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CASE SERIES

Anaesthetic Management of Hybrid Aortic Arch Repair: Supra-Aortic Debranching with TEVAR — A Case Series

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ABSTRACT

Hybrid aortic arch repair using supra-aortic debranching followed by thoracic endovascular aortic repair (TEVAR) has emerged as an alternative to conventional open arch surgery requiring cardiopulmonary bypass with hypothermic circulatory arrest. These hybrid procedures pose distinct anaesthetic challenges related to cerebral protection, haemodynamic instability, systemic anticoagulation, and contrast exposure. We report a case series of three patients with aortic arch pathology who underwent supra-aortic debranching followed by TEVAR in a hybrid operating theatre under general anaesthesia. A standardized perioperative anaesthetic strategy was employed, incorporating invasive arterial pressure monitoring, advanced cardiac output monitoring using FloTrac™ (invasive blood pressure, cardiac output, stroke volume, and stroke volume variation), continuous cerebral oxygenation monitoring with near-infrared spectroscopy (NIRS), urine output monitoring for renal protection, and activated clotting time–guided anticoagulation maintained between 200–250 seconds. All procedures were completed successfully without intraoperative neurological complications, major haemodynamic instability, or perioperative mortality. Postoperative management in the cardiothoracic intensive care unit was uneventful, with preserved neurological function and stable renal parameters in all patients. This case series highlights that meticulous perioperative planning, advanced haemodynamic and cerebral monitoring, vigilant anticoagulation management, and close multidisciplinary coordination enable safe anaesthetic conduct of supra-aortic debranching and TEVAR in a hybrid operating environment

Keywords*: Aorta, Thoracic; Cardiac Output; Endovascular Aneurysm Repair; Spectroscopy, Near-Infrared.*

INTRODUCTION

Aortic arch aneurysms pose considerable surgical and anaesthetic challenges owing to their close anatomical relationship with the supra-aortic vessels and the associated risk of cerebral, spinal cord, and end-organ ischemia. Conventional open aortic arch repair necessitates cardiopulmonary bypass (CPB), deep hypothermic circulatory arrest, and selective cerebral perfusion, all of which are linked to significant perioperative morbidity and neurological complications [1,2].

Hybrid aortic arch repair, comprising supra-aortic debranching followed by thoracic endovascular aortic repair (TEVAR), has emerged as an alternative approach that facilitates creation of an adequate proximal landing zone for endograft deployment while avoiding CPB and circulatory arrest [3,4]. Supra-aortic debranching involves surgical revascularization of the arch vessels, followed by endovascular exclusion of the aneurysm, thereby combining the durability of surgical reconstruction with the minimally invasive advantages of endovascular techniques [5].

Despite reduced surgical invasiveness, hybrid repair introduces distinct anaesthetic challenges related to cerebral perfusion, haemodynamic control, and anticoagulation. These procedures are associated with substantial physiological stress, transient disturbances in cerebral perfusion, haemodynamic fluctuations, systemic anticoagulation, and an increased risk of perioperative neurological injury during both the surgical and endovascular phases [6]. From an anaesthesiologist's perspective, maintaining adequate cerebral perfusion, ensuring precise blood pressure control, and instituting vigilant neurological monitoring are central to achieving favourable outcomes.

The existing literature on hybrid aortic arch repair predominantly emphasizes surgical outcomes, with comparatively limited focus on perioperative anaesthetic management. Published reports addressing anaesthetic considerations are largely restricted to isolated case reports and brief communications [7]. In this context, we present a case series of three patients undergoing supra-aortic debranching followed by TEVAR, highlighting perioperative anaesthetic management, monitoring strategies, and practical considerations relevant to anaesthesiologists involved in these high-risk procedures.

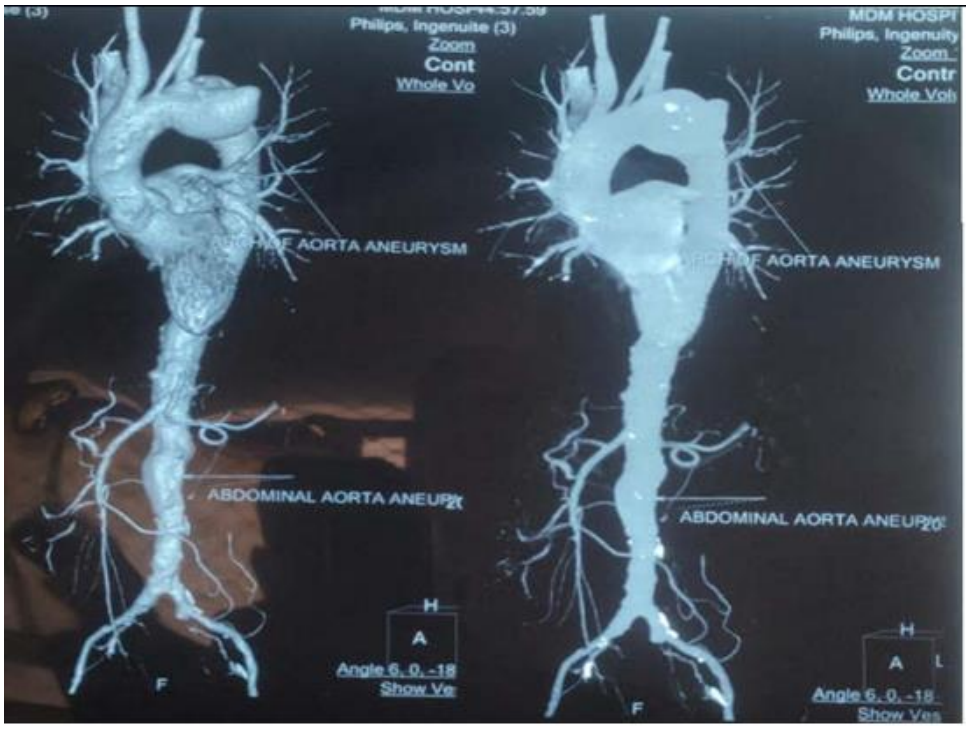
CASE SERIES

Case 1

A 61-year-old male presented with chest discomfort and exertional dyspnoea of three months duration. Computed tomography thoracic and abdominal angiography revealed a long-segment aneurysmal dilatation involving the aortic arch proximally and the entire descending thoracic aorta, while the ascending aorta and supra-aortic branch vessels were of normal calibre. The aneurysm extended over a segment of approximately 21 cm, with a maximum diameter measuring up to 6.8 cm and was atherosclerotic in nature. No evidence of acute dissection or rupture was noted.

Case 2

A 65-year-old male presented with chest pain and hoarseness of voice of two months duration. Computed tomography thoracic and abdominal angiography revealed a focal contrast-filled saccular aneurysm arising from the aortic arch at the origin of the left subclavian artery, with extension into the proximal descending thoracic aorta. The aneurysm measured approximately 6.4 × 6.5 × 5.5 cm and showed surrounding non-enhancing mural thrombus of up to 14.6 mm thickness, consistent with partial thrombosis. The ascending aorta and proximal aortic arch were of normal calibre, and the supra-aortic branch vessels were patent, with no evidence of acute dissection or rupture. Atherosclerotic changes with circumferential calcified and non-calcified plaques causing mild-to-moderate luminal narrowing were noted in the thoracic aorta. No imaging features suggestive of impending rupture were identified. (Table/Figure 1).



Table/Figure 1: Computed tomography angiography (CTA) with three-dimensional volume-rendered reconstruction showing a broad-based saccular aneurysm arising from the distal aortic arch, just distal to the origin of the left subclavian artery (Case 2). The ascending aorta and proximal supra-aortic branches are of normal calibre, with no evidence of acute dissection or rupture.

Case 3

A 60-year-old male presented with cough, chest pain, and low-grade fever of approximately 20 days duration. Computed tomography angiography of the thorax revealed a large fusiform aneurysmal dilatation of the aortic arch proximally extending to descending thoracic aorta without involving abdominal aorta, measuring approximately 12.4 × 13.0 × 12.8 cm in maximum dimensions, with peripheral calcification, consistent with a chronic aneurysmal process. The aneurysm produced mass effect on the adjacent lung parenchyma, associated with minimal left pleural effusion, but no radiological evidence of rupture.

Surgical Technique

In view of the aneurysm size and anatomy, the patient was planned for hybrid aortic repair consisting of supra-aortic debranching followed by thoracic endovascular aortic repair (TEVAR). Surgical exposure was achieved with the patient in the supine position, with neck extension facilitated using a shoulder roll. Bilateral longitudinal carotid crease incisions and a left supraclavicular incision were made. The right and left common carotid arteries were dissected, exposed, and looped. Through the left supraclavicular approach, the left subclavian artery was exposed proximal to the origin of the left vertebral and left internal thoracic arteries (first part of the left subclavian artery). A tunnel was created posterior to the trachea and oesophagus and anterior to the vertebral column.

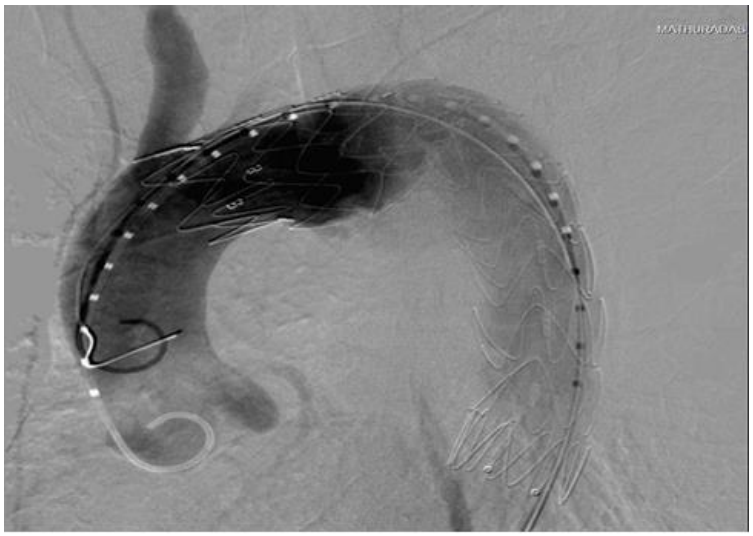
Following systemic heparinisation (100 IU/kg), a 7-mm ringed polytetrafluoroethylene (PTFE) graft was anastomosed to the supra-aortic vessels in an end-to-side or side-to-side configuration based on individual vascular anatomy to achieve supra-aortic debranching (Table/Figure 2). The proximal anastomosis was performed end-to-side to the right common carotid artery, after which the graft was tunnelled posterior to the trachea and oesophagus. Distal revascularisation was completed with end-to-side anastomoses to the left common carotid and left subclavian arteries. Following confirmation of adequate graft flow, the proximal native left subclavian artery was ligated to prevent retrograde perfusion of the aneurysmal segment. All cervical incisions were closed in layers over suction drains.

Table/Figure 2: Intraoperative image demonstrating cervical surgical exposure and supra-aortic debranching with a ringed PTFE graft anastomosed to the target vessel during hybrid aortic arch repair.

Intraoperative angiography confirmed the morphology and extent of the distal aortic arch aneurysm and guided accurate positioning of the thoracic stent graft (Table/Figure 3).

Table/Figure 3: Intraoperative digital subtraction angiography (LAO projection) demonstrating a large saccular aneurysm arising from the distal aortic arch with catheter and guidewire positioned within the aortic lumen prior to thoracic endovascular aortic stent graft deployment

Subsequently, the thoracic endovascular aortic procedure was performed via bilateral femoral arterial access. A 5-Fr pigtail catheter was positioned in the ascending aorta for angiographic assessment. A Lunderquist® extra-stiff guidewire (0.035″ × 260 cm; Cook Medical) was advanced into the ascending aorta. A thoracic stent graft (Valiant™ Captivia, Medtronic; 36 × 36 × 200 mm) was then deployed in aortic arch zone 1, distal to the brachiocephalic artery, under fluoroscopic guidance to exclude the aneurysm. Completion angiography confirmed adequate aneurysm exclusion with no evidence of endoleak (Table/Figure 4). The patients were transferred to the cardiothoracic intensive care unit with stable haemodynamics and no immediate neurological deficits.



Table/Figure 4: Completion digital subtraction angiography (LAO projection) following thoracic endovascular aortic repair demonstrating optimal deployment of the thoracic stent graft across the distal aortic arch (zone 1) with complete exclusion of the aneurysmal sac and no evidence of endoleak.

Anaesthetic Management

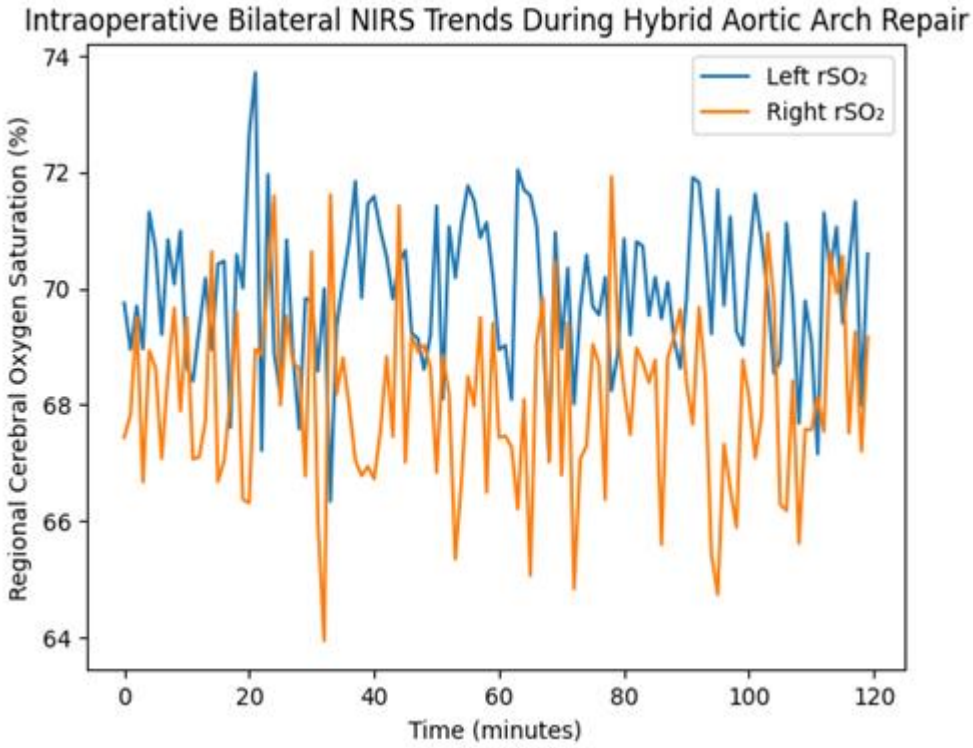
All procedures were conducted in a hybrid operating theatre, allowing seamless conduct of both surgical and endovascular phases without inter-departmental transfer. General endotracheal anaesthesia was used in all patients to ensure airway protection, patient immobility, controlled ventilation, and precise haemodynamic control during hybrid interventions. Multimodal analgesia was employed to facilitate early extubation and neurological assessment in the postoperative period.

Monitoring and Vascular Access

Standard ASA monitoring was instituted in all patients. In addition, invasive arterial blood pressure monitoring was established under local anaesthesia at right radial artery using 20G cannula for beat-to-beat hemodynamic assessment of cardiac output, stroke volume and stroke volume variation using FloTrac™, facilitating goal-directed fluid therapy and optimization of preload during periods of vascular clamping and stent deployment. Two wide-bore peripheral intravenous (14/16G) cannulas were placed in all patients. The femoral vein was prepared and kept as standby for potential surgical use during stent graft deployment, anticipating the need for rapid volume resuscitation or additional vasoactive support during femoral arterial manipulation.

Cerebral Monitoring and Protection

Masimo continuous near-infrared spectroscopy (NIRS) was used to monitor regional cerebral oxygen saturation throughout the procedure. Baseline values were recorded prior to induction, and trends were closely observed during supra-aortic vessel manipulation and endograft deployment. Mean arterial pressure was maintained at or slightly above baseline values to preserve cerebral perfusion. Any reduction in cerebral oxygen saturation prompted immediate corrective measures, including checking for graft patency, augmentation of blood pressure, optimization of ventilation, and correction of intravascular volume status. (Table/Figure 5)



Table/Figure 5: Intraoperative trends of bilateral regional cerebral oxygen saturation (rSO_2) monitored using near-infrared spectroscopy during hybrid aortic arch repair. Left and right frontal rSO_2 values remained stable throughout the procedure, with no significant asymmetry or sustained desaturation episodes.

Induction and Maintenance of Anaesthesia

Anaesthesia was induced with fentanyl (2–3 µg/kg) and propofol (2 mg/kg), titrated to minimise haemodynamic fluctuations, followed by rocuronium (1.2 mg/kg) to facilitate airway control. Anaesthetic maintenance was titrated to depth of anaesthesia using Masimo SedLine® Patient State Index (PSI), with isoflurane (0.8–1.2 MAC) in an oxygen–air mixture and intermittent fentanyl supplementation. Additional boluses of rocuronium (0.1–0.2 mg/kg) were administered as required to maintain adequate neuromuscular blockade.

Anticoagulation and Hemodynamic Control

Systemic anticoagulation was achieved with intravenous heparin at a dose of 100 IU/kg prior to vascular anastomosis and endovascular intervention. Activated clotting time (ACT) was monitored intraoperatively and maintained between 200–250 seconds. Close communication between the surgical and anaesthesia teams was maintained to ensure appropriate timing of anticoagulation and vigilance for bleeding. During stent deployment, transient hemodynamic fluctuations were anticipated. Blood pressure was carefully controlled to facilitate accurate endograft placement while avoiding excessive hypotension that could compromise cerebral or spinal cord perfusion. Cross-matched packed red blood cells (PRBCs) were kept available for all three patients for immediate transfusion if required. One patient required transfusion of a single unit of PRBC intraoperatively, following which haemodynamic stability was maintained.

Renal Protection and Fluid Management
A urinary catheter was inserted in all patients for continuous urine output monitoring (≥ 0.5 mL·kg⁻¹·h⁻¹), particularly in view of contrast dye usage during the endovascular phase. Fluid administration was guided by invasive and advanced hemodynamic parameters to avoid both hypovolemia and fluid overload.

Post-procedure Care
At the completion of the procedure, patients were transferred intubated to the cardiothoracic intensive care unit and planned extubation was performed. Post-extubation neurological assessment was carried out clinically, focusing on level of consciousness, speech, and motor function. Intraoperative and immediate postoperative NIRS trends were reviewed as an adjunct to clinical neurological evaluation. A summary of all cases presented in table 6.

Table 6/Figure 6: Summary of Clinical and Perioperative Characteristics

Variable	Case 1	Case 2	Case 3
Age / Sex	61 / M	65 / M	60 / M
Symptoms (duration)	Chest pain, dyspnoea (3 mo)	Chest pain, hoarseness (2 mo)	Chest pain, cough, fever (20 d)
CT angiography	Arch–DTA aneurysm	Distal arch aneurysm	Fusiform DTA aneurysm
Max diameter (cm)	6.8	~6.5	12.4 × 13.0 × 12.8
Procedure	Debranching + TEVAR	Debranching + TEVAR	Debranching + TEVAR
Debranching graft	7-mm PTFE	6-mm PTFE	7-mm PTFE
Stent graft	Valiant™ Captivia 36×36×200 mm	Valiant™ Captivia 36×36×200 mm	Valiant™ Captivia 36×36×200 mm
Landing zone	Zone 1	Zone 1	Zone 1
Anaesthesia	General endotracheal anaesthesia	General endotracheal anaesthesia	General endotracheal anaesthesia
Monitoring	IBP, FloTrac™, NIRS	IBP, FloTrac™, NIRS	IBP, FloTrac™, NIRS
Anticoagulation	Heparin; ACT 200–250 s	Heparin; ACT 200–250 s	Heparin; ACT 200–250 s
Urinary catheter / UOP	Yes / ≥0.5 mL·kg⁻¹·h⁻¹	Yes / ≥0.5 mL·kg⁻¹·h⁻¹	Yes / ≥0.5 mL·kg⁻¹·h⁻¹
PRBC transfusion	No	No	Yes (1 unit)
Outcome	Uneventful	Uneventful	Uneventful

Abbreviations**:** DTA, descending thoracic aorta; IBP, invasive blood pressure; NIRS, near infrared spectroscopy; ACT, activated clotting time; PRBC, packed red blood cells.

DISCUSSION
Aortic arch aneurysms constitute a particularly challenging subset of aortic pathology because of their close anatomical relationship with the supra-aortic vessels and the associated risk of cerebral ischaemia. Although open aortic arch surgery has long been considered the definitive treatment, its reliance on cardiopulmonary bypass and hypothermic circulatory arrest limits its suitability in elderly patients and those with significant comorbidities due to concerns regarding perioperative morbidity and neurological injury [1,6]. Consequently, hybrid aortic arch repair, combining supra-aortic debranching with thoracic endovascular aortic repair (TEVAR), has emerged as a less physiologically demanding alternative that permits effective aneurysm exclusion while reducing the risks inherent to conventional open repair [2,3,5].

In the present case series, all patients had large aortic arch or descending thoracic aortic aneurysms requiring creation of an adequate proximal landing zone. Supra-aortic debranching followed by TEVAR resulted in successful aneurysm exclusion in all cases, without endoleak, perioperative mortality, or postoperative neurological deficits.

From an anaesthetic perspective, hybrid aortic arch repair poses challenges distinct from both open arch surgery and isolated TEVAR. Cerebral protection is paramount because supra-aortic vessel manipulation and temporary carotid clamping can compromise cerebral perfusion. Previous studies have demonstrated a substantial incidence of neurological injury following aortic arch surgery, underscoring the importance of vigilant cerebral monitoring [1,6]. In our series, maintenance of mean arterial pressure at or above baseline values, together with continuous cerebral oximetry, enabled early detection of cerebral desaturation and prompt corrective measures.

Near-infrared spectroscopy (NIRS) has gained acceptance as a non-invasive tool for monitoring regional cerebral oxygenation during cardiac and vascular procedures. Its utility in detecting cerebral hypoperfusion during cardiac surgery and carotid artery clamping has been well established [8–10]. Our experience corroborates these findings, with NIRS serving as a valuable adjunct to invasive haemodynamic monitoring and postoperative neurological assessment during hybrid aortic arch repair.

Systemic anticoagulation is integral to hybrid aortic procedures to prevent thromboembolic complications but necessitates careful monitoring to mitigate bleeding risk. Activated clotting time–guided anticoagulation, as employed in our patients, has been recommended during complex endovascular aortic interventions [7]. Additionally, exposure to contrast media during TEVAR mandates close renal surveillance; urine output monitoring and postoperative renal assessment remain essential components of perioperative management [11,12].

Postoperative care in a dedicated cardiothoracic intensive care unit facilitates early identification of neurological, cardiovascular, and renal complications following major vascular surgery [13]. In our patients, planned extubation and structured neurological evaluation allowed timely assessment, with no adverse neurological or renal outcomes observed. Despite limitations inherent to a small case series and absence of long-term follow-up, our experience supports hybrid aortic arch repair as a feasible option in selected patients and highlights the pivotal role of meticulous anaesthetic management in optimizing cerebral protection, haemodynamic stability, anticoagulation, and end-organ perfusion during these complex hybrid procedures.

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