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CASE REPORT

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Unexpectedly detected air bubbles in left ventricle during off-pump coronary artery bypass grafting: a case report

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Abstract

Background Unlike on-pump beating coronary artery bypass grafting, off-pump coronary artery bypass grafting (OPCAB) rarely causes intracardiac air embolisms. However, there have been several reports of air embolisms that occurred during OPCAB using a CO_2 blower, which is commonly used to facilitate visualization of the anastomotic site. Herein, we describe a rare case of air bubbles detected only in the left ventricle during OPCAB.

Case presentation A 72-year-old man visited our hospital due to a myocardial infarction. Because of diffuse tight stenosis of the coronary artery, urgent OPCAB was performed under median sternotomy. After successful grafting, a significant number of air bubbles were detected in the left ventricle but not in the right side of the heart. To prevent air embolism, the patient was maintained in the Trendelenburg position. The surgery was completed, and no neurological abnormalities were observed during hospitalization.

Conclusions Air bubbles entered the left ventricle through a specific route. The use of an excessive flow rate of CO_2 blower should be avoided during anastomosis. This case and other similar incidents encourage maintaining vigilant monitoring for air bubbles using transoesophageal echocardiography, even during OPCAB.

Keywords Off-pump coronary artery bypass grafting, Air embolism, Thebesian vessels

Background

Although off-pump coronary artery bypass grafting (OPCAB) rarely causes intracardiac air embolisms, there are some reports of air embolisms occurring during OPCAB using a CO_2 blower. Except for those that occurred due to defects with instruments such as Swan-Ganz introducers, in cases of pulmonary air embolism, the flow of a CO_2 blower entered a torn coronary vein [1] or torn right ventricular outflow tract (RVOT) [2]. In cases of coronary artery ischemia and air embolism of the ascending aorta, the coronary arteriotomy site was incompletely snared down [3], and the pressure of a CO_2 blower exceeded the diastolic pressure [4]. Herein, we describe a rare case of air bubbles detected only in the left ventricle (LV) during OPCAB without such issues.

Case presentation

A 72-year-old man visited our hospital with abnormal electrocardiogram (ECG) findings, which revealed ST-segment depression in the left precordial leads with sinus rhythm. The patient had a history of hypertension and chronic kidney disease. Blood tests showed troponin I at 8.3 pg/mL, CK-MB at 11.1 ng/mL, and NT-ProBNP

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at 1,790 pg/mL. Coronary angiography revealed severe 3-vessel disease: mid-distal right coronary artery (RCA) total occlusion, proximal left circumflex artery (LCx) total occlusion, left main ostium eccentric 80% stenosis, and proximal left anterior descending artery (LAD) eccentric 90% stenosis.

Transthoracic echocardiography revealed akinesia of the basal septum and inferior wall of the LV; the LV ejection fraction was 58%. There was no patent foramen ovale (PFO). The aortic valve was mildly thickened, and there was no aortic insufficiency.

Due to diffuse tight stenosis of the coronary artery, urgent OPCAB was performed under median sternotomy. A Swan-Ganz introducer was previously inserted into the right internal jugular vein. Transoesophageal echocardiography (TEE) was performed, and no air was present in the heart initially. There was neither PFO nor aortic insufficiency. Heparin was infused, and both internal mammary arteries were skeletonized uneventfully. The right internal mammary artery (RIMA) was anastomosed end-to-side to the left internal mammary artery (LIMA) to form a Y-graft configuration. The graft was sequentially anastomosed to the diagonal artery, distal LAD, ramus intermedius artery, obtuse marginal artery (OM), and posterior descending artery (PDA).

An intraluminal shunt was used for LAD anastomosis. When anastomosing other arteries, coronary snaring was performed proximally but not distally. A CO_2 blower was also used. During anastomosis, a continuous running suture with 8−0 PROLENE was performed. Before tying it, proximal snaring was removed first, and then the bulldog clamp on the graft was removed; de-airing was done before tying the anastomosis. The patient was placed in the Trendelenburg position, and the ECG monitor showed no abnormal changes. A tissue stabilizer (Octopus Evolution Tissue Stabilizer, Medtronic Inc., USA) was used. During PDA anastomosis, the heart was displaced using a cardiac positioner (Urchin Heart Positioner, Medtronic Inc., USA), and the LV was upside down. Checking the heart with TEE was also performed at the aortic valve level; no aortic insufficiency was observed. After successful grafting, protamine was infused.

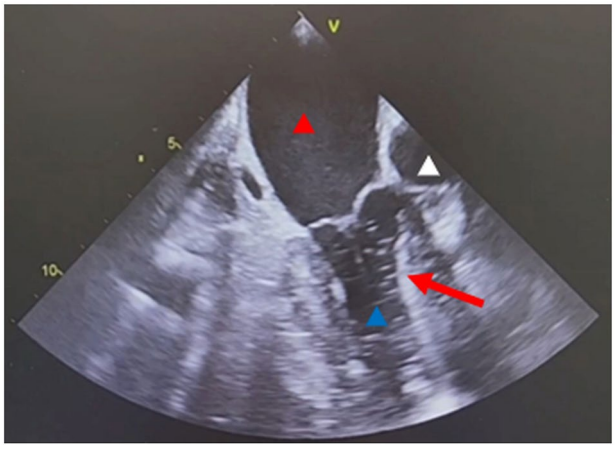

Fig. 1 Intraoperative TEE finding. Left atrium (red arrowhead), left ventricle (blue arrowhead), aorta (white arrowhead), air bubbles (red arrow)

To evaluate the LV function, TEE was rechecked. Systolic function was good, but at that point, a significant number of air bubbles were detected in the LV but not in the right side of the heart (Fig. 1, Video 1). End-tidal CO_2 ($ETCO_2$) was within the normal range, and the vital signs were stable. The air bubbles were found to be trapped at the LV apex. The operator maintained the patient's Trendelenburg position and waited for a while to prevent air embolism. If the amount of air increased or the patient's vital signs became unstable, increasing the oxygen concentration of the inspired gas (up to 100% oxygen), hemodynamic support with inotropes, or even cardiopulmonary bypass and LV venting would have been necessary [5, 6]. The surgery was completed uneventfully, and the patient was transferred to the intensive care unit. No neurological abnormalities were observed during hospitalization. On the first day after surgery, the patient was transferred to the general ward and discharged on the 12th postoperative day.

Discussion

This case represents a rare instance of air bubbles in the LV that occurred during OPCAB. While the source of the air bubbles was a CO_2 blower, it was essential to determine how the air entered the bloodstream. Most relevant previous cases reported issues such as low diastolic blood pressure (DBP), incomplete proximal snaring, and torn coronary venous system or RVOT [1–4] in addition to using a CO_2 blower. However, in this case, there were no defects in the indwelling catheter; the connections of the Swan-Ganz introducer were securely tightened, there were no problems with proximal coronary snaring, and there was no iatrogenic injury to the venous system, including the coronary vein and RVOT. Preoperative examinations and intraoperative TEE findings did not show PFO or obvious coronary cameral fistula, and the air bubbles were not present on the right side of the heart. Moreover, the DBP remained above 50 mmHg throughout the surgery.

The possibility of air entering the ascending aorta in a retrograde fashion and subsequently entering the LV cavity due to trivial aortic insufficiency was unlikely for several reasons. First, the patient had severe multiple lesions in the coronary arteries. Second, proximal coronary snaring was securely performed. Third, intraoperative examination revealed no aortic insufficiency. Furthermore, no air was observed in the ascending aorta. These factors collectively rule out the retrograde entry of air through

the ascending aorta as a probable cause of the air bubbles in the LV.

Among reported cases of air detected only in the left side of the heart, one case described an air embolism caused by a small laceration in the left upper lobe during LIMA harvesting [7]. However, in our case, there was no injury to the lung during harvesting.

A similar case report described microbubbles reaching the LV through the Thebesian system [8]. In that instance, after detection of the intracardiac microbubbles, the surgeon injected saline down the graft, and air reappeared in the LV. TEE also showed extensive microbubbles emanating from the coronary sinus. This phenomenon could be explained by microbubbles following the course of the coronary vessels, especially through the Thebesian system, without dissolving. This case supports the hypothesis that air bubbles can enter the LV via Thebesian vessels during OPCAB.

Anatomically, the coronary venous system (CVS) is divided into two categories: tributaries of the greater CVS and tributaries of the lesser CVS, which consist of Thebesian vessels [9]. Thebesian vessels are bidirectional communicating networks located in the subendocardium and intramyocardium, and consist of four parts: the venoluminal, arterioluminal, venosinusoidal, and arteriosinusoidal part [9]. The Thebesian vessels conduct blood from the epicardial coronary vessels into the cardiac chambers. The flow direction can be reversed when the coronary arterial flow is compromised. Additionally, it has been reported that Thebesian vessels have an increased diameter with chronic myocardial infarction [9]. In this case, the patient's condition was so severe that collateral vessels developed significantly, and the Thebesian vessels might have had an increased diameter. Consequently, air bubbles might have entered the LV through the Thebesian vessels.

It is unlikely that air entered during the anastomosis of the LAD using an intraluminal shunt. However, the incident could have occurred while anastomosing other arteries. We speculate that air might have entered when anastomosing OM or PDA, as the flow rate of CO_2 was stronger than usual due to the distal backflow. Although we routinely perform TEE after heart displacement to check aortic insufficiency, we did not check the LV apex each time. Hence, a limitation of this report is that we are uncertain about the exact timing of air bubble entry. Additionally, we cannot specify the CO_2 flow rate used, as we lack a device to quantitatively measure this.

The patient's condition remained uneventful during hospitalization. The air bubbles may have been spontaneously absorbed owing to the good solubility of CO_2, or they may have flowed into the distal aorta instead of reaching the brain because of the Trendelenburg position. Although the air resolved safely in this case, there was a potential risk of systemic air embolism, which could have been disastrous. Various clinical manifestations may occur depending on the involved organ. Even 2 or 3 mL of air injected into the cerebral circulation can be fatal due to cerebra infarction [10]. As little as 0.5–1 mL of air injected into a pulmonary vein can be fatal due to coronary artery air embolism and subsequent cardiac ischemia [11]. While small emboli in the vessels of the skeletal muscles or viscera are generally well tolerated, obstruction of either the coronary or the cerebral arteries is especially serious and results in severe morbidity or death because of the vulnerability of the heart and brain to short periods of hypoxia [5]. In cases of air embolism, catecholamines, high oxygen concentration, and even cardiopulmonary bypass may be necessary [5, 6]. After surgery, early awakening can be helpful, and careful neurologic examination with early imaging workup, such as brain computed tomography, should be performed if needed. Additionally, close ECG monitoring and blood tests for lactic acid and cardiac enzymes should be conducted to diagnose early visceral organ ischemia, including myocardial ischemia.

It is essential to remember that air bubbles can enter the LV during OPCAB through the Thebesian vessels. It is also important to avoid using an excessive flow rate of CO_2 blower during anastomosis. In the absence of devices to measure CO_2 flow rate, it would be beneficial to keep in mind that a bloodless field is not always desirable. Surgeons might need to permit some blood in the surgical field. If backflow is considerable despite adequate CO_2 insufflation, distal snaring or intraluminal shunt insertion can be helpful. Intraoperative monitoring such as TEE, $ETCO_2$, ECG, and cerebral oximetry monitoring can also be useful. Specifically, checking the LV with TEE after each anastomosis is beneficial. Because TEE is a sensitive and definitive method for detecting intracardiac gas, checking for air bubbles with TEE is encouraged until the sternum is closed [6, 7], even for OPCAB patients with sinus rhythm and normal left ventricular function.

Abbreviations

CVS	Coronary Venous System
DBP	Diastolic Blood Pressure
ECG	Electrocardiogram
$ETCO_2$	End-tidal CO_2
LAD	Left Anterior Descending Artery
LCx	Left Circumflex Artery
LIMA	Left Internal Mammary Artery
LV	Left Ventricle
OM	Obtuse Marginal Artery
OPCAB	Off-Pump Coronary Artery Bypass Grafting
PFO	Patent Foramen Ovale
PDA	Posterior Descending Artery
RCA	Right Coronary Artery
RIMA	Right Internal Mammary Artery
RVOT	Right Ventricular Outflow Tract
TEE	Transoesophageal Echocardiography

Supplementary Information

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Supplementary Material 1: Video 1. Intraoperative transoesophageal echocardiography finding.

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Author contributions
Youna Sim drafted the study and performed the literature search. Boohwi Hong and Man-shik Shim participated in the surgery. Sang-Jun Park and Man-shik Shim supervised manuscript preparation and critically revised the manuscript. All the authors have read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study was approved by Chungnam National University Hospital, Daejeon, Republic of Korea (IRB approval date: 2024.05.03, ID number: CNUH 2024-04-032).

Consent for publication
The requirement for patient consent was waived.

Competing interests
The authors declare no competing interests.

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