PA PSRS
Pennsylvania Patient Safety Reporting System

Patient Safety Advisory

Produced by ECRI & ISMP under contract to the Pennsylvania Patient Safety Authority

Venous Air Emboli and Automatic Contrast Media Injectors

Several reports have been submitted to PA-PSRS in which intravascular air emboli occurred with the use of automatic contrast media injectors during CT scans. One report indicates that the patient became diaphoretic and was transferred to an intensive care environment after undergoing a CT scan with contrast. In this case, the patient was prepared for the CT scan, but the empty contrast syringe from a previous case had not been removed from the injector. The automatic injector injected 25cc of air into the patient.

Small and moderate-sized air emboli are estimated to occur in 12% to 23% of patients undergoing contrast-enhanced CT examination.[1,2] Most of these air emboli are undetected because patients are asymptomatic,[2] and the air is absorbed without difficulty. However, larger air emboli have been reported as a complication of pressure injection of contrast material during CT scans.[2] In contrast-enhanced imaging, venous air emboli are more common than those in the arterial vasculature.[2] Though increased morbidity and mortality is more likely to be associated with arterial air emboli, significant consequences can result from venous air injection, such as cardiac and/or respiratory arrest, seizures, and neurological deficits.[1] Accidental venous injection of air may produce a fatal air embolism.[3]

Three elements must be present in order for air to be admitted into the vascular system: 1) a source of air (the atmosphere); 2) a connection between the vascular system and the air source; and 3) a pressure gradient that favors air entry.[4] Air can enter an open blood vessel when either of the following conditions exist: 1) a negative intravascular pressure relative to air pressure; or 2) the air is under pressure and is pushed into vessels with or without a negative intravascular pressure.[4-6] The use of automatic contrast injectors meets this second condition. Air can also be introduced into the vascular system during contrast administration during cannula insertion, when connecting the cannula to the injector tube, and through microbubbles in the contrast.[7]

Once air enters the venous circulation, it moves toward the right atrium and then to the right ventricle. From there, emboli usually travel via the pulmonary artery to the lungs. Small emboli are usually absorbed in the blood or alveoli of the lungs. Larger emboli may obstruct the outflow from the right ventricle or block pulmonary arterioles.[2,8]

The severity of symptoms resulting from air embolism is dependent upon such factors as the volume of air injected and the speed of the injection.[1,2] The position of the body at the time of air entry and the patient's state of health also affect the outcome.[1]

Certain medical conditions may allow a venous air embolism to enter the arterial circulation, increasing the risk.[1,8] Such conditions may include atrial or ventricular septal defects and those with arteriovenous malformation.[1,2] Approximately 25% to 35% of the general population with otherwise normal hearts retain a patent foramen ovale, which could allow a venous air embolism that reaches the heart to cross over into the arterial circulation. This is significant because an air embolus as small as 1 ml in the arterial circulation may travel to the brain or coronary arteries, causing significant blockage.[5]

While most air emboli associated with the use of intravenous contrast media are asymptomatic, the clinical literature reports numerous symptoms that can indicate this complication (see Table 1). Most significantly, a patient may have a reflexive gasp following an infusion of air into the pulmonary circulation. The gasp causes decreased intrathoracic and central venous pressure, which allows a larger volume of air to enter any patent opening into a vein, potentially contributing to sufficient volume to cause cardiopulmonary collapse.[4] Cardiovascular changes are generally associated with the size of the air infusion. Small air infusions are associated with a moderate decrease in blood pressure, while larger air infusions may result in a further decrease in blood pressure due to decreased cardiac output.

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Venous Air Emboli and Automatic Contrast Media Injectors (Continued)

A large air infusion may create an air lock in the pulmonary artery causing the blood pressure to drop abruptly, followed by cardiovascular collapse. The outcome may be permanent neurological damage or death.[5]

The most specific and sensitive methodologies used to diagnose this complication are transesophageal echocardiography and Doppler ultrasonography.[1,2,9] Contrast-enhanced CT of the chest can also identify intravascular air emboli. Plain chest radiographs have occasionally identified air emboli but are less sensitive.[4] In mechanically ventilated patients, this complication is associated with a reduction in the monitored end-tidal carbon dioxide level.[2]

If symptomatic venous air embolism occurs, the following interventions may help to minimize harm:

- Identifying the source of air entry and preventing further air entry into the venous circulation.[4,8]
- Placing the patient in the Durant position (the left lateral decubitus and Trendelenburg positions). This position may float air back out of the pulmonary vasculature and relieve the airlock blocking the outflow of the heart.[1,2,9]
- When air is in the right atrium, central multiorifice central venous catheters have been used to aspirate the air.[4] A pulmonary artery catheter has been used to aspirate air from the right atrium and ventricle as the catheter is withdrawn from the pulmonary artery.[2,9]
- Observing patients in an intensive care setting and monitoring progress through such diagnostic modalities as serial EKGs, cardiac biomarkers, coagulation studies, ABGs, and repeat imaging procedures.[1,9]
- Hyperbaric oxygen therapy may also reduce the size of the embolus and may benefit patients with cardiac or cerebral symptoms.[1,2,9]

A review was conducted of the FDA's Manufacturer and User Facility Device Experience (MAUDE) database, the FDA's Center for Devices and Radiological Health's Medical Device Reporting (MDR) database, and ECRI's Health Devices Alerts, pertaining to automatic contrast injectors and air emboli. Since 1985, 13 occurrences have been reported to these resources. The procedure was not specified in 38% of these reports. Arterial procedures were documented in 46% of the reports. In two reports, the venous circulation was accessed by a power injector. Patient outcomes of these events include death (cited in 54% of reports), serious injury (15%), and aggressive intervention/life threatening situations (31%). Event descriptions from these resources may shed light on possible factors contributing to this complication:

- The patient died after being injected with air from an empty contrast media syringe that was thought to be full. The empty syringe was not removed from the injector after a procedure.
- The technologist thought there was contrast in the syringe because of the placement of the syringe in the pressure jacket. Air was injected into the patient.
- The first contrast injection was completed successfully. The catheter was disconnected from the connector tubing to reload the syringe. The technologist used the connector tube connected to the syringe for reloading. During reloading, the technologist noticed an air bubble in the syringe. The technologist expelled the air from the syringe with the injector head in the downward position. The technologist proceeded to make the catheter/connector tube connection and set the injector for the second injection. The injection was begun but was aborted when the physician could not see contrast coming out the catheter. The injector was reset and injection was completed. Expelling air from the syringe with the injector head in the downward position is not consistent with the recommended procedure in the operator's manual.

Where documented in the above reports, as well as in reports to PA-PSRS, the automatic injectors were found to have functioned properly. However, there are several things that can be done to address the risk of this complication, which may help reduce the potential for user error:

Education

- Limiting use of contrast media injectors to those with adequate training and those familiar with current operating procedures as well as risks associated with injection of air.[1,3]

Venous Air Emboli and Automatic Contrast Media Injectors (Continued)

Table 1 Symptoms that May Indicate Venous Air Embolism During Power Contrast Injection

Cardiopulmonary	Neurological
Gasp	Focal paralysis
Cough	Seizures
Acute shortness of breath	Loss of consciousness
Tachypnea	Altered mental status
Chest pain/unilateral chest pain	Coma
Chest pressure	Loss of sensation in an extremity
Pulmonary edema	Vertigo
Bronchospasm	Blindness
Crepitus	**Other**
Hypercapnea or hypocapnea	Sense of impending death
Cyanosis	Nausea and vomiting
Hypoxemia	
Hypotension	
Hypercarbia	
Increased central venous or pulmonary artery pressure	
Sinus tachycardia/sinus bradycardia	
Ischemic changes on EKG	
Nonspecific ST segment and T wave changes	
Cardiac conduction disturbance	
Extreme venous congestion	
Acute cor pulmonale	
"Mill-wheel" murmer – if large air embolus in right ventricle	

Sources

Pham KL, Cohen AJ. Iatrogenic venous air embolism during contrast enhanced computed tomography: a report of two cases. *Emergency Radiology* 2003; 10:147-51.

Ie SR, Rozans MH, Szerlip HM. Air embolism after intravenous injection of contrast material. *Southern Medical Journal* 1999 Sep;92(9):930-3.

Aurora R, Ward KR, Garza R, Rivers E. Iatrogenic venous air embolism. *The Journal of Emergency Medicine* 2000 Feb;18(2):255-6.

Temple AP, Katz J. Air embolism: a potentially lethal surgical complication. *AORN Journal* 1987 Feb;45(2):387-400.

Orebaugh SL. Venous air embolism: clinical and experimental considerations. *Critical Care Medicine* 1992 Aug;20(8):1169-77.

Competency

- Periodically verifying radiologists' and technologists' performance compared to current protocols.[1]

Written Procedures/Instructions

- Having contrast injector procedures readily available to the healthcare workers.[10,11]
- Reviewing procedures and operator's instructions before using any invasive diagnostic equipment.[3,10,11]
- Following the manufacturer's instructions and operating manuals concerning all aspects of contrast injection, including the prescribed loading sequence before arming the injector or preparing the contrast for injection.[12]
- Using a double check system to help ensure that the syringe is removed from its jacket and filled with contrast media, the system is purged of air, and the syringe is loaded—all before attaching the injector syringe and tubing to the IV cannula.[10,11,13]
- Verifying that empty syringes are not left in injectors at the end of the procedure.[3]
- Inspecting the cannula and the connection between the cannula and power injector system to verify that no air is introduced into the system, both prior to initial injection and between multiple injections of contrast.[1,3,13]
- Aborting the procedure if air is noticed in the contrast injection system/tubing or when contrast is not seen coming out of the catheter.[3,10,11]

Protocols

Developing protocols, conducting drills, and promoting compliance to clarify:

- How contrast injection responsibilities will be handled and transitioned during work shift changes.
- How specific tasks will be accomplished, according to the type and number of staff involved.[1] For example, while a radiologist is involved in contrast-enhanced imaging, it is possible that one or two technologists may also be involved. Defining tasks for each healthcare worker in these different situations may help to prevent duplication or performance gaps.

Venous Air Emboli and Automatic Contrast Media Injectors (Continued)

Equipment

- Air detection devices may reduce the risk of air embolism associated with contrast media injectors, but only if used in conjunction with other risk reduction measures designed to address user error.
- Using tightly sealed, locking connections to the venous line may reduce the risk of air entry from a source outside of the contrast media injector.

Reporting

- Notifying the person at your facility responsible for reporting air emboli associated with contrast injectors.

Notes

1. Pham KL, Cohen AJ. Iatrogenic venous air embolism during contrast enhanced computed tomography: a report of two cases. *Emerg Radiol* 2003;10:147-51.

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The Patient Safety Authority is an independent state agency created by Act 13 of 2002, the Medical Care Availability and Reduction of Error ("Mcare") Act. Consistent with Act 13, ECRI, as contractor for the PA-PSRS program, is issuing this newsletter to advise medical facilities of immediate changes that can be instituted to reduce serious events and incidents. For more information about the PA-PSRS program or the Patient Safety Authority, see the Authority's website at www.psa.state.pa.us.

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