peated procedures might be required for persistent PAVMs or recanalization, transcatheter embolization is a lung-sparing procedure and should therefore always be considered in cases of PAVM.

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Fatal air embolism during computed tomography-guided pulmonary marking with a hook-type marker

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Pulmonary marking with a hook wire, guided by computed tomography (CT), is often used to assist in the resection of small lung tumors that are difficult to identify by means of thoroscopic surgical techniques or digital palpation. The most common complications accompanying

this procedure are pneumothorax, intrapulmonary hemorrhage, and hemothysis. These complications are usually mild, self-limiting, and curable. Air embolism is a widely recognized complication of transthoracic percutaneous needle biopsy, but in the case of CT-guided pulmonary marking, few complications have been reported. We report a case of fatal arterial gas embolism during hook wire localization of a pulmonary lesion. The patient mortality was mainly attributed to ischemic heart injury caused by air embolism. Physicians should be aware of this possible complication when a hook wire-type marker is used to avoid further fatalities.

Clinical Summary

A 79-year-old woman visited our hospital for an examination of a 2.0-cm abnormal shadow in the left upper lung field revealed by a mass chest radiographic survey. A chest CT demonstrated a 1.5-cm tumor shadow with a faint density and ground-glass opacity in S⁸ of the right lung in addition to a 2.0-cm tumor in S¹⁺² of the left lung (Figure 1).

The patient was known to have had pulmonary tuberculosis in her late twenties. She had no smoking history. Results of her

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Figure 1. Thin-section CT images: *Top*, left lung cancer in S¹⁺²; *bottom*, faint density-type tumor with ground-glass opacity in S⁸.

physical examination were appropriate for her age. Complete blood count, liver function, renal function, and urinalysis showed no abnormality. Pulmonary function tests revealed a vital capacity (VC) of 2.04 L, a percent VC of 78.9%, a forced expiratory volume in 1 second (FEV₁) of 1.04 L, and a ratio of FEV₁ to forced vital capacity (FVC) of 65.8%. A CT-guided transthoracic needle biopsy was performed for the left-sided tumor, which was identified as a well-differentiated adenocarcinoma. The shadow of the right lung also indicated lung cancer. Simultaneous pulmonary wedge resections by video-assisted thoracoscopic surgery for both lesions were scheduled.

On the day of the operation, CT-guided marking for the right pulmonary tumor was performed before the patient was sent to the operating room. The procedure was performed in the left-sided semilateral position with a hook-type marking needle (Guiding Marker System; Hakko Medical Co, Nagano, Japan).

The patient was stable during the procedure. However, she had sudden cardiovascular collapse with unconsciousness, bradycardia, and hypotension as soon as she was returned to the supine position from the left-sided semilateral position after the procedure. Electrocardiography showed a remarkable ST-segment increase in leads II, III, aV_F, and V₁₋₃. One hundred percent oxygen was administered with a facemask. A hypertensor was administered, and spontaneous breathing was maintained. Chest CT scanning was performed promptly. The CT scan showed an air-fluid level in the ascending aorta and air density in the right coronary artery (Figure 2).

After the air embolism was confirmed, the patient was transferred immediately to the intensive care unit (ICU). Although she

Figure 2. Chest CT scan showing air density in ascending aorta and right coronary artery.

temporarily regained consciousness after the accommodation in the ICU, she died of myocardial infarction caused by air embolism 22 hours after admission to the ICU. Although a small amount of hemoptysis was observed in the early period of the course, chest radiography showed no infiltration and pneumothorax. The hook wire was identified on the film. Pathologic autopsy was not performed.

Discussion

Gas embolism is a largely iatrogenic clinical problem that can result in serious morbidity and death.¹ Most reported cases of arterial gas embolism in relation to a lung procedure occur during percutaneous lung biopsy.² A reported case such as ours is rare. Recently, opportunities of locating small lesions in the lung and of performing video-assisted thoracoscopic surgery procedures have increased. Accordingly, some preoperative marking for small lesions are considered. Horan and colleagues³ reported a case of arterial air embolism during hook wire localization for a pulmonary nodule. The structure of the hook wire used in that case was similar to the one used on our patient. Both hook apparatuses open into a V shape with spring force after releasing from an introducer (a covering needle).

The possible mechanisms for air embolism during lung procedures are (1) communication between the bronchus, bronchiole, or air space and pulmonary vein and (2) communication between the pulmonary vein and the atmosphere. The first reason listed above is the most likely explanation for the outcome in our case. Although increase of airway pressure caused by a cough, the Valsalva maneuver, or positive pressure ventilation increases the risk,⁴ such circumstances were not found in our case. The second explanation seems less likely to apply to our case because it is doubtful that a large volume of air was sucked into the pulmonary vein through the needle. We measured the relationship between pressure gradient and airflow through the needle that we used.

TABLE 1. Air embolism complicating CT-guided pulmonary marking

Author (y)	Age (y), sex	Location	Tumor size	Marker	Position	Ventilation in the procedure	Documentation*	Outcome
Our case	79, F	S ⁸ (right)	15 mm	21G, hook type	Left semilateral	Spontaneous	Chest CT (ascAo, CA)	Dead
Satake (2002) ⁷	56, F	S ⁹ (right)	15 mm	21G, hook type	Prone	Spontaneous	Chest CT (LV, descAo)	Alive
Horan (2002) ³	32, M	Lower lobe (left)	10 mm, 10 mm	20G, hook type	Right lateral	Positive airway pressure	Chest CT (descAo)	Alive
Kamiyoshihara (2002) ⁸	24, F	S ⁸ (right)	4 mm	22G, hook type	Left lateral	Spontaneous	—†	Alive

AscAo, Ascending aorta; CA, coronary artery; LV, left ventricle; descAo, descending aorta.

*Documentation: The sites where air was detected by CT.

†A chest CT indicated pneumothorax of the right lung.

Under 6, 11, and 19 cm H₂O of pressure gradient between the needle tip and its tail, 0, 0.14, and 0.39 mL/10 seconds of air passed through the needle, respectively.

Horan and colleagues³ described a probable mechanism of hook wire gas embolism. In that case the wire penetrated both the venule and the bronchiole, and as a result, the springing open hook wire introduced a connection between the two and caused an air embolism. In contrast to their case, in which the marking procedure was performed during positive pressure ventilation, our case was performed during spontaneous breathing. We could not find the cause of the increase in airway pressure. The lesion was located in the periphery of the right lower lobe and became the highest position in the chest under the left-sided semilateral position. Hence, the pulmonary vein blood pressure around where the hook wire was placed might become lower than the pressure of the airway. This situation might facilitate airflow into the pulmonary vein.

The mortality and morbidity associated with transthoracic needle biopsy cannot be precisely determined but has been estimated at 0.02%⁵ and 0.07%,⁶ respectively. Recently, the use of CT-guided pulmonary marking for small pulmonary lesions before video-assisted thoracoscopic surgery became more frequently used. Three cases of air embolism caused by CT-guided pulmonary marking were reported (Table 1).^{3,7,8} A hook-type marker was used in all cases. In 4 cases the lesions were present in the lower lobe of the lung. The positions in marking procedure of the 4 cases were the lateral or prone position.

We have reported a case of fatal arterial gas embolism caused by marking with a hook wire for a pulmonary lesion. Because pulmonary marking will be used more frequently in the future, the risk of the hook wire should be reevaluated.

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