European Journal of Anaesthesiology 2007; **24:** 803–816

Correspondence

Fatal venous air embolism during lumbar surgery: the tip of an iceberg?

doi: 10.1017/S0265021506002201

EDITOR:

Venous air embolism (VAE), the entrainment of air into the venous system during surgery, is a well-known complication of surgery in the sitting position. VAE can also occur in the prone position but is under suspected and under reported. There is only one report of VAE occurring in three separate patients in the prone position. There are no reports published in the European literature.

Though rare, VAE can be a devastating event. We present a case of fatal VAE that occurred during an elective lumbar laminectomy. By reporting this case, we hope to raise awareness that this complication can occur in the prone position and to encourage increased monitoring for VAE in high-risk patients.

A 43-yr old female presented for a repeat lumbar L4/5 laminectomy. Anaesthetic history was unremarkable. A past history of breast malignancy and subsequent resection was noted. On arrival in the anaesthetic room, full monitoring was commenced, including non-invasive blood pressure (NIBP), pulse oximetry, electrocardiogram (ECG) and end-tidal carbon dioxide ($ETCO_2$) measurement. Following induction of anaesthesia and muscle paralysis, the trachea was intubated and lungs ventilated with oxygen-enriched air. Anaesthesia was maintained using a target controlled infusion of propofol 3.1–4.0 $\mu g\,mL^{-1}$ and a remifentanil infusion 0.05–0.1 $\mu g\,kg^{-1}\,min^{-1}$, titrated according to depth of anaesthesia. The patient was transferred into the operating theatre and placed on support cushions in the prone position. Careful adjustment was made to allow for free abdominal movement during ventilation.

Forty-five minutes after the commencement of surgery, an increase in the pulse rate from 75 to 90 beats min^{-1} was noted. The propofol infusion was increased. Shortly thereafter, the $ETCO_2$ level fell from 4.4 to 2.9 kPa, and this was followed by an unrecordable NIBP.

A venous air embolism was suspected. The surgeon was informed and the wound was flooded with saline; the F_iO_2 was increased to 1, and ephedrine and a fluid bolus were given. ST depression was seen on the monitor and although a carotid pulse could not be detected, the oxygen saturation remained at 99%. Within 1 min, the situation improved with the NIBP rising to 82/60 mmHg, a heart rate of 90 bpm, a return to baseline of the ST segments and a rise in the $ETCO_2$ to 4.0 kPa. The surgical wound was kept flooded with saline, and the surgical procedure was rapidly completed. The patient was returned to the supine position, whereupon she began to breathe spontaneously and opened her eyes to command. Without warning, she suddenly became pale and unresponsive, accompanied by a fall in the NIBP to 40/20 mmHg. A precordial Doppler was placed on the chest and a further air embolus confirmed. Resuscitative measures were instituted and the patient was turned into the left lateral position in preparation for right central venous access. Before this could be achieved, the patient suffered a cardiac arrest and was turned back into the supine position for cardiopulmonary resuscitation (CPR). The abdomen was noted to be distended, leading to a presumptive diagnosis of significant intra-abdominal haemorrhage. An exploratory laparotomy was performed, but no source of bleeding could be found. The abdominal aorta was non-pulsatile and after a period of time, when both pupils were fixed and dilated, the attempts at resuscitation were abandoned. At post-mortem, the heart and great vessels were removed en-bloc and moderate-sized air bubbles were found in the right atrium. There was no obvious damage to any of the great vessels close to the operative site. However, a small amount of blood was found in the retroperitoneal space. A patent foramen ovale was not sought.

Correspondence to: Dr Sara Frances McDouall, Department of Anaesthetics, Royal Berkshire Hospital NHS Foundation Trust, London Road, Reading RG1 5AN. E-mail: sara@mcdouall.co.uk; Tel: 0118 322 5111

Accepted for publication 1 September 2006 EJA 3978
First published online 12 March 2007

VAE is a well-known though rare complication of surgery. Patients undergoing neurosurgery in the sitting position are particularly at risk with an incidence of 25–80% [1,2]. However, VAE has also been reported in complicated scoliosis and lumbar laminectomy surgery [3–8]. VAE occurs when a gravitational gradient exists between the operative site and the right atrium, and open vessels are exposed to the atmosphere. VAE can range from subclinical emboli with no adverse effects to a massive embolus with a fatal outcome. Detection of VAE has become much easier with the advent of sensitive monitoring such as the precordial Doppler, transoesophageal echocardiography (TOE) and $ETCO_2$ recording. The precordial Doppler is able to detect $0.05\,mL\,kg^{-1}$ of air, although the auditory signal gives no indication of the size of the air embolus [1]. TOE is even more sensitive, detecting as little as $0.02\,mL\,kg^{-1}$ [2], and has the advantage of quantitative measurement. However, it requires an experienced operator, is invasive, more expensive than the Doppler and requires the patient to be supine for insertion. The $ETCO_2$ level is a less sensitive and non-specific monitor for air, but has the advantage of being part of routine monitoring.

The gravitational gradient between the operative site and the right atrium required for the ingress of air can be as little as 5 cm. Albin and colleagues have demonstrated that this gradient can exist in the prone position [1]. A prone patient is positioned so as to allow free movement of the abdomen, which benefits both ventilation and lessens epidural blood loss by reducing engorgement of these vessels. Thus, in this position, the epidural veins can become relatively empty, particularly if the patient is volume depleted, which can further encourage the entrainment of air. DiStefano and colleagues analysed the effects of positioning on the pressures within the inferior vena cava. They found that pressures as low as $-2.0\,cm\,H_2O$ could exist in the inferior vena cava when a patient is placed in the prone position on a Hastings frame, which allows for free movement of the abdomen [9].

With regard to this case, we surmise that a number of factors contributed to the ingress of air via the epidural veins. These include a gravitational gradient between the right atrium and the operative site, a negative pressure within the veins secondary to the decompression of the abdomen and mild volume depletion. It would seem as if the initial cardiovascular collapse was indicative of a small VAE. Following treatment and stabilization of this episode, one can postulate that a large pocket of air remained trapped in the dorsal part of the right atrium/ventricle, which dislodged on turning into the supine position. The ST depression might have been indicative of either a patent foramen ovale, known to be present in 27% of the population [10], or the transpulmonary passage of air, which has been documented previously [11,12].

It is possible that VAE occurs far more commonly in the prone position than is realized, as routine monitoring with precordial Doppler is not undertaken in spite of its efficacy, simplicity and safety. The majority of VAE may well be subclinical, but the danger of a large VAE cannot be overlooked. Principles of treatment of VAE include prevention of further entrainment of air (flooding the operative site with saline, bilateral jugular compression), measures to increase venous pressure (volume load to raise central venous pressure, positive end expiratory pressure), aspiration of air from the right atrium via a correctly positioned central venous catheter (CVC) and, if feasible, turning the patient to the left side in order to break any air lock within the right atrium. In this position, air can be more easily aspirated from the right atrium. However, placement of central venous lines is difficult in the prone position, and turning the patient supine rapidly has its own inherent risks. CPR is also difficult to perform effectively in the prone position.

One aid to diagnosis and treatment of a VAE in the prone position would be to place air aspiration (CVCs) in all patients thought to be at risk in the prone position, allowing for aspiration of air should a VAE occur. This, however, could expose an unnecessarily large number of patients to the risk of central venous cannulation. Some of the problems that need to be addressed are: Who is the high-risk patient and how can the position of the catheter be easily verified after the patient has been turned into the prone position? Patients who readily fall into the high-risk category include children, those with known cardiac septal defects, congenital cardiac disease or cardiac compromise and patients for procedures with anticipated large blood loss. Less obvious high risk patients are those having repeat procedures such as laminectomy, particularly at the level of L4/5 or L5/S1 (personal communication). These patients are likely to have distorted anatomy as a result of previous surgery, leading to a more difficult dissection and a greater risk of exposing open vessels.

Positioning the CVC is crucial if the aspiration of air is to be successful. Bunegin and Albin provided evidence that air could be maximally aspirated if a multi-orificed catheter was placed with the tip between the sinoatrial node and a point 2 cm below [13]. This was further verified by Colley and Artru [14] who resuscitated a significantly greater

proportion of dogs given lethal doses of air with a multi-orificed catheter placed in the mid-atrium. The catheter tip can be placed using ECG guidance, as described by Colley and Artru subsequently [15], thus avoiding the need to irradiate the patient.

Our case highlights a rare complication of anaesthesia and surgery in the prone position. It demonstrates that it is possible for VAE to present late, even after open vessels have been closed. It may present following a change in patient position. We suggest that VAE occurring in the prone position is under detected and consequently under reported. We advocate increased awareness and monitoring in all cases where the operative site is above the level of the heart, and the placement of a CVC in cases that, in light of the discussion above, could be considered to be high risk.

S. F. McDouall
Department of Anaesthetics
Heatherwood and Wexham Park Hospitals NHS Trust
Wexham, Slough, UK

D. Shlugman
Department of Anaesthetics
John Radcliffe Hospital
Headington, Oxford, UK

References

1. Albin MS, Carroll RG, Maroon JC. Clinical considerations concerning detection of venous air embolism. *Neurosurgery* 1978; **2**: 380–384.
2. Palmon SC, Moore LE, Lundberg J, Toung T. Venous air embolism: a review. *J Clin Anesth* 1997; **9**: 251–257.
3. Lang SA, Duncan PG, Dupuis PR. Fatal air embolism in an adolescent in Duchenne muscular dystrophy during Harrington instrumentation. *Anesth Analg* 1989; **69**: 132–134.
4. Sutherland RW, Winter RJ. Two cases of fatal air embolism in children undergoing scoliosis surgery. *Acta Anesthesiol Scand* 1997; **41**(8): 1073–1076.
5. McCarthy RE, Lonstein JE, Mertz JD *et al*. Air embolism in spinal surgery. *J Spinal Disord* 1990; **3**(1): 1–5.
6. Horlocker TT, Wedel DJ, Cucchiara RF. Venous air embolism during spinal instrumentation and fusion in the prone position. Letter to the editor. *Anesth Anal* 1992; **75**: 152.
7. Frankel AS, Holzman RS. Air embolism during posterior spinal surgery. *Can J Anaesth* 1988; **35**(5): 511–514.
8. Albin MS, Ritter RR, Pruett CE, Kalff K. Venous air embolism during lumbar laminectomy in the prone position: report of three cases. *Anaesth Analg* 1991; **73**: 346–349.
9. DiStefano VJ, Klein KS, Nixon JE, Andrews ET. Intraoperative analysis of the effects of position and body habitus on surgery of the low back. *Clin Orthop* 1974; **99**: 51–56.
10. Hagen PT, Scholz DG, Edwards WD. Incidence and size of patent foramen ovale during the first 10 decades of life: an autopsy study of 965 normal hearts. *Mayo Clin Proc* 1984; **59**: 17–20.
11. Butler BD, Hills BA. Transpulmonary passage of venous air emboli. *J Appl Physiol* 1985; **59**: 543–547.
12. Marquez J, Sladen A, Gendell H *et al*. Paradoxical cerebral air embolism without an intracardiac septal defect. *J Neurosurg* 1981; **55**: 997–1000.
13. Bunegin L, Albin MS, Helsel PE *et al*. Positioning the right atrial catheter: a model for reappraisal. *Anesthesiology* 1981; **55**: 343.
14. Colley PS, Artru AA. Bunegin–Albin cateter improves air retrieval and resuscitation from lethal air embolism in dogs. *Anesth Analg* 1987; **66**: 991–994.
15. Artru AA, Colley PS. Placement of multiorificed CVP catheters via antecubital veins using invasive electrocardiography. *Anesthesiology* 1988; **69**: 132–135.

Acetone poisoning – a diagnostic dilemma

doi: 10.1017/S0265021507000245

EDITOR:
Acetone intoxication is a rarely reported substance involved in poisoning [1–3]. A literature search indicated that, in all cases reported, a clear history of acetone ingestion was obtained, thus facilitating management. We present a case where this information was not immediately available, and subsequent difficulties presented in the diagnosis and management.

Case report

A 47-yr-old female presented to A&E with respiratory distress. She had a past history of alcohol abuse and deliberate self-harm and was receiving citalopram for depression. She had no other medical problems of

Correspondence to: Veerappan Kumarvel, Department of Anaesthetics & Intensive Care, Maidstone Hospital, Hermitage Lane, Maidstone, Kent ME16 9QQ, UK. E-mail: seethakumarvel@hotmail.com; Tel: +1622 670554; Fax: +1622 224669

Accepted for publication 23 December 2006 EJA 4244
First published online 11 April 2007