AIR EMBOLISM DURING NEUROSURGERY

A Case Report

BY

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SUMMARY

A case is reported of venous air embolism occurring during cervical laminectomy in the sitting position. The patient was treated successfully with aspiration of air, oxygen and positive pressure ventilation. The diagnostic features, prevention and treatment are discussed, and the importance of a central venous catheter and an oesophageal stethoscope is stressed.

"Mon sang tombe dans mon corps, je suis mort." These were the last words of a locksmith whose death in 1818 was the first to be ascribed to air embolism, accidentally occurring at operation (Magendie, 1821). Earlier experiments on animals had shown that venous air embolism could be fatal if the air was injected rapidly and in sufficient quantity. In 1830, Barlow had retrospectively made a brief report on a possible case thirty years earlier, but by this time Magendie had not only investigated further, but had suggested methods of treatment still found to be effective today. Although cervical laminectomy in its present form began in 1814, and the sitting position adopted for posterior fossa and cervical surgery at the end of the century, the incidence of air embolism during anaesthesia appears to have been low until the advent of intermittent positive pressure ventilation (Hunter, 1962). Despite precautions, air embolism remains a hazard of neurosurgical procedures in the sitting position, as the following case report indicates.

A man, aged 54 years, weight 104 kg, was admitted to hospital for cervical laminectomy to relieve symptoms of spinal cord compression. His past history included four episodes of myocardial ischaemia, the last being three years previously. He received methohexitone, suxamethonium, endotracheal intubation, nitrous oxide, oxygen and fluoroxyne. His respirations were assisted by occasional pressure on the reservoir bag and he was placed in the sitting position. Monitors used were an oesophageal stethoscope, a sphygmomanometer, an electrocardiograph (lead I), and a central venous pressure catheter. Pulse rate, arterial and venous pressures and respiratory rate were recorded every 5 minutes. The heart sounds were monitored continuously through the oesophageal stethoscope, and the position of the venous pressure catheter in the right atrium verified by radiography (fig. 1). The operation proceeded uneventfully through an incision from the level of C6 to T1 until closure of the fascial layers over the suboccipital muscles. At this time, a harsh metallic systolic murmur was heard through the oesophageal stethoscope and two ventricular ectopic beats were seen on the e.c.g. The blood pressure, hitherto stable at 120/60 mm Hg, dropped to 80/40 mm Hg and the central venous pressure suddenly rose from 5 to 12 cm saline. The pulse and respirations remained unaltered. The patient was given 100 per cent oxygen and was ventilated with continuous positive pressure. The surgeon was unable to locate the port of entry of the air, so a saline-soaked swab was placed over the surgical field. A mixture of air and blood was aspirated from the heart through the venous catheter, and after removal of 20-30 ml of air, the cardiac murmur disappeared, and the venous and arterial pressures returned to normal. No further changes were noted on the e.c.g. Anaesthesia was resumed and the operation proceeded, but, 25 minutes later, further metallic cardiac murmurs were heard and a similar sequence of arterial hypotension, raised venous pressure and occasional ventricular ectopic beats were recorded. Treatment was immediately instituted as previously, and the patient recovered rapidly. The operation ended without further incident, the patient returned to the ward conscious and no cerebral or cardiac abnormalities were noted post-operatively.

DISCUSSION

The incidence of air embolism during anaesthesia in the sitting position varies from 2 per cent (Michenfelder et al., 1969) to 15 per cent (Marshall, 1965), and is even higher when more sophisticated methods of detection are used (Maroon, Edmonds-Seal and Campbell, 1969).
Air may enter not only the diploic veins and dural sinuses but also by way of veins in the suboccipital muscles, as in the above case. Nevertheless, while the sitting and semi-recumbent positions provide near optimal conditions for posterior fossa and other surgery, neurosurgeons will continue to ask for the adoption of such postures. In these cases, early diagnosis of air embolism is essential, and can be attained only by adequate monitoring.

The oesophageal stethoscope (Smith, 1954) is perhaps the most important single piece of equipment, enabling the alteration in heart sounds, heart rate, and respiratory rate to be perceived immediately. Such a stethoscope is reliable, unobtrusive, simple to position properly, easy to use, and inexpensive. Maroon, Edmonds-Seal and Campbell (1969) recommended the use of a Doppler ultrasonic flowmeter to detect small volumes of air in the heart, and by this method were able to diagnose air embolism in five out of seven neurosurgical patients operated on in the sitting position. However, they were unable to quantitate the amount of air involved, and were perhaps measuring insignificant volumes.

A central venous pressure catheter should be used in all cases where the possibility of air embolism exists not solely as a guide of right ventricular obstruction but also as a vital therapeutic aid to allow aspiration of intravascular air. The position of the catheter should be ascertained either under electrocardiographic control (Martin, 1968) or by radiography, to ensure that its distal end lies in the superior vena cava or right atrium. Moreover, it should be large enough to allow rapid aspiration of air and long enough to enter the right ventricle if required.

An electrocardiogram is another valuable monitor, and leads I, III and V, have been recommended as the most suitable to detect pneumoembolic changes (Lewis and Rees, 1964).

Arterial pressure measurement, either by direct cannulation or by indirect methods, is essential to this type of surgery, if not to all cases, as is the recording of heart and respiratory rate. The use of a carbon dioxide analyzer has been advocated (Bethune and Brechner, 1968) in sitting neurosurgical cases so that continuous estimations of carbon dioxide in expired air can be recorded. Any fall in carbon dioxide output may indicate a lowered cardiac output following obstruction of the right ventricle by air.

**Diagnosis.**

Michenfelder and associates (1969) reported that in 90 per cent of their cases of air embolism,
The first observed abnormal sign was a cardiac murmur. The murmur usually occurs during systole and varies from a tinkling sound to a harsh millwheel murmur, depending on the volume of air involved. The pulse increases and may be irregular while hypotension is present in the majority of cases. The central venous pressure is elevated. The respirations have been described as laboured and there may be evidence of spontaneous ventilatory effort despite partial curarization and control of ventilation. Cyanosis is only rarely seen and a sucking noise at the point of entry of the air is occasionally heard. Electrocardiographic changes include P and T wave abnormalities, right bundle branch block, and ventricular arrhythmias (Lewis and Rees, 1964).

**Treatment.**

The most urgent need is for the removal of the intravascular air. This was demonstrated by Magendie in 1821, using a catheter to aid aspiration, and his method remains valid today. The air, or frothy blood, is best aspirated through a wide-bore catheter whose tip lies in the right atrium. Other methods including open-chest aspiration have been advocated, but are less satisfactory. Magendie's other suggestions related to the prevention of further air aspiration. He advised compression or ligation of the injured vessel, or packing of the surgical field if the site of air entry had not been located. Compression of the neck veins is advocated by most authors because not only does this manoeuvre raise the pressure in the neck veins thereby preventing further air embolism, but it may also identify the source of the leak by expelling blood and air from the injured vessel. Neck vein compression was not practical in our patient, in whom the incision extended from the levels of the spines of C3 to T2, and in this type of case, a G-suit might have proved beneficial (Hewer and Logue, 1962).

Hunter (1962) noticed an increased incidence of air embolism in neurosurgical patients in whom controlled respiration and relaxants were used, and he maintained that the low mean intrathoracic pressure predisposed to the formation of air emboli. He suggested that ventilation be controlled using a Magill attachment. Michenfelder and associates (1969), however, attributed their own low incidence of air emboli (2 per cent) in part to the use of controlled ventilation without muscle relaxants. Many authors (Marshall, 1965; Hewer and Logue, 1962) preferred spontaneous ventilation. However, all are agreed that should this complication occur, continuous positive pressure ventilation is necessary to prevent further aspiration of air.

In all cases of air embolism, 100 per cent oxygen should be given to improve oxygenation of lungs and blood. Moreover, if nitrous oxide is being administered, it must be discontinued promptly because this agent increases the size of the air emboli (Nunn, 1959). The solubility of nitrous oxide in blood is greater than that of nitrogen, and consequently the volume of nitrous oxide diffusing out from the blood into the air embolus is greater than the volume of nitrogen leaving the embolus to dissolve in the blood, so the air bubble enlarges. Indeed this may be a reason for never using nitrous oxide in cases where air embolism is a possibility.

The head-down position would appear to be the logical one for a patient whose cardiac output is severely diminished. In 1837, Poiseuille recommended that a patient with intracardiac air embolism be positioned to keep the air away from the pulmonary outflow tract, and Durant, Long and Oppenheimer (1947) demonstrated the advantage of the left lateral position in this respect. The left lateral, head-down position is, however, difficult to obtain in the anaesthetized sitting patient in most operating suites.

Vasopressors may be required to correct the hypotension, and lignocaine has been effective in controlling the ventricular arrhythmias (Lewis and Rees, 1964). External cardiac massage has been advocated to increase cardiac output and to drive the air out of the right ventricle and pulmonary artery into the smaller pulmonary vessels (Ericsson, Gottlieb and Sweet, 1964). These measures, however, may not be necessary if the patient is carefully prepared prior to incision to ensure the early detection of air emboli and to facilitate their immediate removal.

**ACKNOWLEDGEMENT**

I wish to thank Dr. Stephen Young, whose prompt assessment of the dangerous situation saved this patient's life.

**REFERENCES**


**EMBOLIE D'AIR DURANT LA NEUROCHIRURGIE: DESCRIPTION D'UN CAS**

L'auteur décrit une embolie veineuse d'air, survenue au cours d'une laminectomie cervicale en position assise. Le patient fut traité avec succès par aspiration d'air, oxygène et ventilation sous pression positive. L'auteur discute les caractéristiques diagnostiques, la prévention et le traitement, et attire l'attention sur l'importance d'un cathéter veineux central et d'un stéthoscope oesophagien.

**LUFTEMBOLIE IN DER NEUROCHIRURGIE: BERICHT ÜBER EINEN FALL**

Es wird über einen Fall von venöser Luftembolie während cervicaler Laminektomie in Sitzposition berichtet. Der Patient wurde erfolgreich behandelt mit Überdruckbeatmung eines Luft-Sauerstoff-Gemisches. Diagnostik, Prophylaxe und Behandlung werden diskutiert; die Bedeutung eines zentralvenösen Katheters und einer ösophagalen Drucksonde wird hervorgehoben.

**ERRATA**


"Propanidid" by C. M. Conway and D. B. Ellis.

The last sentence of the CONCLUSIONS section should read:

"Thus despite its undoubted advantage the undesirable side effects of propanidid would appear to preclude its wide acceptance."


"Dynamics of Cough" by J. G. Jones and S. W. Clarke.

In the Summary of the paper appearing under this title there is an error in line 5. This should read:

"sudden closure of the dependent airways" and not "independent airways".