CASE SERIES

Hybrid Repair for Complex Thoracoabdominal and Pararenal Aortic Aneurysms in High-Risk Patients: A Case Series

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ABSTRACT

Repair of complex aortic aneurysms such as those involving the thoracoabdominal and pararenal aorta presents a formidable challenge for surgeons with significant perioperative morbidity and mortality. A hybrid procedure combining renovisceral debranching with endovascular aneurysm exclusion has been developed as an alternative approach for high-risk patients. This paper reports our initial experience with hybrid repair for these complex aortic diseases in three high-risk patients.

Keywords: aorta, aortic aneurysm, endovascular procedures, hybrid repair, visceral debranching

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INTRODUCTION

In developed countries, endovascular repair has largely replaced open surgery as definitive treatment of aortic aneurysms, be it thoracic or abdominal.[1] Numerous prospective studies have demonstrated its early benefit over open surgery, including less blood loss, shorter operative times, shorter length of hospital and ICU stay, and lower morbidity and mortality in the perioperative period.[2-4] For pararenal and thoracoabdominal aneurysms (TAAA) however, endovascular repair may entail complex procedures necessitating fenestrated or branched endografts which unfortunately, are not available in the country. Use of parallel grafts (chimney, periscope, snorkel) are feasible but these are correlated with distinct, hard to treat complications such as type 1a endoleaks from gutter formation at the proximal landing zone or modular dislocation.[5] Conventional open aneurysm repair, on the other hand, remains associated with significant morbidity and mortality despite improvements in perioperative management and surgical technique.[6,7]

Given these limitations, hybrid techniques which combine surgical debranching of the reno-visceral arteries with subsequent endovascular repair of the aneurysmal aortic segment have been developed.[8,9] The open segment is limited to the abdomen and thus have the theoretical advantage of sparing the patient of the physiologic stress associated with a thoracotomy, aortic cross-clamping, single lung ventilation, cardiopulmonary bypass, and reno-visceral, spine and limb ischemia inherent in conventional TAAA repair.

This paper describes our initial experience with abdominal visceral debranching followed by endovascular repair for pararenal and TAAA, focusing on outcomes and our technique. We aimed to present the feasibility of hybrid repair in three different patients with various comorbidities.

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Three patients diagnosed with pararenal and thoraco-abdominal aortic aneurysms who underwent reno-visceral debranching surgery followed by endovascular aortic aneurysm repair were the subjects of this study. Clinical data were obtained and retrospectively reviewed from the Department's (ISIS, *Integrated Surgical Information System*) and Institution's (RADISH, *Computerized Registry of Admissions and Discharges*) prospectively maintained databases. Treatment options were discussed extensively with each patient and their family preoperatively, and written informed consent were obtained.

Surgical Technique and Endovascular Repair

All hybrid repairs were performed in two stages, with the debranching procedure done initially, followed by endovascular repair in 2-4 weeks. The debranching surgery was performed with the patient on general anesthesia. A transperitoneal median laparotomy was made to expose the infrarenal aorta, right and left renal arteries, and bilateral common iliac arteries. A left medial visceral rotation was done to dissect the superior mesenteric artery (SMA) and coeliac trunk (CT).

Visceral debranching and repair was performed in a caudad to cephalad order. The R renal artery (RRA) was bypassed first with a retrograde dacron graft (7mm, LeMaitre, Burlington MA) from the R common iliac artery. The rest of the reno-visceral vessels were revascularized using a bifurcated Dacron graft (14 x 7mm, LeMaitre, Burlington MA) from the L common iliac artery. Specific graft and anastomotic configuration (end-to-end vs end-to-side) were created at the discretion of the surgeon depending on intraoperative findings. Likewise, source of inflow for the bypasses may be any uninvolved segment of the aorta or arterial tree, with the iliac arteries being the most commonly used. In Patient A, infrarenal endoaneurysmorraphy was done hence the distal end of the bifurcated graft right before its bifurcation was used as inflow. All anastomoses should be done without tension hence considerable efforts were made to ensure a sufficient length of native artery was dissected. Ligation of all visceral arteries was done at its ostium.

Endovascular repair was done with the patient either on general or regional epidural anesthesia, and a spinal drain placed. The right common femoral artery was exposed for access of the main graft. Following adequate heparinization, deployment of the endovascular stent graft system (Valiant Captiva for TEVAR, Endurant II for EVAR, Medtronic CA) was made to completely exclude the aneurysms.

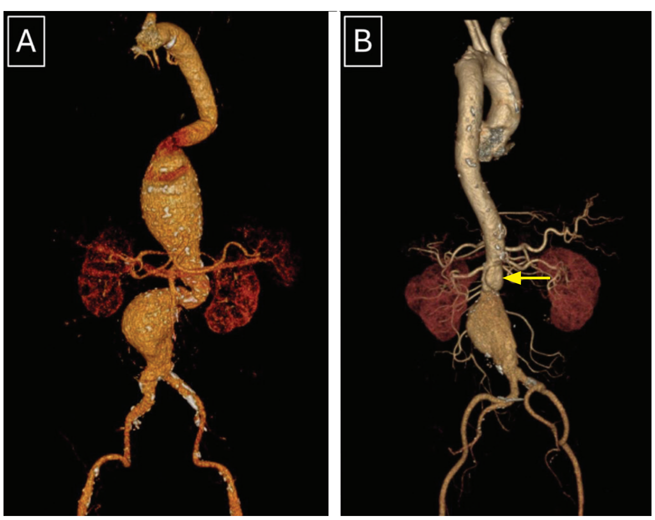

Figure 1. ***Pre-operative CT aortogram of patients A and B.*** In patient A, there is an aneurysm at the distal thoracic aorta involving the celiac and superior mesenteric origins but sparing the renal arteries (Crawford V), a short but normal infrarenal neck, then an infrarenal aortic aneurysm. Patient B exhibits a small saccular aneurysm *(yellow arrow)* and a large infrarenal aortic aneurysm.

Patient A

This is a 68-year-old hypertensive male with oxygen-dependent chronic obstructive pulmonary disease (COPD). He likewise has a history of pulmonary tuberculosis complicated by spontaneous pneumothorax which was treated with chest tube insertion 10 years prior. His current problem started with vague but persistent back and abdominal pain prompting consult and subsequent imaging tests. CT aortography done revealed aneurysmal dilatation at two sites. The first involved the distal descending thoracic aorta from the level of T9 vertebra down vto just above renal arteries, measuring 12.5 x 5.7 x 6.1 cm (L x H x W) (Crawford type V). The second affected the infrarenal aorta commencing 3.5 cm from the left renal artery and measuring 12.0 x 6.7 x 6.8 cm (Figure 1A).

The patient's poor pulmonary status incited the decision to avoid thoracotomy and instead perform a staged hybrid procedure. The first stage entailed a standard endoaneurysmorrhaphy of the infrarenal aorta using a bifurcated Dacron graft (20 x 10 mm, Terumo), followed by debranching of all reno-visceral vessels, including an accessory renal artery on the left (Figure 2A). He was readmitted a month later for the endovascular procedure. Initial aortography done revealed patent bypass grafts with good flow to all renovisceral vessels (Figure 3). A thoracic endograft (Valiant Captiva, Medtronic) was deployed with its distal end encompassing the infrarenal aortic graft. Completion aortography showed good endograft apposition with no endoleak (Figure 4). Patient was discharged on the 3rd post-operative day.

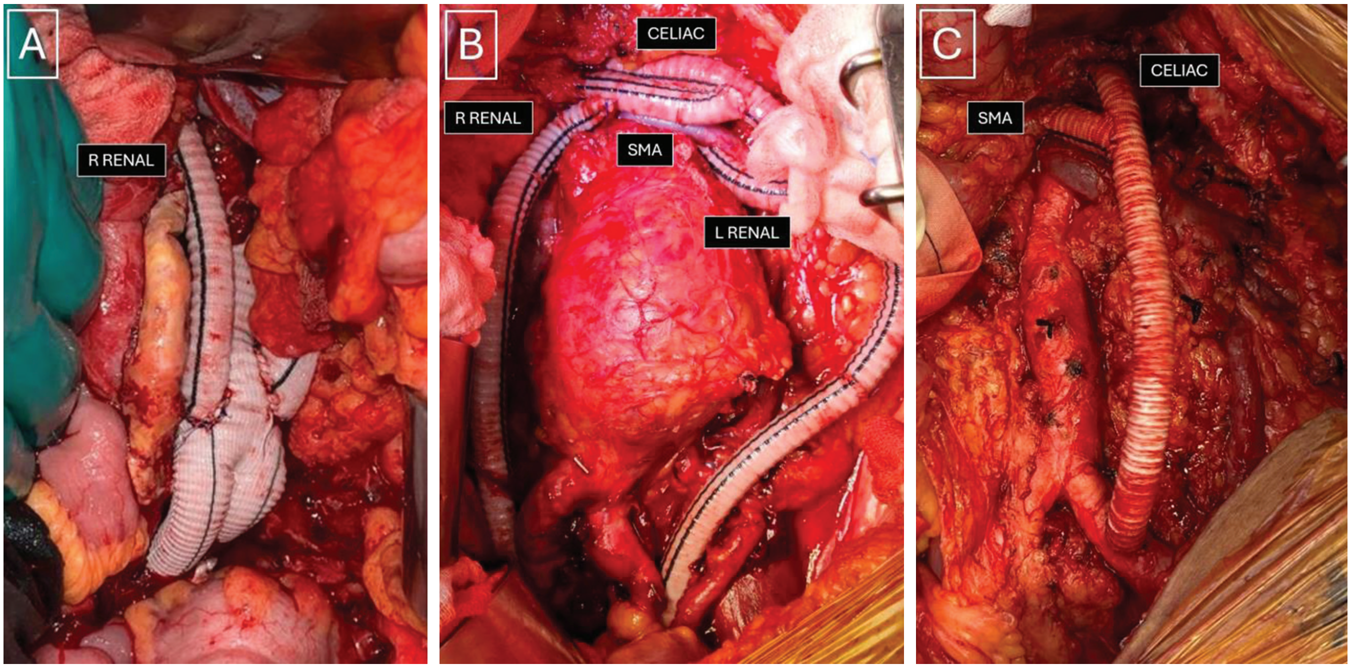

Figure 2. Visceral debranching configurations of patients A, B and C. Note infrarenal aorta of Patient A replaced with a dacron bifurcated graft.

Figure 3. Pre-deployment aortogram of Patient A showing patent reno-visceral branches.

Figure 4. Completion aortograms of Patient A showing **(A)** good flow of contrast from the thoracic to the abdominal aorta with no endoleak. **(B)** All reno-visceral vessels remained patent.

On surveillance CT aortography done six months post-EVAR however, an endoleak at the distal end of the stent graft was seen (Type 1b), associated with sac expansion from 6.4 to 7.0 cm (Figure 5). Patient was readmitted for reintervention wherein stent relining was done (Valiant Captiva, Medtronic), with resolution of the endoleak. He was discharged well on the 2nd post-operative day. Repeat CT aortography 23 months post-EVAR revealed intact right renal, SMA, celiac, left renal, and left accessory renal artery bypasses with no endoleak.

Patient B

This is a 69-year-old male, hypertensive with a history of stroke eight years prior with mild left-sided residuals,

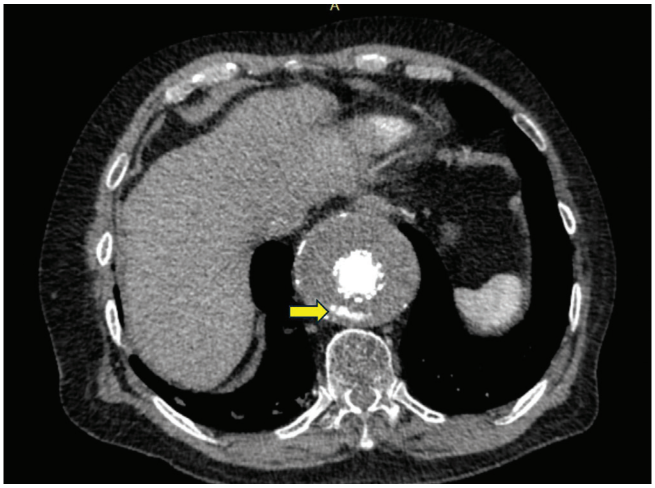

Figure 5. CT aortogram of Patient A eight months post-EVAR showed endoleak *(yellow arrow)* associated with aneurysm sac expansion.

Figure 6. Post-EVAR angiogram of Patient B using CO_2 as contrast medium showing good flow down to both iliac vessels with no endoleak.

who consulted for severe abdominal pain associated with diarrhea. CT aortography done revealed no significant gastrointestinal pathology but with an incidental finding of a saccular pararenal aneurysm measuring 2.2 cm and a fusiform infrarenal aneurysm measuring 6.1 cm in widest diameter (Figure 1B). On preoperative work-up, echocardiography showed an ejection fraction of 50% with anterolateral wall hypokinesia prompting coronary angiography which demonstrated significant 3-vessel coronary artery disease. He subsequently underwent coronary artery bypass grafting (CABG) for which he did remarkably well.

Given the risks of conventional open repair in this multiply co-morbid patient, a staged hybrid procedure was contemplated. Laparotomy with 4-vessel reno-visceral debranching was done 11 days post-CABG (Figure 2B). He developed acute kidney injury post-operatively, with rising creatinine levels but not dialysis-requiring. As soon as his creatinine stabilized, endovascular abdominal aortic aneurysm repair (EVAR) was then carried out after nine days. Angiography was done using the Angiodroid CO_2 injector system to minimize further injury to the kidneys. The endograft (Endurant II, Medtronic) was deployed accordingly, making sure the distal iliac limbs were positioned proximal to the take-off of the branch grafts. Post-deployment angiography revealed no endoleak with good flow to all reno-visceral vessels (Figure 6).

Patient C

Patient is a 56-year-old male who presented with epigastric abdominal pain radiating to the back five months prior. On work-up, he was noted to have a dissection of the descending aorta starting from T9 level down to just above the take-off of the coeliac artery. The coeliac artery arose from the false lumen while all other branches came from the true lumen. A saccular aneurysm measuring 5.4 cm in widest diameter was seen at the mid-descending aorta between T5 and T6 (Figure 7). Incidentally, a thickened segment of the descending colon was observed associated with multiple mesenteric lymphadenopathies for which malignancy was highly considered.

After multidisciplinary discussions with colorectal surgery, the patient underwent a Hartmann's procedure with complete tumor resection, after which a retrograde bypass from the left common iliac artery to the celiac and superior mesenteric artery was created (Figure 2C). The celiac and superior mesenteric arteries were both ligated at the ostia. Thoracic endovascular repair (TEVAR) was performed 10 days after with the endograft deployed just distal to the left subclavian artery proximally down to just above the renal arteries distally (Figure 8). Patient was discharged four days post-TEVAR.

DISCUSSION

Open surgical repair remains to be the intervention of choice for thoracoabdominal aneurysms in general, especially for patients who present with ruptured TAAA, those due to connective tissue disease, and with life expectancy beyond 10 years.[10] However, despite its proven durability, conventional open repair is associated with high 5-25% mortality rate[11,12] and concomitant risk for severe complications such as spinal cord ischemia, respiratory failure, and renal impairment.[13,14]

Due to the prohibitive morbidity and mortality associated with open surgical repair, endovascular treatment is now being recommended specifically in patients with degenerative aneurysms who are hemodynamically stable

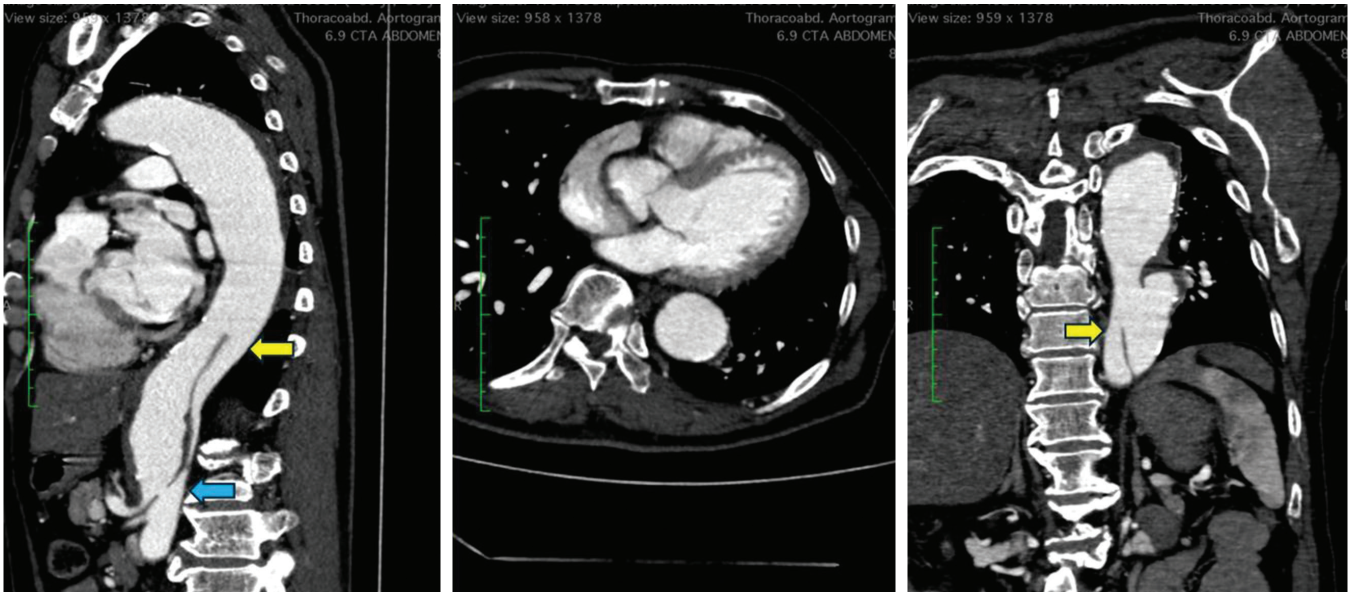

Figure 7. CT aortogram of Patient C showing entry tear at mid-descending aorta *(yellow arrow)* with saccular aneurysmal degeneration. A re-entry is noted at the level of the take-off of the celiac and superior mesenteric artery *(blue arrow)*.

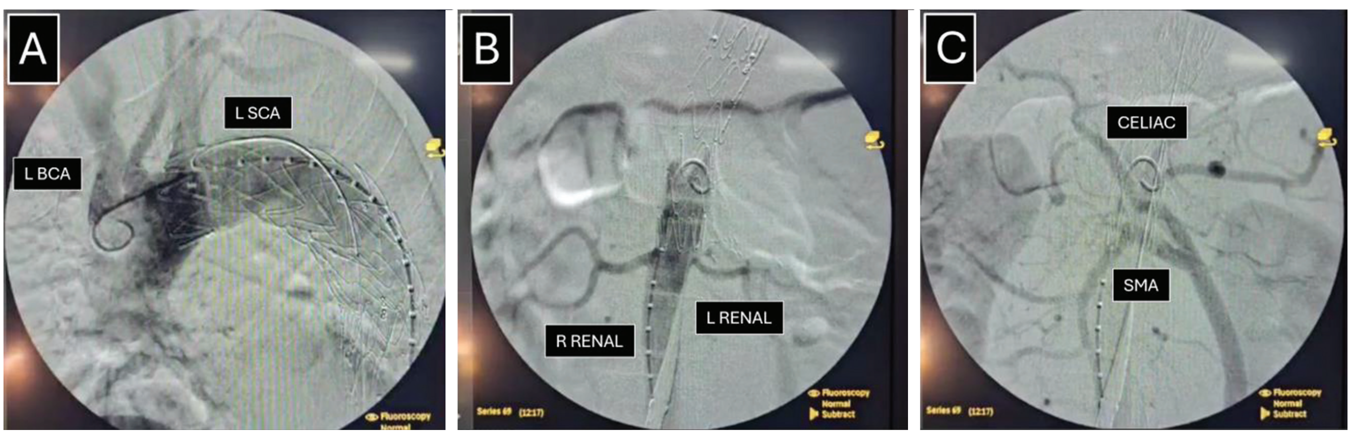

Figure 8. Post-TEVAR angiograms of Patient C showing **(A)** patent arch vessels with no endoleak, **(B)** patent renal, and **(C)** celiac and superior mesenteric arteries.

and have suitable anatomy, as long as they are performed in centers with endovascular expertise.[10] In contrast to open surgery, endovascular repair (EVAR) avoids thoracotomy and the need for single lung ventilation, making it advantageous for patients with COPD and other pulmonary issues. It is also beneficial for patients with previous thoracoabdominal surgeries where adhesions can increase the risk of intraoperative complications.[15] Moreover, endovascular repair does not require aortic cross-clamping, which reduces the risk for acute coronary events especially in patients with borderline cardiac function.

However, endovascular treatment is not without limitations. For one, a suitable aortic anatomy is mandatory for optimal outcome. This is especially true for TAAA extending to the renovisceral arteries for which there may be no adequate proximal or distal landing zones. In such instances, other endovascular options may include custom-made fenestrated or branched endografts which unfortunately, are not available in the Philippines. Intraoperative fenestration is another technique but this method entails extensive training and experience. Snorkel or chimney techniques (ch-EVAR), first described by Greenberg et al.[16] in 2003, where off-the-shelf parallel stent grafts are placed into target renal or visceral side branches to ensure vital organ perfusion and successful aneurysm sac exclusion, have been done locally. This though is correlated with difficult-to-treat complications such as late gutter or type 1a endoleak which has prevailed as the Achilles heel of this technique.[17]

Because of these limitations, hybrid aortic repair, which combines both open and endovascular techniques, was introduced for those 'unfit-for-open' or 'endovascular-excluded' patients. First described by Quinones-Baldrich et al.[8] in 1999, hybrid repair offers the same advantages of endovascular repair. In addition, although laparotomy is still required, it eliminates the need for cardiopulmonary bypass and prolonged visceral ischemia time is minimized as clamping of visceral vessels during anastomoses is limited to one organ at a time. In a single center study which utilized a patient-specific, algorithmic approach whereby higher risk patients with TAAA are treated with a 'hybrid first' strategy and lower risk patients with conventional open repair, one-year and long-term, aorta-specific survival were reported to be similar between groups.[18] Major morbidity though differed by procedure, with postoperative stroke higher in patients who underwent open repair, while a higher rate of new permanent dialysis and reintervention was noted in the hybrid repair group.

The multicenter North American Complex Abdominal Aortic Debranching (NACAAD) registry is the largest report on hybrid repair of thoracoabdominal aortic disease to date.[19] Their pooled mortality of 14%, spinal cord ischemia of 11%, paraplegia rate of 5%, pulmonary complications of 22%, and dialysis of 7% is comparable with the 11.3%, 8%, 5%, 23% and 8%, respectively, to the meta-analysis of published reports by Moulakakis et al.[20] on traditional open repair of TAAAs at high-volume centers of excellence. In this study, hybrid aortic debranching was reported to have low early mortality when done in lower-risk patients (3% if SVS score ≤9) but remains elevated in high-risk patients (34% if SVS score ≥15). Graft patency though was excellent at 90% in five years.

All three patients cited in this study presented with complex aortic anatomy and were deemed high-risk due to the existence of major co-morbidities. Hence, after careful discussion with the patient and their families, the decision was made to perform hybrid aortic repair. In our institution, we opted to perform the hybrid repair in two stages, as studies seemed to suggest a trend towards lower 30-day risks of death.[21] Theoretically, a staged procedure leads to shorter operating time, and longer recovery time for spinal cord ischemia and from surgical stress, factors which may translate to reduced risks for post-operative complications. Indeed, a recent meta-analysis showed significantly lower 30-day risk of death, lower incidence of major adverse cardiac events and intestinal complications for two-stage hybrid repair, although this was seen only in patients who completed the second stage.[22]

While our study contributes to the growing body of evidence supporting the use of hybrid repair for TAAA and pararenal aneurysms, it is important to acknowledge certain limitations. Variability in surgical expertise, patient populations, and institutional practices invariably impact generalizability. Future research should focus on refining patient selection, optimizing perioperative management, and exploring innovative techniques that can enhance the safety and efficacy of treatment.

CONCLUSION

This study serves to reinforce the role of hybrid aortic repair as a viable and effective option with favorable short-term outcomes in the management of complex TAAA and pararenal aneurysms in high-risk patients. Our early experience underscores the importance of careful patient selection and risk stratification in determining the appropriateness of the procedure. Long-term follow-up is essential to assess the durability of the repair and identify potential complications, and guide future management strategies.

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

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REFERENCES

1. Conroy PD, Rastogi V, Yadavalli SD, Giles KA, Lombardi JV, Schermerhorn ML. The rise of endovascular repair for abdominal, thoracoabdominal, and thoracic aortic aneurysms. J Vac Surg 2024. Preprint. Published online June 26, 2024. doi: 10.1016/j.jvs.2024.06.165
2. Lederle FA, Freischlag JA, Kyriakides TA, Padberg Jr FT, Matsumura JS, Kohler TR, et al. Outcomes following endovascular vs open repair of abdominal aortic aneurysm: a randomized trial. JAMA 2009 Oct; 302(14):1535-42. doi: 10.1001/JAMA.2009.1426. PMID: 19826022
3. Greenhalgh RM, Brown LC, Kwong GPS, Powell JT, Thompson SG, EVAR trial participants. Comparison of endovascular aneurysm repair with open repair in patients with abdominal aortic aneurysm (EVAR trial 1), 30-day operative mortality results: randomized controlled trial. Lancet 2004 Sep;364(9437):843-8. doi: 10.1016/S0140-6736(04)16979-1. PMID: 15351191
4. Upchurch GR, Escobar GA, Azizzadeh A, Beck AW, Conrad MF, Matsumura JS, et al. Society for Vascular Surgery clinical practice guidelines of thoracic endovascular aortic repair for descending thoracic aneurysms. J Vasc Surg 2021 Jan;73(1S):55S-83S. doi: 10.1016/j.jvs.2020.05.076. PMID: 32628988
5. Chaudhuri A, Dey R. Multi-component parallel endografts at complex TEVAR may be prone to modular dislocation causing novel endoleaks: a tale of two cases. EJVES Short Reports 2015;29:36-39
6. Coselli JS, LeMaire SA, Preventza O, de la Cruz KI, Cooley DA, Price MD, et al. Outcomes of 3309 thoracoabdominal aortic aneurysm repairs. J Thorac Cardiovasc Surg 2016 May;151(5):1323-37. doi: 10.1016/j.jtcvs.2015.12.050. PMID: 26898979
7. Conrad MF, Crawford RS, Davison JK, Cambria RP. Thoracoabdominal aneurysm repair: a 20-year perspective. Ann Thorac Surg 2007 Feb;83(2):S856-861. doi: 10.1016/j.athoracsur.2006.10.096. PMID: 17257941
8. Quinones-Baldrich WJ, Panetta TF, Vescera CL, Kashyap VS. Repair of type IV thoracoabdominal aneurysm with a combined endovascular and surgical approach. J Vasc Surg 1999 Sep;30:555-60. doi: 10.1016/s0741-5214(99)70084-4. PMID: 10477650
9. Hughes GC, Andersen ND, Hanna JM, McCann RL. Thoracoabdominal aortic aneurysm: hybrid repair outcomes. Ann Cardiothorac Surg 2012 Sep;1(3):311-319. doi: 10.3978/j.issn.2225-319X.2012.08.13. PMID: 23977513

10. Isselbacher EM, Preventza O, Black JH, Augoustides JG, Beck AW, Bolen MA, et al. 2022 ACC/AHA guideline for the diagnosis and management of aortic disease: A report of the American Heart Association/American College of Cardiology Joint Committee on Clinical Practice Guidelines. Circulation 2022 Dec;146(24), e334-482. doi: 10.1161/CIR.00000000000001106. PMID: 36322642. PMCID: PMC9876736
11. Hiremath N, Bhatnagar G, Mapara K, Younes H, Park WM. Hybrid repair of type II thoracoabdominal aortic aneurysm using modified branch-first technique. J Vasc Surg Cases Innov Tech 2023 Jan;9(1):101105. doi: 10.1016/j.jvscit.2023.101105. PMID: 36852319. PMCID: PMC9958055
12. Encalada CP, Prendes CF, Dominguez MR, Al-Sibai AZ, Gay MG, Coto JL, et al Complex aortic aneurysm: A current indication for debranching. Ann Vasc Surg 2017 May;41(281):e15–281. doi: 10.1016/j.avsg.2016.09.034. PMID: 28242405
13. Da Rocha MF, Miranda S, Adriani D, Urgnani F, Riambau VA, Mulet J. Hybrid procedures for complex aortic pathology: initial experience at a single center. Rev Esp Cardiol 2009 Aug;62(8):896-902. doi: 10.1016/s1885-5857(09)72654-4. PMID: 19706245
14. Rana MA, Gloviczki P, Duncan AA, Kalra M, Greason KL, Oderich GS, et al. Comparison of open surgical techniques for repair of types III and IV thoracoabdominal aortic aneurysms. J Vasc Surg Mar 2018;67(3):713-721. doi: 10.1016/j.jvs.2017.07.134. PMID: 29122422
15. Orozco-Sevilla V, Weldon SA, Coselli JS. Hybrid thoracoabdominal aortic aneurysm repair: Is the future here? J Vis Surg 2018 Mar;4:61. doi: 10.21037/jovs.2018.02.14. PMID: 29682471. PMCID: PMC5897682
16. Greenberg RK, Clair D, Srivastava S, Bhandari G, Turc A, Hampton J, et al. Should patients with challenging anatomy be offered endovascular aneurysm repair? J Vasc Surg 2003 Nov;38(5):990-6. doi: 10.10/s0741-5214(03)00896-6. PMID: 14603205
17. Teneva GT, Lee JT, Tran K, Dalman R, Torsello G, Fazzini S, et al. Long term chimney/snorkel endovascular aortic aneurysm repair experience for complex abdominal aortic pathologies within the PERICLES registry. J Vasc Surg 2021 Jun;73(6);1942-49. doi: 10.1016/j.jvs.2020.10.086. PMID: 33259893
18. Benrashid E, Wang H, Andersen ND, Andersen ND, Keenan MD, McCann RL, et al. Complementary roles of open and hybrid approaches to thoracoabdominal aortic aneurysm repair. J Vasc Surg 2016 Nov;64(5):1228-38. doi: 10.1016/j.jvs.2016.04.022. PMID: 27444368. PMCID: PMC5441846
19. Escobar GA, Oderich GS, Farber MA, de Souza LR, Quinones-Baldrich WJ, Patel HJ, et al. Results of the North American complex abdominal aortic debranching (NACAAD) registry. Circulation 2022 Oct;146(15):1149-58. doi: 10.1161/CIRCULATIONAHA.120.045894. PMID: 36148651
20. Moulakakis KG, Karaolanis G, Antonopoulos CN, Kakisis J, Klonaris C, Preventza O, et al. Open repair of thoracoabdominal aortic aneurysms in experienced centers. J Vasc Surg 2018 Aug;68(2):634-645. doi:10.1016/j.jvs.2018.03.410. PMID: 30037680
21. Canaud L, Karthikesalingam A, Jackson D, Cresswell L, Cliff M, Markar SS, et al. Clinical outcomes of single versus staged hybrid repair for thoracoabdominal aortic aneurysm. J Vasc Surg 2013 Nov;58(5):1192-200. doi: 10.1016/j.jvs.2013.04.016. PMID: 23810260
22. Wang J, Wang T, Zhao J, Ma Y, Huang B, Yang Y, et al. Comparison of clinical outcomes following one versus two stage hybrid repair of thoraco-abdominal aortic aneurysms: a comprehensive meta-analysis. Eur J Vasc Endovasc Surg 2021 Mar;61(3):396-406. doi: 10.1016/j.ejvs.2020.11.033. PMID: 33358102