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Original Article

A quality review of the occurrence of a non-fatal venous air embolism event following CT contrast enhanced administration for the purpose of radiation therapy planning

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Abstract

Background: The incidence of venous air embolism (VAE) during and following diagnostic and interventional radiographic procedures utilizing contrast media has been well documented in the literature. However to date a case report of a venous air embolism occurring within an outpatient healthcare facility during a contrast enhanced computer tomography radiation therapy planning procedure remains under reported.

Purpose: Healthcare professionals must remain alerted to the fact that iatrogenic VAE may occur unexpectedly during and following diagnostic and interventional radiographic procedures utilizing the injection of contrast media. The action by all healthcare professionals to implement rapid and clear acute care guidelines will increase the probability of the patient recovering from the event.

Materials and methods: A review of the aetiology and associated pathophysiology of VAE is provided. This is followed by a detailed case report of the occurrence of a non-fatal VAE event (patient consent was obtained and the consent form template was reviewed by a Research Ethics Board).

Conclusion: We conclude with a discussion of quality assurance recommendations that should be considered for implementation in an outpatient facility setting that is performing contrast enhanced computer tomography diagnostic, interventional or radiation therapy planning radiographic procedures.

Keywords: CT contrast; radiation therapy planning; venous air embolism

INTRODUCTION

Venous air embolism (VAE) is an event that results from the entrainment of air or gas inadvertently introduced into the systemic venous circulation during or following surgical and non-surgical patient care procedures[1–6] or any human event that exposes a venous channel to air.[7] The occurrence of VAE can result in serious morbidity and even death and is a known complication associated with venous access procedures during contrast enhanced computed tomography (CT)

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where the injection of 200 ml of air at a rate of 70–100 ml/second would be considered fatal.[8,9] In contrast, a report of an injection of 135 ml of air at the rate of 4 ml/second through the power injector resulted in only non-specific symptoms and no complications.[4] Given the different outcomes noted in the reports of VAE occurring during or following diagnostic and interventional radiologic procedures, the mortality and morbidity rates are related to: the volume of air entrainment and rate of accumulation of air injected,[5,9,10] the presence of comorbidities at the time of contrast procedure, including any prior exposure to trauma,[7,11] the total amount of air injected[11–21] and the patient position throughout the enhanced contrast procedure.[10,22] VAE's are estimated to occur in 11·7–23% of procedures.[4] Woodring et al.[23] reported that the incidence of air embolism was 23% in contrast enhanced CT during hand injection procedures followed by the drip infusion and Groell et al.[24] reported an incident rate of 11·7% where a power injection apparatus was incorporated. Although the clinical manifestations of VAE occurring during or following non-surgical diagnostic radiographic procedures is reported as low as 2·5%[6] and as high as 10·8% for procedures classed as interventional radiology[6] the relative risk of VAE occurring during or following contrast enhanced radiographic procedures is considered to be medium.[5]

The case findings in this report involve a patient inadvertently receiving 19 ml of air (as a result of the line not being primed) while undergoing a contrast enhanced CT procedure during simulation for the purpose of radiation therapy treatment planning. A total of 100 ml of contrast was injected via a peripheral venous cannula in the left dorsal hand at a rate of 2·0 ml/second using a Mallinckrodt Angiomat Illumna (Injector Contrast Delivery Service Canada Covidien, Canada) contrast delivery system. The patient demonstrated clinical symptoms of a VAE and the presence of the VAE in the right atrium was confirmed on the CT slices (Figures 1–3). A critical review of the aetiology and associated pathophysiology of VAE is provided followed by the presentation of the details of the case and concluding with discussion of acute care management approaches in the outpatient facility setting. Health-care professionals must remain alerted to the fact that iatrogenic VAE may occur unexpectedly during and following diagnostic and interventional radiographic procedures utilising contrast media. The implementation by health-care professionals of rapid and clear acute care guidelines will lead to a higher probability of decreased patient morbidity and relative higher percentage of success of the patient recovering from the VAE event.

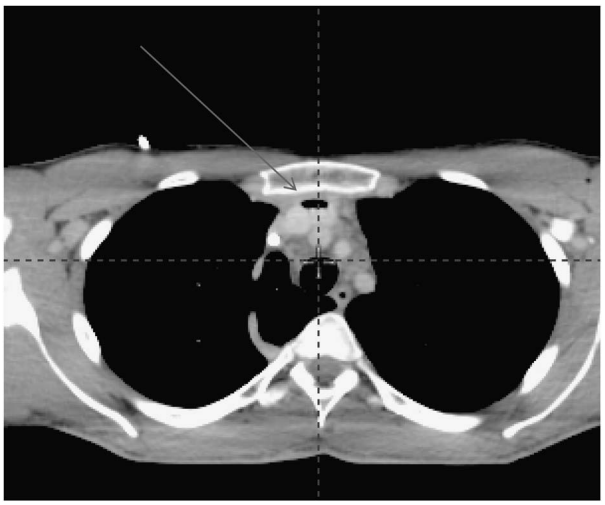

Figure 1. Arrow indicates air within the left brachiocephalic vein.

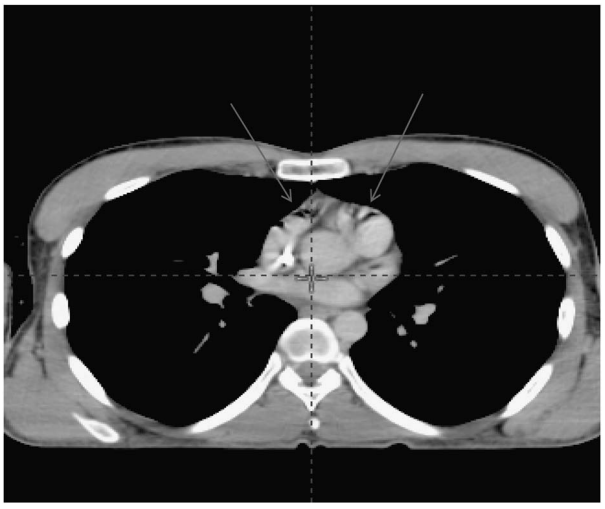

Figure 2. Arrows indicates air within the right atrial appendage and pulmonary outflow tract.

AETIOLOGY

There have been numerous non-surgical clinical incidents and numerous medical specialties

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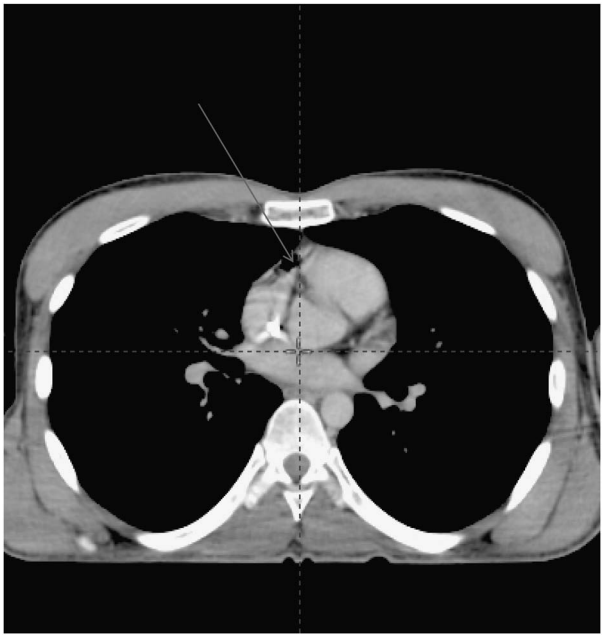

Figure 3. Arrow indicates air within the right atrial appendage.

reporting air embolisation.[2] The causes of air embolism are well known and include entry of air through: intravascular catheters such as peripheral and central venous canulae, pulmonary artery catheters, haemodialysis catheters, pressurised infusion systems and long-term central catheters such as Hickman catheters.[11] Although there are several possible sources of air into the venous system in general, a pressure gradient must exist between the site at which the air enters and the right atrium.[4] As the height of the entrance of air above the heart increases, the pressure gradient in turn between the site of entry and the right atrium increases[12]; thus the risk of the occurrence of VAE during neurological procedures performed with the patient in the sitting position is very high.[11] The injection of air inadvertently during contrast enhanced diagnostic and interventional radiographical procedures have also been implicated in iatrogenic VAE incidents.[2,5,11] Groell et al.[24] showed that 11·7% of patients undergoing CT studies of the chest utilising a power injector had small (<1 cm) and medium-sized (a few small bubbles 1–2 cm diameter bubble) VAE, most of which patients were asymptomatic. An interesting additional finding reported by Groell et al.[24] involved 5·5% of patients who did not have contrast media injected, but underwent non-contrast studies and who had cannula placed through which 5 ml sodium chloride was injected and these patients ended up experiencing VAE. This finding indicates other possible sources of air emboli can occur at the time of the actual insertion of the cannula or during the connection between the cannula and the injector tube and/or perhaps form the microbubbles inherent in the contrast itself.[4,12]

PATHOPHYSIOLOGY

Air introduced into the venous circulation can cause cardiac dysfunction by obstructing a part or the whole of the right ventricular outflow tract, including the pulmonary arteries, pulmonary arterioles and pulmonary microcirculation.[3] The major cause of death from a large embolism (~5 ml/kg)[5] is because of circulatory obstruction which results in significantly diminished cardiac output.[3,10] Large emboli may in addition cause paradoxical (arterial) embolisation because of the sudden increase in right atrial pressure leading to right to left shunting through either a patent foramen ovale or across the pulmonary capillary bed,[1] thus allowing the air embolism to enter into the arterial circulation.[3] The foramen ovale is an opening in the septum between the atria, which is normally closed at birth, but has been found in some patients to have remained open.[2,3] The consequences of paradoxical embolisation can be very severe because the presence of small amounts of air in the arterial system can result in end-organ ischaemia and/or infarction.[12] With slow entry of air into the right ventricle, obstruction may occur at the level of the pulmonary vasculature invoking vasoconstriction and pulmonary hypotension.[1,11]

The occurrence of pulmonary oedema after the development of VAE has been identified as a post-surgical complication,[25] but the amount of air required to produce pulmonary oedema in humans after the occurrence of iatrogenic VAE is unknown.[7] Animal studies indicate that the rapid injection of <1 ml/kg of air is enough to cause symptoms and/or physiologic changes.[22]

CASE DETAILS

While undergoing a contrast enhanced CT procedure during simulation following the

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inadvertent injection of 19 ml of air (Figures 1–3) a 24-year-old male with Stage IVB classical Hodgkin's lymphoma complained of: a sensation of tickling and discomfort in the right side of his neck and chest, shortness of breath and nausea. Patient did not experience wheezing or continuous cough.[5] The patient's mental status remained unaltered.[5] Prior to the injection the recorded baseline vital signs were: blood pressure (BP): 113/62, pulse 67/minute, O_2 saturation rate 99% on room air. The patient was not taking any medications and had stated no known allergies or comorbidities. At the onset of symptoms the vital signs recorded were: BP: 95/52, pulse 63/minute, O_2 saturation rate 99% on room air. The source of air was identified to be the injector and because the patient did not experience symptoms until the end of the procedure further vascular entry of air had stopped.[11] An attempt to remove air from the right atrium was not made because there was no central venous access line.[11] To prevent right ventricular failure the patient was placed in the left lateral decubitus position and the patient was instructed to tilt his head downwards.[11] One hundred per cent oxygen was administered to increase oxygen to the tissues and to aid in the reabsorption of nitrogen gas from the air bubble into the blood.[4] The patient response was positive. The sensation in his neck and chest resolved in ~30 minutes and his vital signs remained stable other than noted hypotension. The patient was continuously assessed by the oncologist and health-care professionals and was asked to remain in the department for several hours. Upon discharge from the outpatient health-care facility the patient was advised to go to a hospital emergency should he feel unwell or if he developed any cardiovascular or neurological signs. Regularly scheduled phone calls to the patient's home were made for a 48-hour period during which the patient's symptoms completely resolved (Figure 4). Although VAE may induce cardiovascular, pulmonary and neurologic sequelae, this patient fortunately displayed predominantly pulmonary symptoms only and thankfully cardiopulmonary resuscitation was not required. The diagnosis of VAE was made based on the clinical observation of patient symptoms and confirmed upon review of the CT slices (Figures 1–3). The patient was not referred for consideration of hyberbaric oxygen treatment and an electrocardiogram was considered not necessary. The patient to date (2012) has no evidence of any long-term morbidity from the VAE.

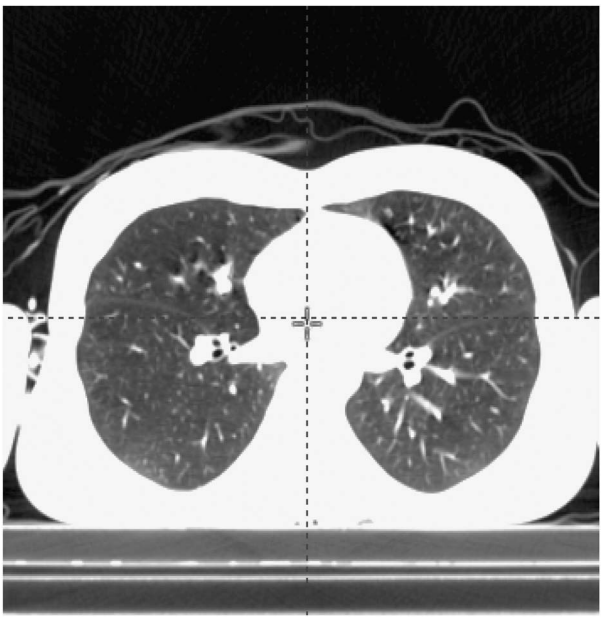

Figure 4. Lung windows: no oedema.

DISCUSSION

Prevention of iatrogenic VAE is as important as the care provided to the patient with VAE.[1] Owing to the potential seriousness of iatrogenic VAE and its association with high long-term mortality and morbidity[2,6] an outpatient facility quality assurance review was performed. A system-based review of the critical incident was performed to identify the root and contributory factors surrounding the occurrence of the VAE event.[26] The authors note that the health-care professionals in this outpatient facility have established a culture of quality improvement with a focus on establishing practices of care that prevent the occurrence of adverse events. Following a comprehensive quality review and an internal department critical review we recommend health-care professionals involved in performing diagnostic and interventional radiographic venipuncture procedures or radiation therapy planning procedures utilising

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injections of contrast media consider embracing and implementing the following practices:

(1) Schedule regular educational sessions/ discussions to review the use of the auto injectors, emphasising the importance of performing visual checks to ensure syringes are correctly loaded and that connecting lines are filled with contrast media before the injection.[12]
(2) Schedule regular educational sessions/ discussions to review and emphasise the adherence to following the established protocols (one-person or two-person) before injection of the contrast media.[4]
(3) Review/discuss on a regular basis the emergency procedure to follow when a patient presents with symptoms of iatrogenic VAE.
(4) Review/discuss on a regular basis the complications associated with the use and injection of contrast media and acute care plan procedures in efforts to remain alerted to the dangers of iatrogenic VAE.
(5) Remain alerted to the importance of implementing prompt acute emergency care measures to reduce the high morbidity and mortality associated with iatrogenic VAE.[6]
(6) Regular scheduled discussions to review any and all reported patient incident(s) associated with the venipuncture procedure(s) and/or the injection of contrast media. The review of incidents will serve to heighten the awareness of the dangers patients may encounter during or following routine procedures like venipuncture and the injection of contrast media.
(7) The patient long-term follow-up care plan should be documented in the patient chart to ensure the transfer of care from an outpatient facility to an emergency care facility (if necessary) has been properly coordinated and within an appropriate timeframe.[6]
(8) A review of the patient's CT scan either during or following the occurrence of the iatrogenic VAE should be performed by the oncologist/radiologist to confirm with radiological evidence the presence of the VAE and a report of the findings should be documented in the patient chart for future long-term care reference.

Within this outpatient facility there exists an onsite college certified venipuncture education programme for health-care professionals.[27] The educational materials were reviewed following this case report of a VAE and a list of current literature discussing VAE were updated and added. In addition current policies and procedures associated with adverse events following venipuncture and the use of contrast media were modified and currently:

(1) include step-by-step care plans and patient care procedures that health-care workers are to follow to manage the patient during any future occurrence of VAE;
(2) discuss specifically how to acutely manage patients who are experiencing cardiovascular, pulmonary and/or neurological sequelae following a VAE event.

CONCLUSION

Although the treatment options for VAE are well documented the most important cure for iatrogenic VAE is prevention.[4,7,12,15] Outpatient facilities that are performing contrast enhanced CT diagnostic, interventional or radiation therapy planning radiographic procedures should perform regular quality improvement reviews to ensure that acute care guidelines and procedures to effectively manage the episodes of VAE are current and known to health-care professionals involved in the care of patients experiencing symptoms of VAE.

Health-care professionals must remain alerted to the fact that iatrogenic VAE may occur unexpectedly during and following diagnostic and interventional radiographic procedures utilising the injection of contrast media. The action by all health-care professionals to implement rapid and clear acute care guidelines will increase the probability of the patient recovering from the event.

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