Incidental detection of paradoxical air embolism with a transoesophageal Doppler probe inserted for measuring descending aortic blood flow

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We present a case of paradoxical air embolism in a patient undergoing neurosurgery of the posterior fossa in the sitting position. Paradoxical air embolism was detected in the descending aorta by a transoesophageal Doppler probe, which was inserted primarily for non-invasive haemodynamic monitoring. The patient suffered no serious complications of paradoxical air embolism and recovered well. We suggest that paradoxical air embolism can be detected intraoperatively not only by transoesophageal echocardiography, but also with a transoesophageal Doppler probe.

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Venous air embolism is a well-known complication of neurosurgery performed in the sitting position. These neurosurgical procedures have the highest rate of venous air embolism with an incidence ranging from 25% for cervical surgery up to 76% for seated posterior fossa surgery.\(^1,2\) Paradoxical air embolism is a serious complication following venous air embolism and may produce coronary and cerebral embolism with lethal consequences.

Increased pulmonary vascular resistance and right atrial pressure following venous air embolism predisposes to paradoxical air embolism. A prerequisite for paradoxical air embolism is the existence of a right-to-left shunt, for example an intracardiac defect, specifically a patent foramen ovale that has a prevalence of 27% according to autopsy data, or an intrapulmonary shunt.\(^3,4\) Paradoxical air embolism has been reported to occur in 14% of patients.
undergoing neurosurgery in the sitting position and may cause serious coronary and cerebral ischaemic complications.\textsuperscript{6–8} Identification of right-to-left shunts by preoperative echocardiography has been advocated to reduce the risk of major morbidity and mortality from air embolism especially in patients at high risk for venous air embolism, such as those undergoing neurosurgery in the sitting position.\textsuperscript{9}

We present a case of paradoxical air embolism detected in the descending aorta by a transoesophageal Doppler probe in a patient undergoing neurosurgery of the posterior fossa in the sitting position. The transoesophageal Doppler probe device was inserted primarily for non-invasive haemodynamic monitoring. Preoperative contrast transthoracic echocardiography had shown no evidence for right-to-left shunt. Postoperative contrast transcranial Doppler ultrasound confirmed the intraoperative finding of a right-to-left shunt. To our knowledge this is the first report of detection of a paradoxical air embolism using a transoesophageal Doppler probe.

Case report
A 70-yr-old woman was undergoing resection of a tumour in the cerebellopontine angle in the sitting position. The patient had a 1-yr history of progressive imbalance, tinnitus, sensory loss in the distribution of the trigeminal nerve, trochlear paralysis, and headache. Besides a history of arterial hypertension, for which she was taking lisinopril, she had no other medical problems. Her arterial pressure before surgery was 150/90 mm Hg and the electrocardiogram showed normal sinus rhythm. A preoperative contrast transthoracic echocardiography detected no evidence of right-to-left shunting during both spontaneous respiration and a Valsalva manoeuvre. In addition, no visible intracardiac shunt was detected by two-dimensional imaging.

General anaesthesia was induced with sodium thiopental and sufentanil. Neuromuscular block was achieved and maintained with rocuronium. After tracheal intubation anaesthesia was maintained with sevoflurane (1 MAC) and supplemental sufentanil, and the patient’s lungs were ventilated with an air–oxygen mixture and a PEEP of 5 mm Hg. Intraoperative monitoring included a 5-lead electrocardiogram, pulse oximetry, capnography, right arterial cannulation to monitor arterial pressure, a central venous catheter, and a pulmonary artery catheter inserted via the right subclavian vein. For non-invasive continuous, real-time haemodynamic monitoring a HemoSonic\textsuperscript{TM}100 transoesophageal probe (Arrow\textsuperscript{®} International), which has 5 MHz Doppler and 10 MHz M-mode ultrasound transducers, was placed in the oesophagus. The best position of the probe was achieved at an insertion depth of 18 cm, which equates to the 3rd or 4th intercostal space. Optimal visual and auditory signals of flow in the descending aorta were confirmed.

After the patient’s blood volume was expanded with 1000 ml of a crystalloids solution administered i.v. and her legs were bandaged she was placed in the sitting position. Thereafter, the monitored haemodynamic variables were stable and the operation began. Soon after craniotomy and opening of the dura an episode of venous air embolism was detected. The end-tidal carbon dioxide tension ($P_{\text{ET}}^\text{CO}_2$) suddenly decreased from 30 to 18 mm Hg, $P_{\text{a}}\text{CO}_2$ increased from 34 to 46 mm Hg, and haemoglobin oxygen saturation decreased from 100 to 89% according to pulse oximetry. Simultaneously, haemodynamic responses included increases in pulmonary artery pressure from 27/6 to 52/15 mm Hg and central venous pressure from 6 to 10 mm Hg, while the arterial pressure and aortic blood flow decreased from 138/80 to 109/58 mm Hg and 4.0–3.1 litre min\textsuperscript{–1}, respectively. In addition, the electrocardiogram showed multiple supraventricular extrasystoles, while auscultation of the ‘mill-wheel’ murmur was not possible. Immediately, the fractional inspired oxygen was increased to 1.0, arterial pressure was increased with norepinephrine 5.1 μg min\textsuperscript{–1}, and bilateral jugular venous compression was performed for about 10–15 s to temporarily increase cerebral venous pressure. Aspiration of the central venous and pulmonary artery catheter yielded no air. About 60 s after the onset of first clinical signs of venous air embolism, air was also detected in the descending aorta with the transoesophageal Doppler probe. This detection of air in the descending aorta was detectable for 35 min, while the signs of venous air embolism lasted 24 min.

At the end of surgery the patient’s trachea was extubated and she was transferred to the intensive care unit. She had no clinical evidence of pulmonary oedema or neurological sequelae. Control cranial embolism CT showed no signs of the paradoxical affecting the brain. The patient was transferred to the normal ward at the second postoperative day. At the seventh postoperative day, contrast transcranial Doppler was performed by insonating the left middle cerebral artery through the temporal bone window. Microbubbles were detected both spontaneously and after a Valsalva manoeuvre. Thus, the existence of a right-to-left shunt was confirmed by contrast transcranial Doppler.

Discussion
To reduce the risk of major morbidity and mortality from air embolism, preoperative identification of right-to-left shunts has been recommended in patients at high risk for venous air embolism. Preoperative detection of a right-to-left shunt is commonly performed non-invasively with contrast thoracic echocardiography (with a sensitivity of 60–100% and a specificity of 78%) and more recently with contrast transcranial Doppler (with a sensitivity of 90–100%) or with semi-invasive contrast transoesophageal echocardiography, which is regarded as the ‘gold standard’\textsuperscript{10–14} Following this case we have adopted the contrast transcranial Doppler as the assessment method of choice for screening for the
presence of a right-to-left shunt in patients undergoing an operation in the sitting position. To prevent a potentially devastating paradoxical air embolism, patients with a known right-to-left shunt should not undergo surgery in the sitting position.

There are several methods in clinical use to detect an intraoperative venous air embolism, for example capnography, the pulmonary artery catheter, precordial ultrasonic Doppler, or transoesophageal echocardiography. In contrast, an intraoperative paradoxical air embolism can only be detected with transoesophageal echocardiography, a method that is expensive, requires skilled operators and is therefore not in widespread use in any hospital for 24 h a day. This is the first report of a patient with signs of paradoxical air embolism detected intraoperatively with a transoesophageal Doppler probe. The HemoSonic™100 transoesophageal Doppler probe was inserted for non-invasive continuous, real-time haemodynamic monitoring. The distal part of the oesophageal probe contains two ultrasound transducers, Doppler and M-Mode that continuously measure aortic diameter and blood flow velocity in the descending aorta, calculating absolute descending aortic blood flow. From this, cardiac output and stroke volume are calculated. The probe is easily inserted and the correct position quickly established. In our patient microbubbles were detected by acoustic and optical signals in the descending aorta with the transoesophageal Doppler probe 60 s after the beginning of venous air embolism. Air was continuously detected in the descending aorta for 11 min after the signs of venous air embolism had resolved. One could suppose that the mechanism of paradoxical air embolism was due to an intrapulmonary shunt, because of the late onset and long duration of air detection in the descending aorta. These findings are in accordance with the detection of right-to-left shunts with contrast transcranial Doppler in the absence of an intracardiac defect as in our patient.12 14 Other authors reported that transoesophageal Doppler probe was a highly sensitive monitor which provided an early detection of venous air embolism.15 16 In these cases the transoesophageal Doppler probe was placed primarily to detect venous air embolism in the junction of the right atrium and the inferior vena cava or in the azygos vein.

To our knowledge this is the first case report of the detection of an intraoperative paradoxical air embolism with a transoesophageal Doppler probe. Without transoesophageal Doppler probe the paradoxical air embolism would have been difficult to detect. In contrast to the transoesophageal echocardiography the transoesophageal Doppler probe is less invasive because of its small outer diameter of 7 mm; insertion of the probe is easily performed and even unskilled investigators quickly establish the correct positioning. In addition, it enables a continuous, real-time monitoring of several haemodynamic variables such as measures of left ventricular contractility and ejection time as well as flow resistance. We suggest that prompt detection of paradoxical air embolism with a transoesophageal Doppler probe is feasible and can prevent devastating consequences and thus may affect patients’ outcome.

References

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