RESEARCH PAPER

Anaesthetic Management for the Excision of a Vascular Ring Causing Tracheoesophageal Compression in a Neonate: A Case Report and Review of the Literature

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ABSTRACT

Background: Vascular rings represent a rare subset of congenital cardiovascular malformations, comprising 1–3% of congenital heart defects. Characterised by abnormal regression of embryonic aortic arches, these anomalies form a compressive circle around the trachea and oesophagus. The resulting symptoms are mechanically driven, ranging from mild dysphagia to life-threatening airway obstruction.

Case Presentation: We report the anaesthetic and perioperative management of an 18-day-old, full-term female neonate presenting with critical respiratory distress and dysphagia. Computed tomography angiography confirmed a right aortic arch with an aberrant left subclavian artery (RAA-ALSA) and a left ligamentum arteriosum, forming a complete vascular ring with 60% tracheal stenosis.

Management and Outcome: Urgent surgical division of the ligamentum arteriosum via a left posterolateral thoracotomy was performed. Anaesthetic management prioritized the preservation of spontaneous ventilation during inhalational induction to prevent dynamic collapse of the malacic trachea. Following bronchoscopy-guided intubation with a 3.5 mm endotracheal tube and successful surgical decompression, the patient was managed in the pediatric cardiac intensive care unit. Extubation was achieved 48 hours postoperatively, with complete resolution of feeding difficulties and marked respiratory improvement.

Conclusion: This case highlights the necessity of meticulous preoperative planning and multidisciplinary collaboration. Successful management of severe vascular rings demands a thorough understanding of patient-specific anatomy, deviation from standard airway paralysis algorithms to preserve intrinsic airway tone, and the immediate availability of advanced airway adjuncts.

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INTRODUCTION

Vascular rings are a unique anatomical subset of congenital heart disease (CHD). Unlike intracardiac shunts (e.g., ventricular septal defects) or cyanotic lesions (e.g., Tetralogy of Fallot) that primarily disrupt hemodynamics and oxygenation, vascular rings act primarily as space-occupying lesions (1). Their clinical danger stems not from aberrant blood flow, but from the mechanical strangulation of the trachea and oesophagus. Since the first successful surgical division by Dr Robert Gross in 1945, vascular rings have remained a diagnostic challenge for pediatricians and a high-stakes airway management scenario for anaesthesiologists (2).

Clinical presentations vary according to the degree of compression. Mild cases may manifest as "noisy breathing" erroneously attributed to laryngomalacia, while severe phenotypes can present with near-total airway obstruction requiring emergency intervention (3). The functional outcome of a restrictive vascular ring a narrowed, malformed, and highly collapsible trachea (tracheomalacia) poses a significant risk during the induction of general anaesthesia (4).

This article presents a detailed case report of a neonate with critical airway compromise secondary to a right aortic arch with an aberrant left subclavian artery (RAA-ALSA). Utilising this case as a framework, we review the embryological basis of vascular rings, evaluate diagnostic modalities, and explore the ongoing anaesthetic debate regarding the preservation of spontaneous ventilation versus controlled ventilation.

REVIEW OF THE LITERATURE

Embryological Basis and Anatomical Classification

The normal development of the great vessels originates from a bilaterally symmetrical system comprising a ventral aortic sac, bilateral dorsal aortae, and six pairs of branchial arches. Normal human anatomy results from the programmed involution of the right-sided distal dorsal aorta and the right fourth arch (5):

- **1st and 2nd Arches:** Regress early to form the maxillary and hyoid arteries.
- **3rd Arch:** Transitions into the common carotid arteries.
- **4th Arch:** The left arch persists as the definitive adult aortic arch; the right forms the proximal right subclavian artery.
- **6th Arch:** Develops into the pulmonary arteries and the ductus arteriosus.

Pathological variations occur when segments that typically regress persist, creating a circumferential entrapment of mediastinal structures. According to the National Library of Medicine's Medical Subject Headings (MeSH), a vascular ring refers specifically to these congenital vascular anomalies that encircle the trachea and oesophagus (6).

The most common symptomatic forms are:

Double Aortic Arch (DAA): Characterized by the persistence of the distal right dorsal aorta. Two patent arches (usually a dominant right and hypoplastic left) encircle the trachea and oesophagus. Because both limbs are vascular and often pulsatile, DAA typically causes high-grade compression and early neonatal presentation with severe stridor or dysphagia (7).

Right Aortic Arch with Aberrant Left Subclavian Artery (RAA-ALSA): A right-sided arch is formed with the left subclavian artery arising distally and crossing behind the oesophagus. The ring is completed anteriorly and laterally by a fibrous cord, the left ligamentum arteriosum. While the surgeon's anatomical approach differs from DAA, the functional implication for the anaesthesiologists remains identical: a severely narrowed airway prone to collapse (8).

CASE PRESENTATION

Patient History and Physical Examination

An 18-day-old female infant, born at term weighing 2.9 kg, was referred to our tertiary care centre for the management of neonatal respiratory distress. The infant had a history of oxygen requirement and a brief period of continuous positive airway pressure (CPAP) support immediately following birth.

The parental history was classic for vascular ring pathology. They reported persistent "noisy breathing" present during sleep but exacerbated significantly during periods of agitation. Feeding was notably impaired; the infant would latch, take a few swallows, and subsequently pull away gasping or coughing. This dysphagia-induced respiratory distress is a hallmark pathophysiological sign. As a bolus of milk distends the oesophagus, it presses anteriorly against the membranous posterior wall of the trachea (which is already compressed by the vascular ring), critically narrowing the airway lumen.

On admission, the infant was alert but tachypnoeic (respiratory rate: 42–50 breaths/minute) with mild subcostal and intercostal retractions. Auscultation revealed a biphasic stridor that was more pronounced during inspiration. Lung fields were clear of crackles. The precordial examination was unremarkable, with normal heart sounds

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and no murmurs, consistent with an isolated vascular anomaly. Oxygen saturation was 94% on room air at rest but demonstrated significant lability, declining to 88% during crying or feeding attempts.

Diagnostic Assessment

An initial chest radiograph (CXR) revealed a right-sided aortic arch, indicated by an indentation of the tracheal air column on the right and the absence of a left-sided aortic knob. While a right aortic arch can be an isolated, non-pathologic finding, its presence in an infant with stridor is highly suggestive of a vascular ring.

Contrast-enhanced computed tomography angiography (CTA) of the chest with 3D reconstruction was performed to delineate the anatomy. Imaging confirmed a right aortic arch with an aberrant left subclavian artery originating from a Kommerell's diverticulum and coursing retro-oesophageally. A left ligamentum arteriosum completed the ring. Crucially, the CTA visualised the "compression zone." The trachea was narrowed to a diameter of 3.2 mm at the level of the arch, representing an approximate 60% stenosis relative to the expected diameter for a neonate. Furthermore, the oesophagus exhibited significant extrinsic posterior compression.

Preoperative Anaesthetic Considerations

Anaesthetic management was predicated on a singular physiological goal: the preservation of intrinsic airway tone. In healthy infants, cartilaginous tracheal rings maintain patency. In infants with vascular rings, chronic *in utero* compression frequently results in tracheomalacia. While the infant is awake and breathing spontaneously, pharyngeal muscle tone and the negative intrathoracic pressure generated during spontaneous inspiration create a pressure gradient that stents the airway open. The induction of general anaesthesia, particularly when combined with neuromuscular blocking agents, abolishes this muscle tone and precipitates fatal airway collapse.

Intraoperative Management

A comprehensive airway rescue strategy was prepared. Endotracheal tubes (ETT) ranging from sizes 3.0 to 4.5 mm (cuffed and uncuffed) were available. A video laryngoscope equipped with paediatric Miller 1 and Macintosh 1 blades was selected as the primary intubation device, with a 3.5 mm outer-diameter flexible fibreoptic bronchoscope ready for immediate use. A perfusion team was on standby with a primed heart-lung machine in the operating theatre; the surgical team was prepared to perform an emergency sternotomy and cannulate for cardiopulmonary bypass (CPB) in the event of intractable airway collapse.

Standard American Society of Anesthesiologists (ASA) monitors were applied, supplemented by invasive arterial blood pressure, central venous pressure, continuous end-tidal carbon dioxide ($EtCO_2$), nasopharyngeal temperature, and urine output monitoring.

An inhalational induction maintaining spontaneous ventilation was chosen, representing the classical and arguably safest approach for severe, fixed tracheal compression. The patient was positioned with 30-degree head elevation. Sedative premedication was avoided to prevent pre-induction apnoea. Following 3 minutes of pre-oxygenation with 100% oxygen via a tight-fitting mask, sevoflurane was introduced at 1% and incrementally increased by 1% every 30–45 seconds until reaching 5–6%. Intravenous propofol and fentanyl were withheld during this phase.

Once a deep plane of anaesthesia was achieved without the administration of muscle relaxants, gentle direct laryngoscopy was performed using a Miller 1 blade. The glottic view was optimal (Cormack-Lehane Grade 1). An uncuffed 3.5 mm ETT was advanced beyond the stenotic tracheal segment. Immediately following intubation, the flexible fibreoptic bronchoscope was inserted through the ETT to verify that the tip was positioned distal to the zone of pulsatile external compression but proximal to the carina. Following connection to the ventilator and confirmation of stable $EtCO_2$ waveforms and tidal volumes, neuromuscular blockade (vecuronium 0.1 mg/kg) and analgesia (fentanyl 3–5 mcg/kg) were administered. The patient was successfully ventilated throughout the procedure with acceptable mean airway pressures (16–19 cm H_2O).

Surgical Intervention

The surgical objective was to break the ring and relieve the constriction. The approach requires meticulous dissection to avoid iatrogenic injury to the phrenic, vagus, and recurrent laryngeal nerves, the latter of which loops in close proximity to the ligamentum arteriosum.

A left posterolateral thoracotomy was performed, and the left lung was retracted anteriorly. The aberrant left subclavian artery was visualised arising from the dorsal aorta, and the ligamentum arteriosum was identified connecting the pulmonary artery to the descending aorta. The ligamentum was successfully divided. Extensive

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dissection was performed around the aberrant subclavian artery and the oesophagus to lyse adhesive fibrous bands. Intraoperative bronchoscopy confirmed immediate improvement in tracheal calibre and the resolution of the previously noted pulsatile compression on the posterior tracheal wall.

Postoperative ICU Course

The patient was transferred to the Paediatric Cardiac Intensive Care Unit (PCICU) intubated, receiving a continuous infusion of dexmedetomidine and low-dose propofol. To mitigate airway oedema, dexamethasone (0.1 mg/kg) was administered every 8 hours for 24 hours prior to extubation.

On postoperative day two, the infant was successfully extubated and transitioned to a High-Flow Nasal Cannula (HFNC). HFNC delivered heated, humidified oxygen and generated physiological positive end-expiratory pressure (PEEP, approximately 4–5 cm H_2O), safely stenting the tracheomalacic segment. Neonatal pain management was balanced to provide comfort without inducing apnoea; a multimodal regimen of carefully titrated opioids and non-steroidal anti-inflammatory drugs (NSAIDs) was utilised.

The postoperative prognosis for isolated vascular rings is excellent, though respiratory morbidity is common during the recovery phase. For this patient, feeding difficulties resolved entirely, indicating complete relief of oesophageal compression. Mild stridor was only audible during extreme agitation, consistent with an expected trajectory for resolving tracheomalacia.

DISCUSSION

The "Spontaneous vs. Controlled" Ventilation Debate

The management of this patient strictly adhered to the classical anaesthetic teaching: maintain spontaneous ventilation (SV) to prevent catastrophic airway collapse. However, this dogma is subject to active debate within contemporary paediatric anaesthesia literature (9).

The Argument for Spontaneous Ventilation (SV): The traditional view asserts that the negative intrathoracic pressure generated by the diaphragm during spontaneous inspiration actively pulls the structurally compromised trachea open. Conversely, positive pressure ventilation (PPV) forces air into the lumen; if the obstruction is extra-thoracic or if the tissues are highly compliant (malacic), this positive pressure can compress the surrounding soft tissues against the rigid vascular obstruction, worsening the block. Furthermore, the administration of muscle relaxants abolishes pharyngeal muscle tone, removing the critical scaffolding that keeps the airway patent (10,11).

The Argument for Controlled Ventilation (CV): Recent literature suggests that the hazards of CV may be historically overstated. Proponents argue that the profound hypoventilation, hypercapnia, and hypoxia that can occur during a prolonged, difficult SV induction pose a greater tangible risk than the theoretical risk of airway collapse. With the advent of sugammadex, some experts advocate for a modified rapid sequence induction using high-dose rocuronium to rapidly achieve optimal intubating conditions. In the event of airway collapse, the blockade can be reliably reversed within minutes. Furthermore, modern anaesthesia workstations deliver highly precise Pressure Control Ventilation (PCV), allowing anaesthesiologists to continuously stent the airway open with PEEP (12).

Despite the growing acceptance of CV techniques, in a neonate presenting with a fixed 60% stenosis and secondary tracheomalacia, the margin for error is virtually non-existent. We contend that the SV approach remains the safest initial strategy to prevent the catastrophic complication of hypoxic brain injury (13).

Tracheomalacia: The Postoperative Challenge

It is imperative to recognise that while surgical intervention corrects the vascular anatomy, it does not immediately reverse the resulting airway deformity. The infant's tracheal cartilage, having been compressed *in utero* for months, remains soft, abnormally compliant, and "C-shaped" rather than "O-shaped". This tracheomalacia persists even after the extrinsic vascular ring is divided (14). Consequently, when the infant cries or coughs, increased intrathoracic pressure can still precipitate dynamic tracheal collapse. This physiological reality dictates that symptoms often persist for weeks or months post-surgery. Parents must be adequately counselled that respiratory noise will not vanish immediately; the cartilaginous rings require time to grow and stiffen (15).

CONCLUSION

The perioperative management of a neonatal vascular ring is a quintessential demonstration of precision medicine. It requires radiologists to map complex, anomalous vessels, surgeons to navigate delicate neurovascular terrain, and anaesthesiologists to expertly

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balance the maintenance of spontaneous respiration against the necessity of securing a critical airway.

This case reinforces the clinical validity of the classical anaesthetic approach: inhalational induction with the preservation of spontaneous ventilation. While advancements in pharmacological reversal agents and ventilator technology offer alternative strategies, the safety profile of relying on the patient's intrinsic respiratory mechanics remains superior when managing severe, fixed airway obstructions. As the field advances, the integration of preoperative 3D anatomical modelling promises to further refine these surgical and anaesthetic strategies. Ultimately, for this 18-day-old infant, the convergence of heightened vigilance, classical anaesthetic techniques, and seamless multidisciplinary teamwork successfully bridged the gap to a normal life.

REFERENCES

1. Sahu A, Moe TG. Identification and management of vascular rings and slings. JACC Case Rep. 2024;29(8):102316. doi:10.1016/j.jaccas.2024.102316.
2. Al-Dairy A, Ibrahim R, Hawat A, Al-Bitar A. Surgical repair of a vascular ring: A frequently misdiagnosed disease. Int J Surg Case Rep. 2025;128:111038. doi:10.1016/j.ijscr.2025.111038.
3. Al-Alwan A, Kaminsky D. Vocal cord dysfunction in athletes: Clinical presentation and review of the literature. Phys Sportsmed. 2012;40(2):80-89. doi:10.3810/psm.2012.05.1961.
4. Vinograd I, Filler RM. Tracheomalacia. In: Newborn Surgery. 2nd ed. 2023. p. 259-266.
5. Khalid N, Bordoni B. Embryology, great vessel. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2023.
6. Backer CL, Mongé MC, Popescu AR, Eltayeb OM, Rastatter JC, Rigsby CK. Vascular rings. Semin Pediatr Surg. 2016;25(3):165-175. doi:10.1053/j.sempedsurg.2016.02.009.
7. Majid Y, Warade M, Aziz Z, Karthik GA. Double aortic arches, esophageal atresia and tracheal compression. J Indian Assoc Pediatr Surg. 2009;14(2):70-72. doi:10.4103/0971-9261.55157.
8. Fekadu D, Fantahun S, Alemayehu A, Eshetu Y, Assefa G, Hailu SS. Right-sided aortic arch with aberrant left subclavian artery arising from Kommerell's diverticulum: A case report. Radiol Case Rep. 2024;19(10):4675-4679. doi:10.1016/j.radcr.2024.06.090.
9. Lotke PA, Abboud JA, Ende J. Lippincott's Primary Care Orthopaedics. Philadelphia: Lippincott Williams & Wilkins; 2014. p. 382.
10. Nouraei SAR, Giussani DA, Howard DJ, Sandhu GS, Ferguson C, Patel A. Physiological comparison of spontaneous and positive-pressure ventilation in laryngotracheal stenosis. Br J Anaesth. 2008;101(3):419-423. doi:10.1093/bja/aen171.
11. Sattari S, Mariano CA, Kuschner WG, Taheri H, Bates JHT, Eskandari M. Positive- and negative-pressure ventilation characterized by local and global pulmonary mechanics. Am J Respir Crit Care Med. 2023;207(5):577-587. doi:10.1164/rccm.202111-2480OC.
12. Jain RK, Swaminathan S. Anaesthesia ventilators. Indian J Anaesth. 2013;57(5):525-532. doi:10.4103/0019-5049.120150.
13. De Campos Vieira Abib S, Chui CH, Cox S, Abdelhafeez AH, Fernandez-Pineda I, Elgendy A, et al. International Society of Paediatric Surgical Oncology (IPSO) surgical practice guidelines. Ecancermedicalscience. 2022;16:1356. doi:10.3332/ecancer.2022.1356.
14. Warburton D, El-Hashash A, Carraro G, Tiozzo C, Sala F, Rogers O, et al. Lung organogenesis. Curr

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Top Dev Biol. 2010;90:73-158. doi:10.1016/S0070-2153(10)90003-3.

15. Aneeshkumar S, Thaha M, Varun S. Excessive dynamic airway collapse presenting as intractable cough: A case report. Lung India. 2018;35(6):525-527. doi:10.4103/lungindia.lungindia_89_18.

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