

Report

# Cerebral Infarction by Paradoxical Gas Embolism Detected Non-Stop Extracorporeal Circulation Tricuspid Annuloplasty Surgery with Real-Time TEE: A Case Report

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## Abstract

**Background:** There is a risk of significant complications due to paradoxical gas embolism during tricuspid annuloplasty under non-stop extracorporeal circulation without aortic block. Intraoperative real-time transesophageal echocardiography (TEE) is the most sensitive indicator for the detection of gas embolism. **Case:** This case presents a patent ductus arteriosus (PDA) patient with pulmonary hypertension and severe tricuspid regurgitation scheduled for PDA closure and tricuspid annuloplasty. Intraoperative real-time TEE also showed a large number of small bubbles appearing in the left atrium near the orifice of the pulmonary vein. This case demonstrates that the amount of bubbles from the right heart may have exceeded the gas exchange capacity of the lung and entered the left atrium through the pulmonary vein. The patient delayed awakening after surgery and developed convulsive symptoms, decreased muscle strength of the left extremity, and head MRI suggested the possibility of acute cerebral embolism. **Lessons:** As a relatively simple tricuspid annuloplasty under non-stop extracorporeal circulation without aortic block, surgical may have catastrophic arterial embolism complications.

## Keywords

Paradoxical Gas Embolism, Cerebral Infarction, Transesophageal Echocardiography, Non-Stop Extracorporeal Circulation

## 1. Introduction

The technique of non-stop beating-heart tricuspid valvuloplasty in reoperative cardiac surgery represents a novel approach [1]. The outcomes for this technique in the treatment of severe tricuspid regurgitation following cardiac surgery are favourable. An air embolism has previously been reported after cardiac surgery with cardiopulmonary bypass (CPB) [2-4]. Patent foramen ovale (PFO), ventricular septal defect, and patent ductus arteriosus may lead to paradoxical gas embolism [5, 6]. Paradoxical gas embolism may also occur

during laparoscopic surgery without intracardiac right-to-left shunt [7, 8]. Paradoxical gas embolism represents an uncommon cause of acute arterial embolism. It has the potential to affect both the coronary arteries, resulting in myocardial ischaemia, and the cerebral vessels, leading to ischaemic stroke. Real-time transesophageal echocardiography (TEE) can usually detect intraoperative cardiac function very well, especially in structural heart disease surgery also plays a very important role, meanwhile, the detection of residual gas in the

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**Received:** 5 July 2024; **Accepted:** 23 July 2024; **Published:** 31 July 2024



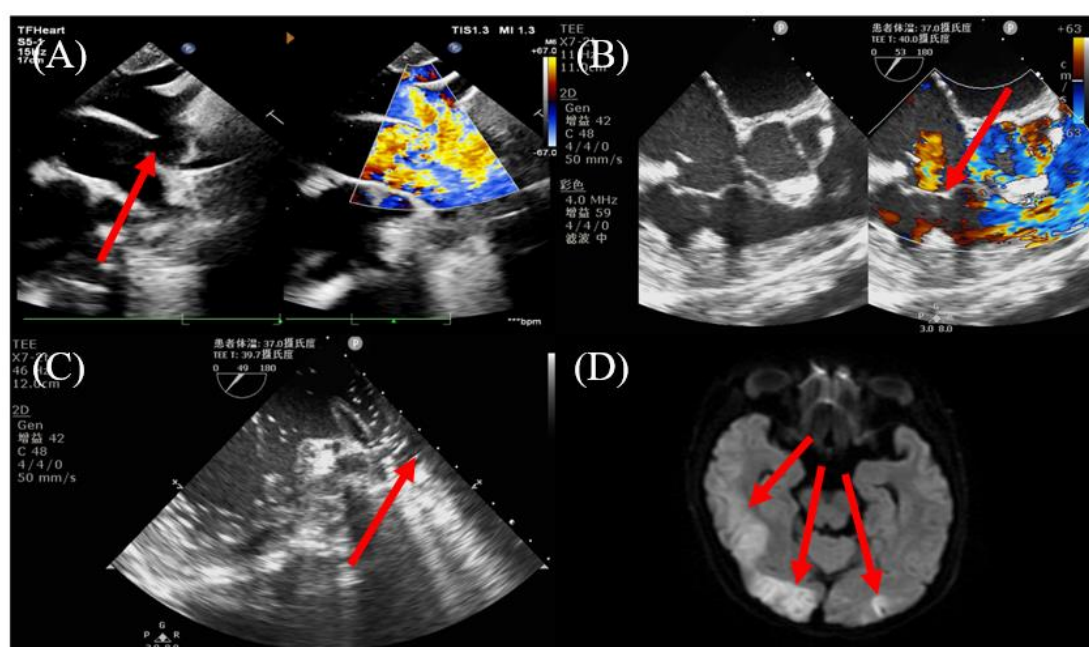
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heart cavity is even easier, so-called “the doctor's third eye”. Intraoperative transesophageal echocardiography is a sensitive and reliable tool for real-time detection of gas embolism [9]. This case demonstrates how the vigilant anaesthesiologist used intraoperative real-time TEE to detect a significant amount of gas leaking from the pulmonary veins during non-stop extracorporeal circulation for tricuspid annuloplasty surgery, causing a cerebral arterial air embolism.

## 2. Case Report

A 35-year-old female was admitted to the hospital for recent exertional dyspnea. The admitting transthoracic echocardiography (TTE) showed patent ductus arteriosus (PDA) (Figure 1A) with pulmonary hypertension and severe tricuspid regurgitation. The elective surgery involved closing the

PDA and tricuspid annuloplasty techniques under cardiopulmonary bypass (CPB). Following a standard cardiac induction with propofol, sufentanil, and rocuronium, transesophageal echocardiography (TEE) was placed. The patient underwent PDA repair and tricuspid annuloplasty under CPB, and real-time TEE showed that moderate regurgitation remained after tricuspid valve surgery (Figure 1B). The cardiac surgeon immediately decided to do tricuspid annuloplasty again under non-stop extracorporeal circulation without blocking the aorta. Intraoperative real-time TEE detected that a large amount of gas was gushing from the pulmonary vein into the left atrium (Figure 1C). Immediate head-down position and enhanced aortic root exhaustion were performed. The operation was completed within seven hours and twelve minutes, and there was three hours and ten minutes of extracorporeal circulation time.



**Figure 1.** (A) Transthoracic echocardiography showing patent ductus arteriosus (red arrow). (B) Transesophageal echocardiography showing moderate regurgitation tricuspid valve after first postoperative (red arrow). (C) Transesophageal echocardiography shows a large amount of gas coming out of the pulmonary veins (red arrow). (D) Postoperative magnetic resonance imaging of the head image showing several cerebral infarct area (red arrow).

After surgery, the patient was transferred to intensive care unit (ICU) with an endotracheal tube around 5:00 pm. Upon reaching the ICU, halt the use of sedatives to prepare for the removal of the tracheal tube and ventilator. The patient experienced delayed awakening after surgery and developed convulsive symptoms at approximately 9 hours. The patient received immediate sedation and antiepileptic therapy. At that stage, the differential diagnosis was a neurological complication, either ischemic or hemorrhagic, seizure, or air embolism. A magnetic resonance imaging (MRI) scan was performed and the MRI showed: diffusion restriction and cortical damage in the right frontotemporo-parieto-occipital

lobe and the left occipital region (Figure 1D), which were considered to be associated with left cardiac systemic intake as depicted by the imaging. The hypothesis of air embolism was discussed in consultation with the surgical surgeon and the neurosurgeon. Intraoperative real-time TEE identified evidence of air entry into the left cardiac system, and the procedure also confirmed that there were a significant amount of air bubbles after decanulation of the aorta, which is an occasional occurrence with CPB that maintains heart-beat.

On the afternoon of the second day after surgery, she was extubated, and her neurologic examination showed that her

left limb muscle strength was approximately grade I, with no pathologic signs elicited, and her right limb muscle strength was approximately grade III, with no other neurologic findings. On post-operative day 13 after receiving rehabilitation and treatment, the patient was discharged with good clinical condition and could move around.

### 3. Discussion

A potentially catastrophic event, air embolism can involve the venous or arterial vasculature. Paradoxical gas embolisation may occur in structural heart abnormalities such as PFO, ventricular septal defect and patent ductus. There have been several reports of paradoxical gas emboli during laparoscopy [7, 8, 10, 11], with intraoperative TEE showing numerous left atrial and ventricular air bubbles, but no evidence of right-left shunting on pulmonary angiography or contrast echocardiogram.

In this patients, intraoperative TEE did not evidence of atrial or ventricular septal defects or PFO. However, intraoperative real-time TEE demonstrated a considerable number of small bubbles within the left atrium in the region of the orifice of the pulmonary vein. It is recommended that tricuspid annuloplasty under non-stop extracorporeal circulation without aortic block be performed with particular vigilance for the potential for left heart systemic air intake.

TEE is the most sensitive indicator for the detection of gas embolism. Gas as small as 0.19mL/kg or gas bubbles of 5-10 microns can be detected, which is currently considered to be the gold standard for diagnosing gas embolism [12]. Intraoperative real-time TEE can quickly confirm the diagnosis and be the guidance for treatment. TEE did not reveal any intracardiac shunt in this patient, but bubbles filled the left heart chamber. In addition to intracardiac shunt, bubbles from the right heart to the left heart can be for the following three reasons: First, the intrapulmonary shunt may be present [5]. Intrapulmonary shunting can occur by intrapulmonary vascular dilatation (up to 160mm) at the precapillary level, or by direct arteriovenous communications in patients with liver cirrhosis. Second, pulmonary capillary filtration. Small amounts of venous gas embolism are often tolerated due to filtration by pulmonary capillaries. The dog's venous gas embolism experiment proves that when the gas diffusion rate is lower than 0.3ml/kg/min, the venous gas bubbles can be completely filtered through the pulmonary capillaries [13]. When the gas doses were increased to 0.35 ml/kg/min, the filtration threshold was exceeded with the arterial spillover of bubbles occurring in 50% of the animals and reaching 71% for 0.40 ml/kg/min. Third, pulmonary arteriovenous malformation [14]. When the patient has a congenital pulmonary arteriovenous malformation, the pulmonary artery and pulmonary vein are directly connected without capillaries, and bubbles can directly reach the left heart through the arteriovenous malformation, causing the cerebral embolism [15]. Therefore, even patients without an intracardiac shunt require

heightened vigilance, with the potential for left heart systemic air intake during tricuspid annuloplasty under non-stop extracorporeal circulation without aortic block.

As in this case, cerebral embolism was caused by arterial embolism in the absence of an intracardiac shunt. The patient delayed awakening after surgery and developed convulsive symptoms, decreased muscle strength of the left extremity, and head MRI suggested the possibility of acute cerebral embolism. When TEE found that this patient had bubbles in the left heart, means that it could reach the coronary artery, ascending aorta, brain, and systemic organs through the left heart, probably resulting in cerebral arterial embolism. After conservative treatment, the patient was discharged 13 days after the operation with good clinical condition and could move around.

### 4. Conclusion

As a relatively simple tricuspid annuloplasty under non-stop extracorporeal circulation without aortic block, surgical may have catastrophic arterial embolism complications. This case demonstrates the full course of fatal gas embolism and difficult resuscitation during tricuspid annuloplasty under non-stop extracorporeal circulation without aortic block, and emphasizes the importance of Real-Time TEE for early detection, and prompt intervention.

### Abbreviations

TEE	Transesophageal Echocardiography
PDA	Patent Ductus Arteriosus
CPB	Cardiopulmonary Bypass
PFO	Patent Foramen Ovale
TEE	Transesophageal Echocardiography
ICU	Intensive Care Unit
MRI	Magnetic Resonance Imaging

### Informed Consent

Written consent was obtained from the patient before the publication of this case.

### Author Contributions

**Guangchao Zhang:** Conceptualization, Data curation, Formal Analysis, Investigation, Visualization, Writing – original draft

**Jiaqi Yang:** Conceptualization, Data curation, Formal Analysis, Visualization

**Xuejie Li:** Conceptualization, Data curation, Formal Analysis, Software, Supervision, Validation, Visualization, Writing – review & editing

## Conflicts of Interest

The authors declare no conflict of interest.

## References

- [1] Chen, Z., Ke, Y., Xie, X., et al. Beating-Heart Totally Endoscopic Tricuspid Valvuloplasty in Reoperative Cardiac Surgery. *The Annals of thoracic surgery*. 2019, 107(1), e79-e82. <https://doi.org/10.1016/j.athoracsur.2018.07.013>
- [2] Niyibizi, E., Kembi, G. E., Lae, C., et al. Delayed hyperbaric oxygen therapy for air emboli after open heart surgery: case report and review of a success story. *Journal of cardiothoracic surgery*. 2016, 11(1), 167. <https://doi.org/10.1186/s13019-016-0553-5>
- [3] Oka, Y., Tsuzaki, K., Kamei, M., et al. Postoperative cerebral air embolism with delayed abnormal brain MRI findings. *eNeurologicalSci*. 2021, 22, 100305. <https://doi.org/10.1016/j.ensci.2020.100305>
- [4] Wei, S., Cao, Y. R., Liu, D. X., et al. Cerebral infarction after cardiac surgery. *Ibrain*. 2022, 8(2), 190-198. <https://doi.org/10.1002/ibra.12046>
- [5] Brown, B., Frasco, P. E., Stoker, A. D. Intrapulmonary Shunting and Paradoxical Air Embolism in Liver Transplantation: A Case Report. *The American journal of case reports*. 2024, 25, e943042. <https://doi.org/10.12659/ajcr.943042>
- [6] Sherlock, S. Paradoxical gas embolism during hysteroscopy. *British journal of anaesthesia*. 2008, 101(5), 742; author reply 742-743. <https://doi.org/10.1093/bja/aen284>
- [7] Hou, W., Zhong, J., Pan, B., et al. Paradoxical carbon dioxide embolism during laparoscopic surgery without intracardiac right-to-left shunt: two case reports and a brief review of the literature. *The Journal of international medical research*. 2020, 48(8), 300060520933816. <https://doi.org/10.1177/0300060520933816>
- [8] Jeon, S., Hong, J. M., Lee, H. J., et al. Paradoxical carbon dioxide embolism during laparoscopic hepatectomy without intracardiac shunt: A case report. *World journal of clinical cases*. 2022, 10(9), 2908-2915. <https://doi.org/10.12998/wjcc.v10.i9.2908>
- [9] Nishant, A. R., Maddali, M. M. Intraoperative Transesophageal Echocardiography: A Sensitive and Reliable Tool for Detecting Air Embolism in Real Time. *Journal of cardiothoracic and vascular anesthesia*. 2019, 33(3), 878-880. <https://doi.org/10.1053/j.jvca.2018.11.016>
- [10] Kawahara, T., Hagiwara, M., Takahashi, H., et al. Cerebral Infarction by Paradoxical Gas Embolism During Laparoscopic Liver Resection with Injury of the Hepatic Vessels in a Patient without a Right-to-Left Systemic Shunt. *The American journal of case reports*. 2017, 18, 687-691. <https://doi.org/10.12659/ajcr.903777>
- [11] Shimizu, K., Usuda, M., Kakizaki, Y., et al. Cerebral infarction by paradoxical gas embolism detected after laparoscopic partial hepatectomy with an insufflation management system: a case report. *Surgical case reports*. 2023, 9(1), 34. <https://doi.org/10.1186/s40792-023-01611-0>
- [12] Glenski, J. A., Cucchiara, R. F., Michenfelder, J. D. Transesophageal echocardiography and transcutaneous O<sub>2</sub> and CO<sub>2</sub> monitoring for detection of venous air embolism. *Anesthesiology*. 1986, 64(5), 541-545. <https://doi.org/10.1097/00005542-198605000-00001>
- [13] Butler, B. D., Hills, B. A. Transpulmonary passage of venous air emboli. *Journal of applied physiology (Bethesda, Md: 1985)*. 1985, 59(2), 543-547. <https://doi.org/10.1152/jappl.1985.59.2.543>
- [14] Harlan, N. P., Davies, L. H., Weaver, L. K., et al. Spontaneous cerebral gas embolism and pulmonary arteriovenous malformation: a case report. *Undersea & hyperbaric medicine: journal of the Undersea and Hyperbaric Medical Society, Inc*. 2015, 42(5), 425-428.
- [15] Lee, H. N., Hyun, D. Pulmonary Arteriovenous Malformation and Its Vascular Mimickers. *Korean journal of radiology*. 2022, 23(2), 202-217. <https://doi.org/10.3348/kjr.2021.0417>