

Patient Safety and Quality Improvement:

Iatrogenic Venous Air Embolism in Diagnostic Imaging

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Introduction

The Medicines and Healthcare products Regulatory Agency (MHRA), the executive agency for the Department of Health (DoH) in England, ensures medicines and medical devices work and are safe. An incidence of fatal arterial embolism (AE) was reported, in which air was inadvertently injected into a patient rather than contrast media during a Computer Tomography (CT) examination with a contrast power injector pump. Instigating the issuing of safety notification MDA_SN_9626¹ however this was withdrawn² with the implication being that the equipment is safe and the incidence was human error.

Venous Air Embolism

Incidents of venous air embolism (VAE) occur when air enters the systemic venous system and travels to the lungs via the pulmonary arteries, where perfusion takes place to facilitate gas exchange³, causing bubbles to get lodged in the capillary bed disturbing normal gas exchange. This increases pulmonary arterial pressure, right ventricular strain, and cardiac arrhythmias. Leading to coronary artery occlusion, myocardial ischemia and ultimately cardiac failure. Additional complications involve the disruption in pulmonary perfusion and ventilation creating alveolar dead space, hypoxia and hypercapnia⁴.

Paradoxical AE can also occur mid or post procedure when VAE enters the arterial system through a patent foramen ovale, right to left shunts or arteriovenous malformation⁴. A systemic review by Mirski et al⁵ explained that a patent foramen ovale is present in approximately 20% of adults although a more reliable peer reviewed study by Hagen et al⁶ discussed autopsies of 965 specimens and evidenced a high level of 27.3%, and remains a significant risk factor of potential death resulting from VAE.

What, Where, Why and How

So what is the basic evidence do we know of to support these claims? Three significant physical law's relating to VAE explain the behaviour of gases such as, Boyle's Law, Henry's Law and Hagen-Poiseuille's Law.

Boyle's Law explains if the temperature is constant, a fixed volume of gas is inversely proportional to the pressure applied⁷. For example, if the temperature of the contrast agent is constant, any volume of gas within the contrast will decrease as the power injector applies pressure on the liquid, i.e. as soon as the pressure decreases, the volume of the gas will increase when contrast reaches the lumen of the vessel.

Henry's Law affirms, the amount of air dissolved in a fluid is proportional to the pressure applied⁸. For example, air in the syringe will dissolve into the contrast when pressure is applied by the power injector and when depressurisation occurs in the lumen of the vessel air will release, akin to a bottle of fizzy drink.

Hagen-Poiseuille's Law explains laminar flow in the vessel. Flow is proportional to the radius to power of 4 (r⁴) and inversely proportional to viscosity of the fluid and vessel length, meaning small changes to the diameter of the lumen of a vessel can make a large variation to the flow rate⁹.

Detection

So what studies, research or evidence is there out there? Due to the occult nature the majority of VAE are overlooked, go unreported and any adverse post injection incident can mimic cardiovascular conditions which can be nonspecific on clinical presentation, and the true incident may be underestimated. Episodes of iatrogenic VAE in CT contrast-enhanced imaging will inevitably go undetected when imaging other body regions, due to the area in which emboli occur not being demonstrated and therefore not reported, such as abdominal and pelvic scanning for example.

Groell et al¹⁰ studied 677 patients, after vigilant injection technique of a 5ml saline flush and power injection of between 43-155ml of contrast agent, incidence of VAE was evident on contrast-enhanced images in 11.7% of patients.

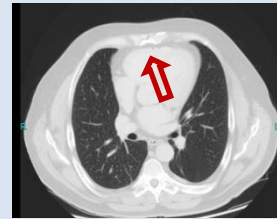


Image 1. Normal contrast in the left subclavian vein

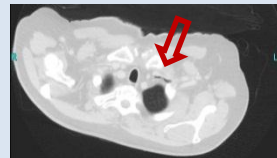


Image 2. VAE in the left subclavian vein

What size bubble is trouble?

In a study on dogs Durant et al¹¹ established the volume of air, rate of injection and patient position were all factors influencing production of VAE. The amount of air required to cause fatality was extremely variable; 25-150 ml of air was tolerated but more recent case reports show in humans a power injected non-fatal volume of 135ml¹². Toung et al¹³ estimates the lethal volume of air in humans to be 200ml, however the definitive fatal volume remains unknown.

Conclusion

The DOH is in consultation to make intravenous AE within healthcare a "Never Event". To qualify, the event has to:-

Have the potential to cause harm or death

Have national guidance for prevention and if followed the event is preventable.

Has to be easily defined.

Occurrence of such an event indicates an organisation has failed to prevent it and failed to prevent harm to the patient. If AE becomes a "Never Event", prevention of VAE will require a more stringent approach than currently practiced and it also has financial implications to healthcare providers as any associated costs resulting from a "Never Event" have to be borne by the provider¹⁴.

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