Journal of The Cardiovascular Thoracic Anaesthesia and Intensive Care Society

GKDA Derg 2025;31(4):183-186
Doi: 10.14744/GKDAD.2025.13540

CASE REPORT

Refractory Hypoxemia During One-lung Ventilation Indicating an Undiagnosed Atrial Septal Defect

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ABSTRACT

Hypoxemia during one-lung ventilation is uncommon in healthy patients. When standard measures fail, intracardiac shunts should be considered. A healthy 15-year-old girl underwent bilateral thoracic sympathectomy. Profound desaturation occurred during one-lung ventilation despite 100% oxygen. The tube position was correct, and oxygenation returned to normal with two-lung ventilation. Switching from sevoflurane to propofol-based total intravenous anesthesia provided partial improvement. Intraoperative transesophageal echocardiography revealed an atrial septal defect, which was later confirmed postoperatively. Refractory hypoxemia during one-lung ventilation may suggest hidden intracardiac shunting. Prompt intraoperative echocardiography is essential for diagnosis and safety.

Keywords: Atrial septal defect, hypoxic pulmonary vasoconstriction, one-lung ventilation, refractory hypoxemia, sevoflurane

Please cite this article as: "Karaçay T, Oğur SY, Altıparmak B, Özdemir F, Korkmaz Toker M. Refractory Hypoxemia During One-lung Ventilation Indicating an Undiagnosed Atrial Septal Defect. GKDA Derg 2025;31(4):183-186".

Introduction

Intraoperative hypoxemia during one-lung ventilation (OLV) is generally attributed to ventilation–perfusion mismatch or improper positioning of the double-lumen tube. In otherwise healthy individuals, ongoing desaturation despite adequate airway treatment necessitates an exploration of other etiologies, such as intracardiac shunts. Volatile anesthetics, especially sevoflurane and desflurane, can impede hypoxic pulmonary vasoconstriction (HPV), resulting in an elevated intrapulmonary shunt fraction.[1,2] An atrial septal defect (ASD) may exacerbate hypoxemia by facilitating right-to-left shunting. We provide a case of severe, refractory hypoxemia during one-lung ventilation in a young patient following bilateral thoracic sympathectomy, where intraoperative transesophageal echocardiography showed an undetected atrial septal defect.

Case Report

Written consent was obtained from her parents. A 15-year-old female, classified as American Society of Anesthesiologists (ASA) physical status I, weighing 71 kg and measuring 170 cm in height (body mass index: 24.6 kg/m^2), was scheduled for bilateral thoracic sympathectomy to address primary hyperhidrosis. She had no identifiable comorbidities, allergies, or previous cardiac assessments. Preoperative laboratory testing, chest X-rays, and electrocardiograms were unremarkable.

Following the implementation of standard monitoring, anesthesia was initiated with propofol at 3.5 mg/kg, fentanyl at 1.5 µg/kg, lidocaine at 1 mg/kg, and rocuronium at 0.7 mg/kg. A 35 French left-sided double-lumen tube was inserted, verified via fiberoptic bronchoscopy, and secured at 25 centimeters. After endotracheal intubation, arterial cannulation was performed to enable continuous invasive blood pressure monitoring and blood gas analysis. Anesthesia was sustained with 3% sevoflurane in 80% oxygen at a fresh gas flow rate of 3 L/min.

The patient was placed in the semi-sitting (beach chair) position, and right-lung deflation commenced for OLV. Shortly after initiating OLV, oxygen saturation (SpO_2

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Submitted: December 01, 2025 **Revised:** December 06, 2025 **Accepted:** December 11, 2025 **Available Online:** December 29, 2025

The Cardiovascular Thoracic Anaesthesia and Intensive Care - Available online at www.gkdaybd.org

measured by pulse oximetry) dropped to 78%. The fraction of inspired oxygen (FiO_2) was promptly increased to 1.0, which improved SpO_2 to 93%. At this point, an arterial blood gas sample was obtained. Arterial blood gas tests were conducted post-intubation, during one-lung ventilation with 100% oxygen, and during total intravenous anesthesia (TIVA) with 80% oxygen. Oxygenation, initially diminished during one-lung ventilation, significantly enhanced after the administration of TIVA (Table 1). The tube location was re-evaluated and verified as accurate. Two-lung ventilation reinstated SpO_2 to 100%; however, desaturation promptly reoccurred upon reinitiating one-lung ventilation. In light of the possible inhibitory impact of sevoflurane on HPV, the anesthesia was transitioned to TIVA utilizing propofol (100 µg/kg/min). SpO_2 increased slightly to 91% at FiO_2 0.8.

Intraoperative transesophageal echocardiography (TEE) was performed due to persistent desaturation and revealed a secundum-type atrial septal defect with primarily left-to-right shunting. During one-lung ventilation under positive pressure, TEE showed mild right ventricular dilation with intermittent flattening of the interventricular septum, indicating transient increases in right-sided pressures. Color Doppler revealed an atrial septal defect approximately 10–12 mm in size, with an estimated Qp:Qs ratio of about 1.5:1. Short episodes of bidirectional flow occurred across the defect during mid-systole, showing a temporary reversal of shunt direction. After switching to TIVA, the septal contour returned to normal, and color-flow imaging again demonstrated a predominantly left-to-right shunt. There were no signs of pulmonary hypertension, intracardiac thrombus, or pericardial effusion (Fig. 1).

Table 1. Arterial blood gas results during one-lung ventilation

Timepoint	FiO_2	PaO_2 (mmHg)	$PaCO_2$ (mmHg)	pH	SaO_2 (%)
Baseline (two-lung)	0.8	(240.3)	(37.5)	(7.38)	(100)
During OLV	1.0	(69.3)	(42.3)	(7.39)	(93.3)
After TIVA	0.8	(133.8)	(35.6)	(7.37)	(98.7)

FiO_2: Fraction of inspired oxygen; PaO_2: Arterial partial pressure of oxygen; $PaCO_2$: Arterial partial pressure of carbon dioxide; pH: Potential of hydrogen; SaO_2: Arterial oxygen saturation; OLV: One-lung ventilation; TIVA:Total intravenous anesthesia.

These findings suggest that the right-to-left component was transient and limited to short mid-systolic episodes without sustained reversal. Immediately after initiation of TIVA, right-sided pressures decreased, bidirectional jets disappeared, and the shunt returned to its baseline predominantly left-to-right pattern. No prolonged or continuous right-to-left flow was observed. No additional structural cardiac abnormalities were observed. The mitral and tricuspid valves demonstrated only trivial physiologic regurgitation, with no hemodynamically relevant lesions. Right ventricular systolic function was preserved. Pulmonary artery systolic pressure estimated from tricuspid regurgitation velocity remained within normal limits throughout the case (≈20–25 mmHg) and did not show significant variation between OLV and TIVA. Intraoperative arterial waveform analysis and TEE assessment suggested that the patient was euvolemic.

At the onset of one-lung ventilation, volume-controlled ventilation was maintained with a tidal volume of 6 mL/kg (≈420 mL), a respiratory rate of 14 min^{-1}, PEEP of 5 cmH_2O, and FiO_2 of 1.0. Peak airway pressures reached 24–26 cmH_2O. After

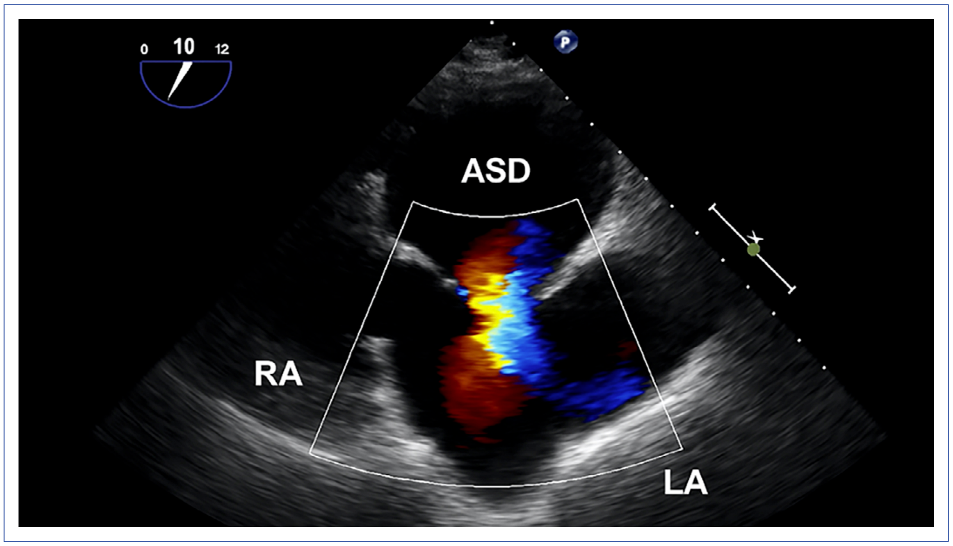

Figure 1. Transesophageal echocardiography (TEE) demonstrating color Doppler flow across a secundum-type atrial septal defect (ASD). Bidirectional flow is visible, consistent with transient fluctuations in interatrial pressure during one-lung ventilation.

switching to TIVA, ventilator parameters were unchanged, but a gradual improvement in dynamic compliance and oxygenation was noted, with SpO_2 rising from 93% to 98% within approximately 10 minutes. The surgical operation was consequently deferred for additional heart assessment.

The patient was extubated without complications and sent to the recovery room, where SpO_2 measured 98% on 2 L/min oxygen via nasal cannula. A postoperative cardiology consultation and transthoracic echocardiography verified the presence of a secundum-type ASD. The patient maintained hemodynamic stability and was discharged for outpatient cardiology follow-up.

Discussion

An undiagnosed atrial septal defect is the clinically significant but uncommon cause of intraoperative desaturation during OLV, as illustrated by this case. Refractory hypoxemia in patients with normal preoperative assessments should prompt the consideration of intracardiac or intrapulmonary shunts after technical factors have been ruled out.

Until physiological stressors such as one-lung ventilation, positive pressure ventilation, or variations in intrathoracic pressure reveal a right-to-left shunt, small or hemodynamically insignificant ASDs frequently remain undetected.[1] Minor or hemodynamically inconsequential atrial septal defects may remain undetected until physiological stressors such as one-lung breathing, positive pressure ventilation, or alterations in intrathoracic pressure expose a right-to-left shunt.[2,3] Propofol-based TIVA is associated with less attenuation of HPV compared with volatile anesthetics, though it does exert some degree of inhibition. Clinical studies have consistently shown that the impact on HPV is smaller than with agents such as sevoflurane or desflurane.[4] Switching to TIVA can enhance oxygenation by retaining HPV function, as shown in our patient. Volatile anesthetics such as sevoflurane have been related to higher shunt fraction and reduced arterial oxygenation during OLV compared to propofol in experimental and clinical scenarios.[5]

In the presence of an ASD, altered pulmonary vascular responsiveness in the non-ventilated lung together with transient increases in right-sided pressures during positive-pressure ventilation may reverse the shunt direction, producing intermittent right-to-left flow and profound hypoxemia.[6,7] One-lung ventilation during positive pressure ventilation creates a unique hemodynamic environment that can transiently alter shunt direction in patients with an atrial septal defect. Under normal physiological conditions, left atrial pressure exceeds right atrial pressure, resulting in a predominantly left-to-right shunt. However, collapse of the non-ventilated lung, hypoxic pulmonary vasoconstriction, and increased intrathoracic pressure during positive pressure ventilation can acutely elevate right-sided pressures. This may reduce or transiently reverse the interatrial pressure gradient, producing short episodes of right-to-left flow and abrupt desaturation. The intermittent mid-systolic bidirectional shunting observed on TEE in our case is consistent with these transient pressure fluctuations. Thus, the combination of OLV-induced increases in pulmonary vascular resistance, impaired venous return due to the semi-sitting position, and positive pressure ventilation likely contributed to episodic right-to-left shunting and refractory hypoxemia.[8]

When hypoxemia occurs unexpectedly during anesthesia, intraoperative TEE is a potent diagnostic tool. Hemodynamic instability, postoperative complications, and inappropriate surgical continuation can be prevented through the early identification of cardiac anomalies.[9] Recent echocardiographic literature emphasizes that even hemodynamically mild secundum ASDs can exhibit dynamic shunt reversal when acute increases in right-sided pressures occur during one-lung ventilation. Positive pressure ventilation, elevated pulmonary vascular resistance in the non-ventilated lung, and reduced venous return in semi-sitting positioning can transiently equalize or surpass left atrial pressures, resulting in episodic mid-systolic right-to-left flow. In our case, intraoperative TEE demonstrated intermittent septal flattening and bidirectional shunting, which normalized after conversion to TIVA and improvement of oxygenation. These findings are consistent with contemporary reports showing that shunt direction in ASD patients is highly sensitive to ventilatory mechanics and acute pressure shifts, even in the absence of pulmonary hypertension or major valvular pathology.[10]

Transesophageal echocardiography provides real-time visualization of intracardiac shunts, including directionality of flow, and is invaluable in diagnosing unexpected desaturation intraoperatively.[11] Limited reports have documented intraoperative desaturation during one-lung ventilation due to an undetected atrial septal defect, with enhancement observed after transitioning to total intravenous anesthesia, underscoring the necessity of evaluating intracardiac shunt physiology in cases of refractory hypoxemia.[12]

In our case, immediate echocardiographic assessment resulted in the identification of a previously undetected ASD, facilitating the secure deferral of the procedure and subsequent cardiology care.

Conclusion

In conclusion, refractory hypoxemia, intracardiac, and intrapulmonary shunts should always be considered as potential underlying causes once technical and ventilatory factors have been ruled out. If standard remedial interventions are ineffective, early intraoperative echocardiography must be performed to exclude structural heart anomalies. Transitioning from volatile anesthetics to TIVA may offer partial improvement by maintaining hypoxic pulmonary vasoconstriction.

Disclosures

Ethics Committee Approval: This is a single case report, and therefore ethics committee approval was not required in accordance with institutional policies.

Informed Consent: Written informed consent was obtained from the patient for the publication of the case report and the accompanying images.

Conflict of Interest Statement: The authors declare that there is no conflict of interest.

Funding: The authors declared that this study has received no financial support.

Use of AI for Writing Assistance: We used artificial intelligence for English translation.

Authorship Contributions: Concept – T.K., M.K.T.; Design – S.Y.O.; Supervision – S.Y.O.; Materials – S.Y.O., F.Ö.; Data collection and/or processing – F.Ö.; Analysis and/or interpretation – T.K., B.A.; Literature search – B.A., F.Ö.; Writing – T.K., M.K.T.; Critical review – B.A.

Peer-review: Externally peer-reviewed.

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