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Massive systemic arterial air embolism caused by an air shunt after blunt chest trauma: A case report

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ABSTRACT

INTRODUCTION: Systemic arterial air embolism (SAAE) is a rare but fatal condition, with only a few cases reported, and the detailed etiology underlying SAAE remains unknown. We report a first case of massive SAAE after blunt chest injury, wherein the presence of traumatic air shunt was confirmed by direct observation during surgery. We also summarize our experience with six other SAAE cases.

PRESENTATION OF CASE: A 68-year-old woman was admitted in a state of cardiac arrest after a fall. Emergency room thoracotomy determined complete transection of left main bronchus and left superior pulmonary vein. Postmortem computed tomography (CT) revealed full of air in the aortic arch, the descending aorta, and the great vessels. Therefore, one of the cause of death might be SAAE.

DISCUSSION: An air shunt after blunt chest trauma can cause SAAE, and clinical signs and operative findings can provide clues for possible SAAE. The bronchopulmonary vein fistula, the aortic injury and full-thickness myocardial injury have the potential to become traumatic air shunts. In cases with a coexisting air shunt, pneumothorax, lung contusions and positive-pressure ventilation can be risk factors for SAAE, as sources of air continually entering the systemic arterial circulation.

CONCLUSION: SAAE is caused by an air shunt following trauma. Clinical signs and operative findings summarized in this case should aid in the recognition of possible SAAE.

1. Introduction

Systemic arterial air embolism (SAAE) is a rare but potentially fatal condition and there are few reports on SAAE, especially after injury because of blunt trauma [1], and the detailed etiology of SAAE remains unknown. We report the case of a massive SAAE which was caused by a fistula between the left main bronchus and the left pulmonary vein after blunt chest injury. Importantly, direct confirmation of the traumatic air shunt was achieved during surgery. We also summarize our experience with six other SAAE cases. This work is reported in line with the SCARE criteria [2].

2. Case report

A 68-year-old woman who fell from the sixth floor of a building exhibited pulseless electrical activity at the time of arrival of emergency medical services, and cardiopulmonary resuscitation was performed. The patient was immediately transferred to our emergency department.

On admission, the patient presented with no cardiopulmonary activity and dilated pupils, but there were no signs of cerebral prolapse. Cardiopulmonary resuscitation was continued and she was intubated with vigorous manual ventilation. After intubation, we checked the sounds of forced oxygen into the lungs at the bilateral chest but could not see the elevation of both sides of the chest.

Considering cardiac arrest because of trunk injury, especially chest injury, an emergency room thoracotomy was performed. At the time of entry into the chest cavity immediately after anterolateral thoracotomy, a sound of air withdrawal was heard, which was followed by discharge of massive hemorrhagic pleural effusion. Pericardium was exposed and found no drainage of blood or no cardiac lacerations, and open cardiac massage was initiated. The descending thoracic aorta was cross-clamped immediately above the diaphragm. When we infused oxygen into the lungs with vigorous manual ventilation, the left lung did not inflate, and there was minimal elevation of both chest; in addition, intrathoracic sounds of air exiting the chest cavities were heard and we felt exhaust air. The site of air exit was explored, and complete transection of the left main bronchus (Fig. 1A) was discovered. In front of the transected bronchus, the complete transected left superior pulmonary vein (Fig. 1A) and severe contusion to the left superior pulmonary lobe were also confirmed (Fig. 1B). Pulmonary hilum

Abbreviations: SAAE, systemic arterial air embolism; CT, computed tomography.

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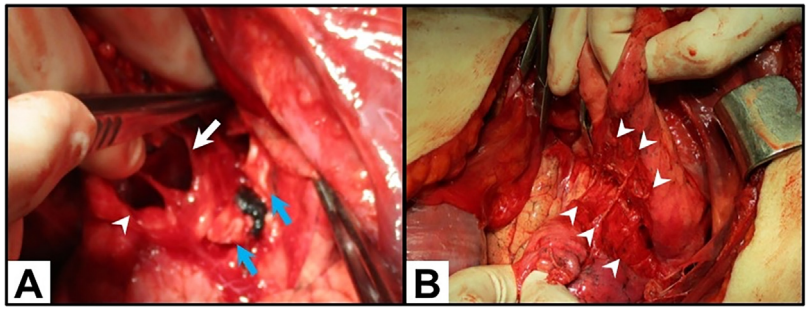

Fig. 1. Operative findings.
Complete transection of the left main bronchus (**A**, proximal, white arrowhead; distal, white arrow) and left superior pulmonary vein (**A**, blue arrows), and severe contusion to the left superior lobe (**B**).

was cross-clamped by a Satinsky clamp to control hemorrhage, improve ventilation, and prevent bronchovenous air embolism. A chest tube was inserted into the right thorax, and no sounds of air withdrawal or hemorrhage were observed. Massive blood transfusion and intravenous administration of adrenalin were performed concurrently with surgery. However, the heart did not respond to resuscitation attempts over a 50-minute period, and the patient was declared deceased.

Postmortem full-body computed tomography was performed approximately 30 min after death. Head CT scan showed multiple skull fractures including the skull base and facial bones and extensive pneumocephalus. Chest CT scan revealed extensive air in the left ventricle (Fig. 2A), the aortic arch (Fig. 2B), the descending aorta (Fig. 2C), and great vessels including the brachiocephalic trunk, bilateral common carotid arteries, and bilateral subclavian arteries (Fig. 2D). Pneumomediastinum, bilateral hemopneumothorax, multiple rib fractures, and lung contusions, especially in the superior lobe of left lung, were also demonstrated. The left main bronchus was disrupted (Fig. 2E). Abdominal CT revealed limited ascites around the liver and in Douglas pouch and pelvic fracture. Air bubbles were also observed in the abdominal aorta, the celiac artery, the superior mesenteric artery, and bilateral common, internal, and external iliac arteries (Fig. 2F). The volume rendering technique was employed to create 3D images, which demonstrated air in the ascending aorta, aortic arch, and great vessels (Fig. 2G, H). Based on postmortem CT scans, we considered SAAE as one of the likely cause of death.

3. Discussion

The current case illustrates two important clinical issues. An air shunt after blunt chest trauma can cause SAAE, and clinical signs and operative findings can provide clues for possible SAAE.

First, an air shunt following blunt chest trauma causes SAAE. The detailed etiology of SAAE, especially those precipitated by trauma, has not been described in the very few cases that has been reported to date. Saada et al. reported three cases of SAAE and they speculated pulmonary contusion caused SAAE [3]. Hashimoto et al. reported a case of cerebral air embolism and speculated that air may have entered the heart during artificial respiration by means of the shunt from the major bronchus to the pulmonary artery, after severe blunt trauma [4]. Yadav et al. also reported a case of SAAE and they considered that a bronchopulmonary vein fistula that may have formed in the contused lung caused SAAE [5]. Iwata et al., Yamaki et al, Karegowda et al. and Buyukkaya et al. reported cases of cerebral air embolism from pulmonary barotrauma due to cardiopulmonary resuscitation [6–9]. They speculated that air entered the pulmonary vein via pulmonary vessels ruptured by the closed manual cardiac massage and vigorous mechanical ventilation and reached the systemic circulation. However, in previous case reports, they did not confirm the internal injury directly which could be an air shunt. SAAE occurs when air that enters the pulmonary vein or the left side of the heart travels to an organ until it is trapped. Two conditions are necessary for air to enter the closed arterial system. One is a connection between air and the pulmonary vein or heart. Second, a pressure gradient is necessary, which enables the flow of air into the vessel. In the current case, the patient was injured with blunt chest trauma, and the complete transection of the left main bronchus and the left superior pulmonary vein was confirmed. Additionally, a fistula that formed between the left main bronchus and the left pulmonary vein allowed air bubbles to enter the left side of the heart and travel in the arterial system; this event was substantiated by the air bubbles in the left ventricle. The air withdrawal sound observed during surgery suggests the development of a massive pneumothorax, which could have augmented the pressure gradient to promote air entry into the vessel. Additionally, endotracheal intubation and positive-pressure ventilation, together with the low pulmonary venous pressure due to blood loss might have accelerated the process.

Second, clinical signs or operative findings can provide clues for possible SAAE. The clinical significance of SAAE is comparable to that of coronary or cerebral infarction, yet it is very difficult to suspect SAAE. SAAE diagnosis can be overlooked because its symptoms are not specific, and confirmation of the presence of air in the arterial system is difficult. Although CT is the most useful modality for the diagnosis of air embolism, performing CT during resuscitation is nearly impossible. There are several signs that suggest SAAE: a sudden change or cardiopulmonary arrest in cases of massive pneumothorax or severe lung contusions, or after intubation and the introduction of positive-pressure ventilation. Operative findings can also hint at SAAE and are effective in locating the causative lesion. In the current case, during surgery, the left lung failed to inflate, and we could not observe elevation of both chest cavities; additionally, we heard intrathoracic sounds of air exiting the chest cavities and felt exhaust air when we infused oxygen into the lungs. Furthermore, we also found that the left main bronchus and the left superior pulmonary vein were completely transected, which required cross-clamping at the pulmonary hilum. These findings suggest that clinical signs and operative findings can aid in earlier diagnosis and faster intervention.

At our institution, six of the trauma-associated cardiopulmonary arrest cases that were admitted between January 2013 and December 2016 were determined as SAAE based on CT scans (Table 1). Pneumothorax or lung contusions were observed in all cases, and pneumomediastinum was found in five of the six cases. Importantly, resuscitative thoracotomy was performed in three of the six cases, which revealed complete transection of the aortic root (case 3), incomplete transection of the aortic isthmus (case 5) and full-thickness myocardial injury (case 4). These injuries were considered to cause a traumatic air shunt, which allowed air to enter

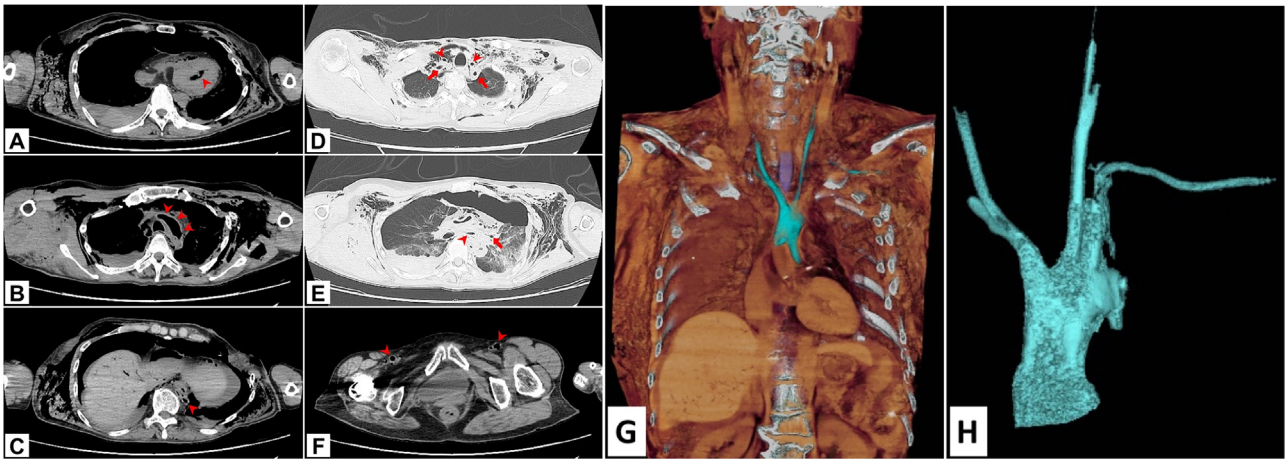

Fig. 2. Postmortem computed tomography.
Air in the left ventricle (A), the aortic arch (B), the descending aorta (C), the bilateral common carotid arteries (D, red arrowheads) and bilateral subclavian arteries (D, red arrows). Disrupted left main bronchus (E, proximal, red arrowhead; distal, red arrow). Air bubbles in the bilateral external iliac arteries (F). The 3D volume-rendered images demonstrate a large amount of air (G/H, blue region, vessel lumen replaced by air).

Table 1
Our experienced cases of traumatic cardiac arrest with SAAE.

Case	Age	Sex	Mechanism	major chest trauma	intubation	pneumothorax	lung contusion	pneumomediastinum	ERT
1	41	F	fall	bilateral hemopneumothorax, multiple rib fracture, multiple vertebral fracture	○	○	○	×	×
2	19	M	traffic accident	suspect of aortic root injury, cardiac sliding, bilateral hemopneumothorax, multiple rib fracture	×	○	○	○	×
3	34	M	fall	complete transection of aortic root, SVC and rPA, complete tracheal injury, bilateral hemothorax	○	○	○	○	○
4	59	F	fall	bilateral hemopneumothorax	○	○	○	○	×
5	34	M	traffic accident	incomplete transection of aortic isthmus, pulmonary hilar injury, bilateral hemopneumothorax, mediastinal injury	○	○	○	○	○
6	82	M	traffic accident	cardiac full thickness injury, injury of SVC, bilateral hemopneumothorax, multiple rib fracture	○	○	○	○	○

ERT: emergency room thoracotomy, SVC:superior vena cava, rPA: right pulmonary artery.

the systemic arterial circulation. In cases with a coexisting air shunt, pneumothorax, lung contusions and positive-pressure ventilation can be risk factors for SAAE, as sources of air continually entering the systemic arterial circulation.

4. Conclusion

This case illustrates that traumatic air shunt after blunt chest trauma can cause SAAE and that certain clinical signs and operative findings can aid in earlier diagnosis and faster intervention. The bronchopulmonary vein fistula, the aortic injury and full-thickness myocardial injury have the potential to become traumatic air shunts, which allow air to enter the systemic arterial circulation. Pneumothorax, lung contusions and positive-pressure ventilation might be considered as a source of air and risk factors for SAAE.

Conflicts of interest

The authors state that they have no competing interests.

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Ethical approval

Ethical approval was exempted for case reports by our institution.

Consent

Written informed consent was obtained from the patient for publication of this case report and any accompanying images. A copy of the written consent is available for review by the editor of this journal.

Author contribution

Dr. Kenji Kandori: major decision-maker during the surgery, data collection, data analysis, writing the paper.
Dr. Wataru Ishii: major decision-maker during the surgery.
Dr. Ryoji Iiduka: major decision-maker during the surgery.
All authors have read and approved the final manuscript.

Registration of research studies

N/A.

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Kenji Kandori.

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