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Air embolism during anaesthesia for shoulder arthroscopy

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We report a case of venous air embolism during an elective shoulder arthroscopy in which air was used as a joint distending agent. Venous air embolism was diagnosed by the sudden decrease in the end-tidal carbon dioxide concentration. The patient suffered no serious complications of venous air embolism and made a full recovery. We present this case to make surgeons and anaesthetists aware of the possibility of gas/air embolism during elective arthroscopy, when gas/air is used to distend the joint. This case also illustrates that the end-tidal carbon dioxide monitor, which is part of the standard anaesthetic monitoring system, is very sensitive in detecting venous air embolism.

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Venous air embolism is a known complication during anaesthesia for hip replacements, laparoscopies and operative procedures in which the operative site is above the level of the heart, as in neurosurgical and major head and neck procedures, especially in the sitting position. Although rare, venous gas embolism can occur during arthroscopy, when air or another gas is used to distend the joint. We are aware of only one report where air embolism occurred during shoulder arthroscopy. We report an additional case of air embolism during a diagnostic arthroscopy of a shoulder joint, during which the surgeon had injected 50 ml of air into the joint.

Case report

A 28-yr-old man was scheduled for elective arthroscopy of the left shoulder and subacromial decompression. He had suffered left shoulder pain for 2 yr but there was no history of trauma to the joint. Two preoperative MRI scans had not shown any abnormalities in the joint. His health status was unremarkable, apart from a history of mild asthma for which he had not taken any medication in the previous 2 yr. He had undergone an uneventful general anaesthetic in the past for inguinal hernia repair.

Anaesthesia was induced with propofol 200 mg, fentanyl 0.1 mg, and vecuronium bromide 10 mg. The trachea was intubated and ventilation of the lungs was controlled. Anaesthesia was maintained with sevoflurane and nitrous oxide in oxygen. Morphine 10 mg and ondansetron 4 mg was administered. Routine monitoring included end tidal carbon dioxide measurements. The patient was placed in the beach chair position. After a stab incision in the skin, the arthroscope with a pointed trochar was introduced into the left shoulder joint. The joint was seen using the arthroscope and 50 ml of air was injected into the joint by attaching a syringe with air to the inflow portal on the arthroscope. Within 1 min after the injection, a marked drecrease in the end tidal carbon dioxide ($E\mathrm{T}_{\mathrm{CO}_2}$) from 4.0 to 1.5 kPa was noted. The electrocardiogram showed a 1-mm rise in the ST segment, and the heart rate increased from 56 to 90 beats min^{-1}. There were no changes either in the oxygen saturation or in the non-invasive blood pressure. An air embolism was suspected and the patient was placed horizontal and nitrous oxide discontinued. The end tidal carbon dioxide concentration returned to 4.0 kPa after 4 min. The surgical procedure was allowed to continue after ensuring the condition of the patient was stable and the $E\mathrm{T}_{\mathrm{CO}_2}$ concentration had returned to normal. There was an episode of bradycardia 15 min following the incident during which the heart rate decreased to 38 beats min^{-1}. This responded to 0.6 mg of i.v. atropine.

The patient made a full recovery from the anaesthetic at the end of the procedure, without any sequelae. He remained stable for the next 48 h and was discharged home.

Discussion

Venous air embolism may occur during any operative procedure in which the operative site is above the level of the heart and non-collapsible veins are exposed to atmospheric pressure, or when air or any other gas is introduced under pressure into a body cavity. The clinical presentation and complications of venous air embolism depend on the dose and the speed of air entry into the vein and the filtering capacity of the lungs.

Although venous air embolism of some degree is detected in all patients undergoing neurosurgical procedures in the sitting position,[1] it is very rare in shoulder arthroscopy. Air

and other gases have been used to distend the joint in arthroscopy since 1921. Fatal pulmonary air embolism has been reported during arthroscopy of injured knee joints.[2 3] It is presumed that air entered the circulation through the exposed venous sinuses in these cases. We are aware of only one case of venous air embolism during a shoulder arthroscopy.[4] There are, however, theoretical risks of embolism during this procedure. In the beach chair position, used for shoulder operations, the operative site is higher than the right atrium. In addition, during arthroscopy the pressure inside the joint may be 5–10 times higher than the venous pressure and if a vein is punctured during insertion of the arthroscope, any agent used to distend the joint may enter the venous system.

Because of the low morbidity and anaesthetic complication rate associated with shoulder arthroscopy, the procedure is performed as a day case in most hospitals. Air is commonly used as the joint distending agent because of the better view obtained, when compared with normal saline.

The possible mechanisms of developing a venous air embolism during arthroscopy are: injection of air into an injured joint, where the air can get into the exposed venous sinuses because the intra-articular pressure during arthroscopy is high and may reach peak values of 300 mm Hg with sudden manipulation of the joint;[5] or accidental injection of air into a vein in the joint.

In our case there was no history of trauma, preoperative MRI scans showed no abnormalities in the joint and arthroscopy did not show any disruption in the joint surface. It is presumed that a vein was accidentally punctured during the stab incision or by the introduction of the arthroscope into the joint. The raised intra-articular pressure because of the injected air and the manipulation of the joint resulted in air entering an open vein.

There are several reports in the anaesthetic literature where the use of sophisticated monitors to detect venous air embolism early in operations, with a high risk of development of venous air embolism, has resulted in a significant reduction in morbidity and mortality.

Transoesophageal echocardiography is the most sensitive monitor for early detection of venous air embolism (detects as little as 0.02 ml kg^{-1} of air).[6] Others include pulmonary artery catheters, pre-cordial Doppler probe and $E_{T_{CO_2}}$ and nitrogen measurements.

For day case arthroscopies an inexpensive, non-invasive, sensitive and easy-to-use monitor is essential. The pre-cordial Doppler probe meets the above criteria. It is very sensitive, but picks up interference from other sources. Before it becomes a useful tool for early detection of venous air embolism, familiarity with its use is essential. In most district general hospitals, however, capnography remains the main monitor for the early diagnosis of venous air embolism. It has fewer sources of interference than echocardiography and pre-cordial Doppler. It is widely used and is sensitive (sensitivity of 0.4 ml kg min^{-1}),[7] but is non-specific for air embolism. Above all, awareness of the possibility of air embolism, a high index of suspicion and vigilance are most important in arthroscopy when air or other gases are used to distend the joint. Early detection of venous air embolism will allow for prompt treatment before serious clinical complications develop.

A significant venous air embolism will manifest as bronchospasm, hypoxaemia, hypercapnia, decreased $E_{T_{CO_2}}$, hypotension, cardiac dysrhythmias and cardiovascular collapse, depending on the size of the embolus and the rate of entry of air into the veins.

Management of clinical venous air embolism includes measures to prevent expansion of the embolus and further entry of air into the venous system. The operative site should be lowered below the level of the heart, if possible and flooded with fluids while haemostasis is obtained. Nitrous oxide should be discontinued and oxygen increased to 100%. Blood pressure and central venous pressure should be supported with fluids, vasopressors and inotropes. If a large amount of air is entrained, the left lateral decubitus position may improve right ventricular outflow. Further treatment includes insertion of right atrial catheter and aspiration of air from the right side of the heart. In the event of cardiovascular collapse, cardiovascular resuscitation should be commenced.

Prevention is the key to the management of venous air embolism. Patients at risk should be well hydrated in order to reduce the pressure gradient between the surgical site and the right atrium. Surgical haemostasis is essential at all times. Intravenous air is five times more dangerous than carbon dioxide.[8] Therefore, carbon dioxide or normal saline are safer agents for distension of joints during arthroscopy.

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