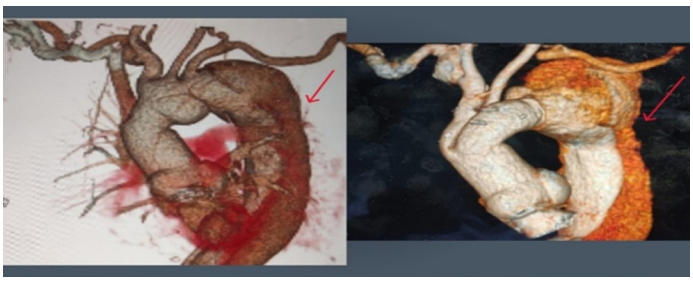

Figure 1. Preoperative CT aortography with 3D reconstruction of aneurysmal type B dissection

Randomization and Blinding

All patients were candidates for the same technique (arch debranching and TEVAR) and data collectors were not blinded to the technique.

Anesthesia

All operations were done under general anesthesia.

Surgical Technique

All patients underwent hybrid aortic arch repair in two phases: supra-aortic debranching followed by TEVAR. Surgical planning was based on multi-detector computed tomography with 3D reconstruction to evaluate arch anatomy, landing zones, and branch vessel take-off angles.

Debranching Phase

The debranching procedure was tailored to the intended proximal landing zone, categorized according to Ishimaru's classification:

1. Zone 0 debranching (Total Arch Debranching): Performed via full median sternotomy or partial upper mini-sternotomy. A side-biting clamp was applied to the ascending aorta (free of significant calcification or dilation), and a Dacron trifurcated graft was anastomosed using continuous 4-0 polypropylene sutures. Individual graft limbs were then tunneled and sequentially anastomosed to the innominate artery, left common carotid artery (LCCA), and left subclavian artery (LSA). Care was taken to ensure proper graft orientation, avoid kinking, and secure flow. Intraoperative Doppler and direct pressure monitoring confirmed patency.

2. Zone 1 or 2 debranching (Partial Debranching): In patients with suitable landing zones distal to the innominate artery, partial revascularization was performed. Access was obtained via a left supraclavicular or cervical incision.
3. LCCA to LSA bypass or LSA to LCCA transposition was performed using an 8 mm Dacron graft, anastomosed end-to-side using standard vascular technique.
4. In select cases, LCCA and LSA were both revascularized to the innominate artery using Y-graft configuration tunneled via a retroclavicular route.

Native vessel ligation (typically LCCA or LSA) performed after flow through the bypass graft was confirmed via Doppler and back-bleeding was controlled. Hemostasis was meticulously secured. Temporary shunts were not required in any case.

Thoracic endovascular aortic repair phase

After confirming the integrity of the graft anastomoses and hemodynamic stability, patients were prepared for TEVAR in the same or staged session.

Access

The common femoral artery was exposed surgically in most cases. In some patients, percutaneous access with ProGlide closure system was employed. A stiff guidewire (e.g., Lunderquist) was advanced under fluoroscopic guidance across the arch into the left ventricle (Figure 2).

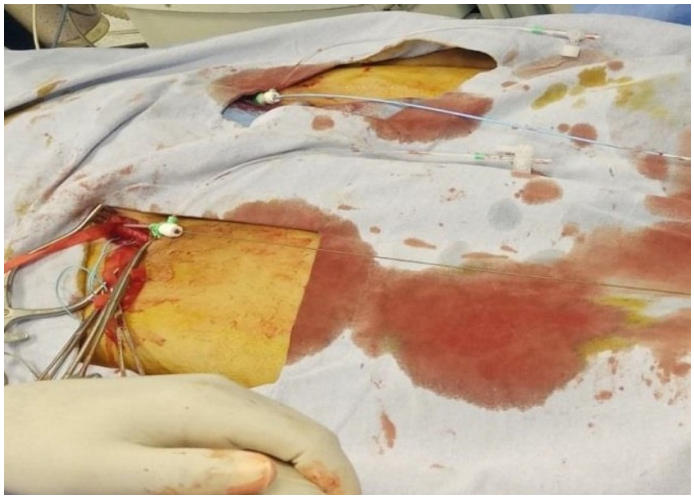

Figure 2. Access to stent deployment

Deployment

A thoracic endograft (e.g., Medtronic Valiant®, Gore TAG®, or equivalent) was advanced over the guidewire and positioned across the aortic arch based on preoperative measurements. Oversizing was 10–20% for aneurysmal pathology and ≤10% for dissection cases. Care was taken to align the stent with the intended landing zones. Rapid ventricular pacing or pharmacologically induced hypotension (<80 mmHg systolic) was used to minimize aortic movement during deployment. Final angiography confirmed graft position, exclusion of pathology, and absence of endoleaks (Figure 3).

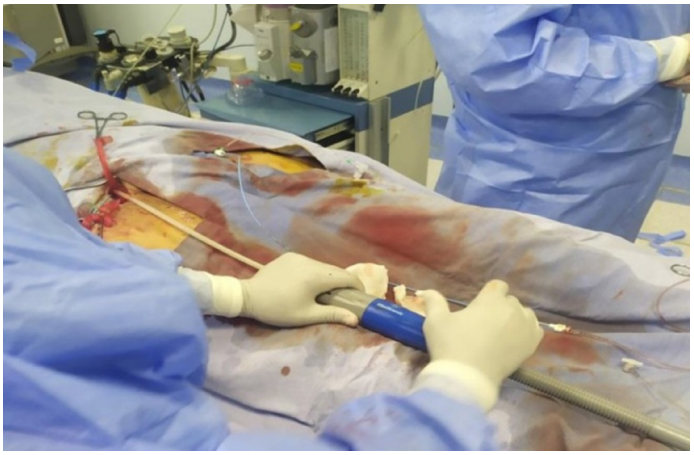

Figure 3. Stent deployment via right femoral artery

Adjuncts

In cases where the LSA origin remained perfused and risked type II endoleak, endovascular coil embolization was performed using detachable microcoils through a brachial or femoral access.

Postoperative Care and Monitoring

All patients were admitted postoperatively to the surgical ICU. Neurological assessments were performed daily. Contrast-enhanced computed tomography (CT) angiography was conducted prior to discharge to evaluate stent position, patency, and potential endoleaks (Figure 4).

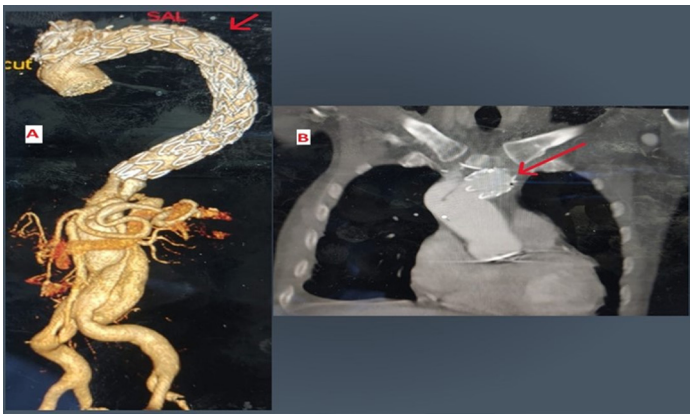

Figure 4. A. CT aortography with 3D reconstruction, B. conventional CT aortography both after total debranching and TEVAR

Study parameters

Primary outcomes

Incidence of post operative neurological complications like stroke and cerebral infarction. Secondary outcomes: the

morbidity/mortality rate and the complications/ re-interventions' rate, endoleak rate, ICU stay duration, Hospital length of stay and early procedural success (defined as absence of mortality, conversion to open surgery, or major complication).

Statistical analysis of the data

This prospective study was conducted on sixty patients diagnosed to have different aortic arch pathologies and candidates for Debranching & TEVAR at cardiothoracic department, Kasr Al-Ainy university hospitals. Data was coded and entered using the statistical package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Data was summarized using mean and standard deviation for quantitative variables and frequencies (number of cases) and relative frequencies (percentages) for categorical variables. Comparisons between groups were done using unpaired t test. For comparing categorical data, Chi-square test was performed. Exact test was used instead when the expected frequency is less than 5. P-values less than 0.05 were considered statistically significant.

RESULTS

This prospective study was carried out on a total of 60 patients diagnosed to have different aortic arch pathologies and candidates for TEVAR at cardiothoracic surgery department, Kasr Al Ainy university hospitals (Table 1).

Table 1. Basic demographic data and operative time and their relation to complications

Variable	Complication				P value
	Yes		No		
	Mean	Standard Deviation	Mean	Standard Deviation	
Age	63.14	±10.17	65.83	**±7.60**	0.291
Operative time, h	3.39	±0.80	3.20	**±0.75**	0.415

Variable		Complication				P value
		Yes		No		
		Count	%	Count	%	
Gender	**Male**	12	25.5%	35	74.5%	0.713
	Female	2	15.4%	11	84.6%	
HTN	**Yes**	9	22.5%	31	77.5%	1
	No	5	25.0%	15	75.0%	
DM	**Yes**	9	30.0%	21	70.0%	0.222
	No	5	16.7%	25	83.3%	
CKD	**Yes**	2	20.0%	8	80.0%	1
	No	12	24.0%	38	76.0%	
IHD	**Yes**	6	28.6%	15	71.4%	0.532
	No	8	20.5%	31	79.5%	
COPD	**Yes**	3	20.0%	12	80.0%	1
	No	11	24.4%	34	75.6%	
Connective tissue diseases	**Yes**	2	14.3%	12	85.7%	0.485
	No	12	26.1%	34	73.9%	
Previous stroke	**Yes**	2	40.0%	3	60.0%	0.582
	No	12	21.8%	43	78.2%	
Previous aortic intervention	**Yes**	0	0.0%	7	100.0%	0.184
	No	14	26.4%	39	73.6%	

HTN: hypertension, DM: diabetes mellitus, CKD: chronic kidney disease, IHD: ischemic heart disease, COPD: chronic obstructive pulmonary disease

In our study 6 patients had total debranching of all supra-aortic trunks (SAT) to a tube graft to ascending aorta, while the rest of our patients had different types of partial debranching procedures in different ways according to the anatomical extension of the pathology and the state of adjacent parts of aortic tissue. 29 patients (48.3%) had Partial 2 vessel debranching (LCCA, LSC to innominate a).10 patients (16.7%) had Partial one vessel debranching (LCC to Innominate a). Only 15 patients (25%) Partial one vessel debranching (LCCA to LSCA) (Table 2).

Partial mini-sternotomy approach was the one most used to do most of our partial debranching procedures; it was our approach in 40 (66.7%) of all our studied patients. The Cervical, subclavian approach was used to bypass LSA to Lt CCA in 15 patients (25%). Full sternotomy approach a used for total arch debranching in 10 patients (8.3%) (Table 2).

Hybrid aortic arch repair is a two staged procedure composed of debranching of SAT, and then stent deployment to exclude the diseased part of the aorta. These two parts can be done simultaneously (sequential) or as a staged manner according to surgeon preference or patient condition. In our study, 36 cases had simultaneous procedures, and the other 24 had staged procedures (Table 2).

The idea of percutaneous aortic intervention, with either TEVAR or even EVAR we have to exclude all the diseased part of aorta completely by stent deployment, so one or multiple stents may be used to achieve this target. Regarding our cases, one stent deployment was sufficient in most cases, about 44 patients (73.3%). The other 16 cases (26.7%) had 2 stents (Table 2).

Debranching strategies were as follows (Table 2):

Table 2. Arch pathology and surgical details and their relation to complications

Variable		Complication				P value
		Yes		No		
		Count	%	Count	%	
Aortic pathology	Aneurysm	6	19.4%	25	80.6%	0.560
	Acute dissection	4	26.7%	11	73.3%	
	Chronic dissection	2	50.0%	2	50.0%	
	Penetrating ulcer or intramural hematoma	2	20.0%	8	80.0%	
Type of debranching	Total debranching	0	0.0%	6	100.0%	0.593
	Partial 2 vessel debranching (LCCA, LSA to Innominate A)	8	27.6%	21	72.4%	
	Partial one vessel debranching (LCCA to Innominate A)	2	20.0%	8	80.0%	
	Partial one vessel debranching (LCCA to LSA)	4	26.7%	11	73.3%	
Approach	Mini sternotomy	9	22.5%	31	77.5%	0.889
	Cervical, Subclavian	4	26.7%	11	73.3%	
	Full sternotomy (to facilitate total debranching)	1	20.0%	4	80.0%	
n. of stents	1	10	22.7%	34	77.3%	1
	2	4	25.0%	12	75.0%	
TEVAR timing	Sequential (same day hybrid)	8	22.2%	28	77.8%	0.803
	Staged	6	25.0%	18	75.0%	
Arch diameter, cm	Mean				+/- SD	
	3.32				0.5	

LCCA: left common carotid artery, LSA: left subclavian artery, SD: standard deviation

1. Total arch debranching (Zone 0): 6 patients (10%)

2. Partial debranching:

a. Two-vessel (LCCA and LSA to Innominate artery): 29 patients (48.3%)

b. One-vessel (LCCA to Innominate artery): 10 patients (16.7%)

c. One-vessel (LSA to LCCA): 15 patients (25%) (Figure 6)

There are many causes and conditions of endoleak, in our study there were 3 cases of endoleak (5%) (Figure 7) one that was managed by ballooning of proximal end of the stent. The 2 other cases were the source was LSA; hence it was occluded by coiling (Figure 8).

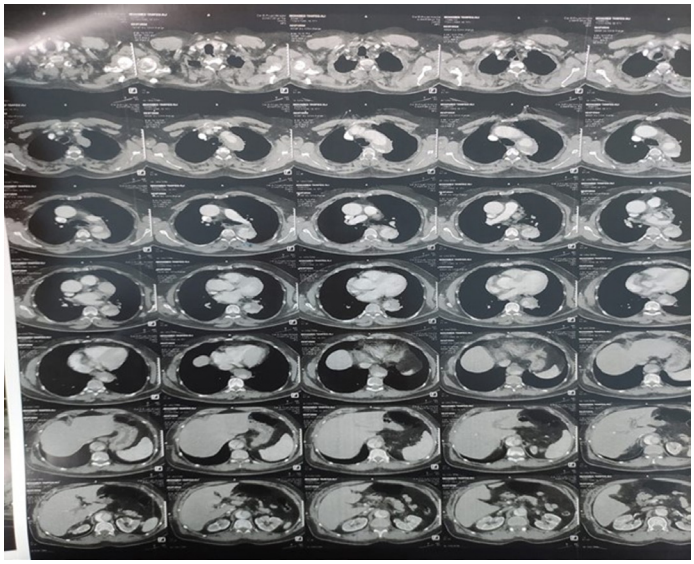

Figure 5. CT Aortography of Type B Aortic dissection

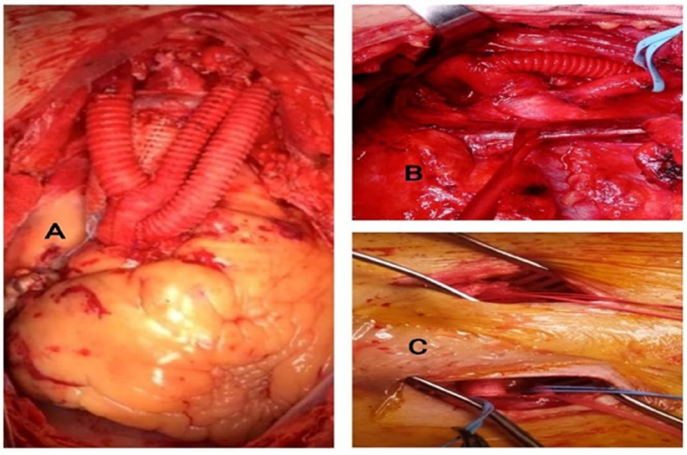

Figure 6. A. tube graft anastomosed to ascending aorta with distal ends to Innominate artery and LCCA and LSA to tube graft B. partial debranching (LSA to Innominate artery before LCCA to graft anastomosis) C. LSA to LCCA bypass via cervical and sub clavicular approach

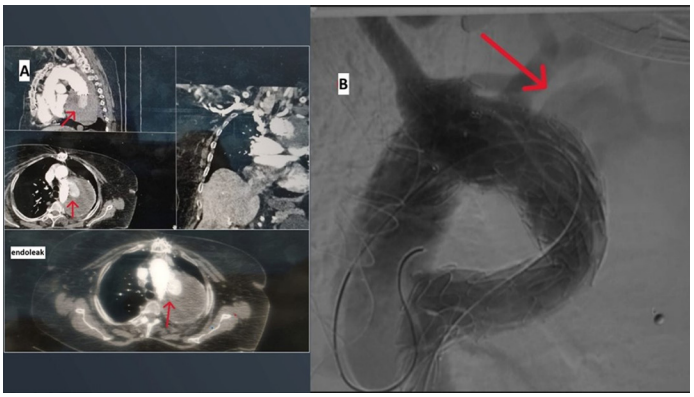

Figure 7. Red arrows pointing at Endoleak A. in CT cuts. B. in angiography

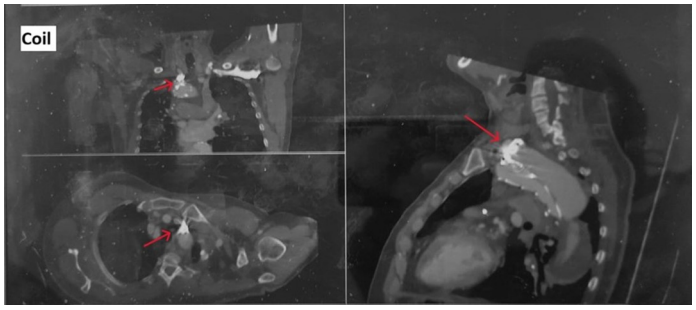

Figure 8. Red arrows pointing at Coil in Subclavian artery at CT angiography

Comparing open surgical repair, hybrid arch repair is a less invasive maneuver but still has some complications. Stroke and spinal cord ischemia are the most devastating ones. In our study, we had 6 cases of post-operative stroke (10.0%), but no one had any spinal cord ischemia manifestations. Stroke was significantly associated with the two-vessel debranching (LCCA and LSA to innominate artery; p=0.008) (Tables 3 & 4). 4 of them developed left sided hemiplegia improved with physiotherapy, 1 patient didn't regain consciousness and died in ICU with sepsis on top of chest infection, and 1 patient had right sided hemiplegia improved with physiotherapy.

Access complications like local hematoma, retroperitoneal hematoma or AV fistula did not occur. No stent related complications (migration, collapse) were detected intraoperatively or in early post-operative period. We had no cases of post-operative surgical bleeding.

Only one case needed surgical re-intervention for urgent exploration of the descending thoracic aorta as we suspected a stent deployment in false lumen so, we did a fenestration of the flap in the descending thoracic aorta. Regarding 30-day mortality, 2 patients died (3.3%), one of them died with stroke complicated with sepsis on top of chest infection post-operatively, another one had sudden cardiac arrest on postoperative day 1 in the ICU (mostly due to development of retro A dissection and mostly ruptured) (Table 3).

ICU and Hospital stay, postoperative drainage, blood transfusion, and vasopressor/dilator support are shown in Table 5.

Table 3. Postoperative complications

Variable		Count	%
Stroke	**(most common with LCCA+LSA to Innominate A.) p=0.008***	6	10.0%
Spinal cord affection		0	0%
Limb ischemia		0	0%
Access complications		0	0%
Reopening for bleeding		0	0%
Surgical reintervention		1	1.7%
Hospital mortality		2	3.3%
Endoleak		3	5.0%
Management of leak	**Ballooning to proximal end of stent**	1	33.3%
	LSA Coiling	2	66.7%
Wound infection (femoral)		2	3.3%
Stent-related re-intervention		1	1.6%
Operative mortality		0	0%
30-day mortality		2	3.3%

LCCA: left common carotid artery, LSA: left subclavian artery, *: Significant at p<0.05

Table 4. Relation between technique of debranching and stroke

Debranching		LZ	No. of cases	Stroke (n=6)	
				No.	P value
Debranching	**Total debranching (all SAT to asc. Aorta)**	0	5	0	0.008*
	LCCA, LSA to Innominate A	1	25	4	
	LCCA to Innominate A	1	9	1	
	LSA to LCCA	2	12	1	

SAT: supra-aortic trunks, Asc. Aorta: ascending aortic, LCCA: left common carotid artery, LSA: left subclavian artery, LZ: Landing Zone, *: significant at P <0.05

Table 5. ICU and hospital stay, postoperative drainage, blood transfusion, and vasopressor/dilator support

Variable		Mean	SD
SICU stay (hours)		86.1	±50.1
Total Hospital stay (ward + SICU) (days)		8.98	±2.92
Postoperative drainage (mL)		186.6	±100
		Count	**%**
n. of patients required blood transfusion		7	11.7%
Vasopressor/dilator support	**None**	38	63.3%
	Nitroglycerin	19	31.6%
	Magnesium sulfate	2	3.3%
	Norepinephrine	1	1.6%

SICU: surgical ICU, SD: standard deviation

DISCUSSION

This prospective study evaluated 60 patients with aortic arch pathologies undergoing hybrid aortic arch repair using supra-aortic trunk debranching followed by TEVAR. Our data affirms that this approach is technically feasible and associated with acceptable short-term outcomes in terms of neurological complications, endoleaks, and reintervention rates.

The majority of our patients were elderly males (mean age 65.2 years, 78.3% male), with hypertension (66.7%) and diabetes mellitus (50%) being the most prevalent comorbidities—reflecting the typical risk profile for aortic disease. These figures are consistent with De Rango et al.'s [7] series of 104 patients, in which 86.5% were male and 86.5% were hypertensive [1]. Chronic obstructive pulmonary disease and chronic kidney disease were also notable risk factors in both cohorts.

Connective tissue disorders such as Marfan syndrome were present in 23.3% of our patients, higher than the 3.6% reported by De Rango et al. [7] This discrepancy may be attributed to referral patterns or increased use of TEVAR in syndromic patients at our institution.

Aortic aneurysm was the most frequent indication for intervention (51.7%), followed by aortic dissection (31.7%) (Figure 5). These rates align with global trends showing aneurysmal degeneration as the primary driver for hybrid repair.

Partial debranching was utilized in 90% of cases, favoring a two-vessel bypass (LCCA and LSA to innominate artery) to achieve an adequate proximal landing zone. Mini-sternotomy (66.7%) and cervical/subclavian approaches (25%) provided versatile access for debranching based on anatomical requirements.

Postoperative stroke occurred in 10% of cases (n=6). Notably, stroke incidence was significantly higher in patients undergoing LCCA and LSA to innominate artery bypass (p=0.008), suggesting this configuration may be associated with greater embolic risk. Total debranching (zone 0 repairs) was not associated with stroke in our cohort, corroborating findings from Singh et al., who reported lower stroke rates in zone 0 interventions when cerebral perfusion is optimized [8]. Our stroke rate falls within the reported range of 5–15% for hybrid arch repairs, which remains lower than the 20–30% historically observed with open arch replacements under circulatory arrest [9].

Three patients (5%) experienced endoleaks—two from the LSA managed by coil embolization (type II) and one type Ia leak corrected via proximal ballooning. This low incidence supports the role of preoperative planning and proper oversizing strategies. Prior literature has shown endoleak rates as high as 15–25% in hybrid repairs, particularly in zone 1 deployments [8,10].

We performed oversizing cautiously: ~10% in dissections and ~20% in aneurysms to avoid aortic rupture, especially in fragile dissected tissue. No cases of stent migration or collapse were noted during early follow-up, aligning with results from Dueppers et al [11].

The mean SICU stay was 86.1±50.1 hours, and hospital stay averaged 8.98±2.9 days. While longer ICU stays compared to some series may reflect our cautious postoperative monitoring, our total hospital stay was shorter than reported in older or higher-risk cohorts [12,13].

Only one patient (1.6%) required surgical reintervention for suspected stent deployment into a false lumen, which was resolved by fenestration of the dissection flap.

Implications and clinical relevance: Hybrid aortic arch repair is a less invasive alternative to open arch surgery, particularly suitable for elderly or high-risk patients. It avoids deep hypothermic circulatory arrest and allows for tailored reconstructions depending on pathology extent and arch anatomy. Our results support growing evidence that debranching with TEVAR is a safe and effective strategy for managing complex aortic arch disease with acceptable neurological and vascular outcomes [10,11].

CONCLUSION

Hybrid aortic arch repair using supra-aortic trunk debranching followed by TEVAR is safe and effective, particularly in high-risk or elderly patients. Our short-term results demonstrate low rates of stroke and endoleak, with acceptable ICU and hospital stays. The two-vessel debranching technique involving the LCCA and LSA to the innominate artery was associated with a higher incidence of postoperative stroke, highlighting the need for careful patient selection and cerebral protection strategies.

These findings support the growing role of hybrid approaches in the management of complex aortic arch pathologies. However, further studies with long-term follow-up are necessary to confirm durability and identify late complications such as endoleak, graft failure, and aneurysm progression.

Limitations

The study is limited by the short time period of Follow-Up (30 days). We also need to conduct more stratified analysis from the collected data about the cases whose anatomy was suitable for total endovascular arch replacement and urgent and emergent cases with more concentration on their characteristics in relation to complications and strategies to lessen them. Further studies with higher numbers of each pathology may be conducted to overcome the low natural incidence of some pathologies to lessen the heterogeneity of pathologies and allow the subdivision of the total population to compare their unique characteristics and potential refining of conventional techniques accordingly. Lastly, in the future we need to conduct a case control study to compare between open and hybrid repair techniques.

Highlight key points

- Early neurological complications were observed in 10% of patients, mainly after carotid–subclavian/innominate debranching.
- Endoleak occurred in 5% of cases, reflecting low procedure-related complication rates.
- Careful patient selection and refinement of surgical technique are crucial for optimal outcomes.

Ethics Committee Approval: It was received from the Faculty of Medicine, Cairo University, Egypt (MD-90-2023) (14.10.2023).

Patient Consent for Publication: Not necessary for this manuscript.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: All authors contributed equally to the article.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

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