AIR EMBOLUS IN NEUROSURGICAL ANAESTHESIA, ITS DIAGNOSIS AND TREATMENT

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WITH THE INTRODUCTION of controlled positive-negative-pressure ventilation in neurosurgical anaesthesia, our attention was focused upon the possibility that the technique might cause air embolism. In order to facilitate the early detection of an air embolus, the use of an oesophageal stethoscope, as described by C Smith,¹ was instituted as an additional monitoring device. This paper describes the occurrence of six cases of air embolism, two of which occurred in the same patient from different sites, and will discuss the diagnosis, clinical course, and treatment. The cases are taken from a 26-month period, during which time there was a total of 281 cases in the categories in which it was thought that air embolism might occur. These groups are outlined in Table I.

TABLE I

	Posterior fossa exploration	Craniotomy	Cervical laminectomy	Craniotomy with hypothermia
Position	Sitting	Supine	Prone	Supine
Total number	34	161	37	49
Incidence of air embolus	5	—	1	—
Positive and negative controlled ventilation	Nil	80%	80%	100%

The anaesthetic technique varied only slightly in each group of cases. Induction of general anaesthesia with thiopentone was followed by intubation, aided by succinylcholine relaxation. Nitrous oxide, and oxygen plus halothane, were used as the basic anaesthetics. Controlled ventilation with intermittent positive and negative pressure was used when surgical or anaesthetic factors so indicated. Controlled ventilation was not used for any cases in the sitting position, it was usually used for intracranial tumours with the patient in other positions, and it was always used in conjunction with hypothermia.

The cases are described in Table II. Cases 1, 2, and 5 involved patients undergoing posterior fossa exploration in the sitting position. Each patient was breathing spontaneously. In each case the air embolism occurred during the surgical exposure while bone was being removed. Case 3 was a patient with a tumour of the upper mediastinum in whom a decompression of the lower cervical and upper thoracic spinal cord was being carried out. The patient was in the prone position. In this case the air entered by a vein in the fascia overlying the thoracic lamina. The vein was held open by a self-retaining retractor. Air embolism

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occurred on two occasions in patient 4, initially during the surgical exposure, and subsequently after the bone had been removed. This patient was undergoing re-exploration for a posterior fossa tumour which had been removed initially about seven years previously.

The initial diagnostic feature noted in five of the six instances was the sound of air in the cardiac chambers, as described in Table III. In the other instance, the oesophageal stethoscope was not in use at the moment when the embolus occurred. Of special interest is the amount of time which elapsed in each case between the initial diagnostic sign and any change in cardiovascular or respiratory function. The rapidity of onset and the magnitude of the change in cardiac or respiratory function appeared to be associated with the rapidity of entry into, and the amount of air trapped in, the heart chambers.

TABLE II

	Case 1	Case 2	Case 3	Case 4A and 4B	Case 5
Operative procedure	Post fossa exploration	Post fossa exploration	Lower cervical and upper thoracic cord decompression	Post fossa exploration	Post fossa exploration
Position	Sitting	Sitting	Prone	Sitting	Sitting
Spontaneous respiration	Yes	Yes	Yes	Yes	Yes
Anaesthetic risk (1-5)	2	1	2	1	1

TABLE III

	Case 1	Case 2	Case 3	Case 4A	Case 4B	Case 5
First sign of air embolus noted	Heart sound	Heart sound	Heart sound	Irreg resp	Heart sound	Heart sound
Second sign of air embolus noted	Blood pressure fall	Blood pressure fall	Blood pressure fall	Heart sound	Blood pressure fall	Air forced from vein
Time interval 1st-2nd sign	30 sec	60 sec	30 sec	0 sec (?)	30 sec	2 min
Operation completed?	Yes	Yes	Yes	Yes	Yes	Yes
Sequelae	None	None	None	Dimness of vision for 16 hours		None

The clinical course in each instance was similar. The initial sound of air in the heart was followed by a drop in blood pressure. There was always a measurable period of time between these two events. It was possible in each case, except of course case 4B, to record a "normal" blood pressure at least once before any decrease in systolic reading was noted. This was followed by a varying degree of hyperpnoea, or on some occasions by tachycardia, and an irregular cardiac rhythm. The duration and extent of the cardiovascular and respiratory dysfunctions varied with the general condition of the patient, the rapidity and effectiveness of the treatment, and also, we assume, with the amount of air in the heart chambers.

The management of these cases was not complicated, and required no special apparatus. The steps are outlined in Table IV. As soon as the diagnosis was made, the surgeon was advised and requested to cover the area in which he was working, in order to prevent the entrance of more air. At the same time the anaesthetic expiratory valves were closed, and/or pressure was applied to the jugular veins. This resulted in air being forced from the open vein. In each case the site of entrance of the air was confirmed in this manner. It was then necessary to remove the air from the heart chamber and to maintain adequate cardiovascu-

TABLE IV

Treatment	Case 1	Case 2	Case 3	Case 4A	Case 4B	Case 5
Positive pressure	Yes	Yes	Yes	Yes	Yes	Yes
External cardiac massage	No	No	No	Yes	No	No
Position change	Sitting to lateral	No	Horizontal to head-down	Sitting to lateral	Sitting to lateral	No
Vasopressor	Yes	Yes	Yes	Yes	Yes	No

lar function. On one occasion nothing was required other than to prevent further air from entering the vein. On another occasion a small amount of vasopressor only was required. To remove the air from the right side of the heart it was found adequate simply to increase venous return by moving the patient to the horizontal or head-down position. In those patients who were in the sitting position, it was possible, because of a special arrangement described below, to place them in the lateral-horizontal position. The resulting increase in venous return was sufficient to clear the air from the heart quickly. This manoeuvre was equally effective in either the right or left lateral position. A vasopressor drug was sometimes given. When the cardiovascular function became stable, the patient was returned to his previous position and the operation continued.

The clinical course in each case was, we hope, altered by the treatment. In five cases the diagnostic sound preceded by 30 seconds or more any change in cardiovascular function. In the one case in which the stethoscope was temporarily not in use, the diagnosis was made on the basis of the sound of air in the heart after the occurrence of tachypnoea and drop in blood pressure. This patient was the only one in whom possible sequelae occurred.

DISCUSSION

The ease and accuracy of diagnosis came as rather a surprise. Reference texts imply that a diagnosis of cardiac air embolism is made mainly on the basis of cardiovascular collapse, or signs of gross respiratory insufficiency.² The presence of a "millwheel" type of cardiac murmur has been regarded as pathognomonic of the condition.³ In all cases that we have noted, the only constant sign has been the murmur described. In five of the six instances it was the initial and diagnostic sign. There have been no false positive diagnoses, nor, we feel, have there been any occasions when the presence of air in the heart chambers was not detected while the stethoscope was being used.

THE MODIFIED SITTING POSITION

The ease and rapidity with which the patient could be moved from the sitting to the lateral recumbent position are due to the technique described by Frances Garcia Bengorhia in 1962 at the 15th Annual Meeting of the Neurosurgical Society of America.⁴ The patient is placed in a legless armchair or other suitable supporting frame facing sideways on the operating table. The cephalic end of the table is elevated to the vertical position and the chair is placed flush with this support. The head frame may be attached to this portion of the table. The surgical draping is done so that the patient is draped free of the instrument tables. The chair and patient are then strapped firmly to the vertical portion of the operating table. To place the patient in the lateral recumbent position it is necessary merely to rotate the entire table through 90°. In this way the patient does not change position relative to the table nor is the draping disturbed. The surgeon still has full view of the operating field and he can continue any urgent or emergency measures albeit with increased difficulty (see Figs 1 to 4)

FIGURE 1 Operating table chair and frame

CONCLUSION

We have found air embolism to occur in neurosurgical operations involving exploration of the posterior cranial fossa or posterior cervical region. The embolus may occur when the patient is in either the prone or sitting position. We have not found an air embolism associated with operations on the anterior or middle cranial fossae, the cervical spine using the anterior approach, or the lumbar spine either with or without the use of positive negative controlled ventilation.

We have found that the endo oesophageal stethoscope gives an instantaneous

FIGURE 2 Position of patient

FIGURE 3 Patient draped with head draping pulled aside

and accurate diagnosis of the presence of air in the heart. Our treatment of these cases which has been completely successful is as follows:

- 1 Prevent further entry of air into the vein
- 2 Force all air out of the vein by jugular compression and/or by increasing intrathoracic pressure
- 3 Wash air out of the heart into the lung by increasing greatly the blood flow from the inferior vena cava. This is done by changing the position of the patient

FIGURE 4 Patient and table in lateral position

from the sitting to the lateral recumbent position or from the prone to the head down position

4 Use measures to support cardiovascular and respiratory function such as vasopressors and ventilation with pure oxygen

SUMMARY

Six cases of air embolus were noted in a total of 218 neurosurgical procedures over a period of 26 months. The operations included craniotomies posterior and middle fossa explorations cervical laminectomies and upper thoracic and cervical spine explorations. Five cases occurred with the patient in the sitting position and one in the prone position. No case occurred in conjunction with the use of positive-negative controlled ventilation.

It was found that the use of an endo oesophageal stethoscope afforded an immediate and accurate diagnosis of this condition. Changes in respiratory and cardiovascular function followed at least 30 seconds after the earliest evidence was noted by means of the oesophageal stethoscope.

The treatment of the cases consisted of preventing more air from entering through the open vein, washing the air out of the heart chambers by increased venous return and supporting cardiovascular and respiratory function where necessary. By a special positioning arrangement it is possible to move the patient from the sitting to the lateral position without disturbing the draping or the operative field. As a result of this all operations were continued after a short delay and concluded successfully.

It is suggested that an endo-oesophageal stethoscope be used whenever it is considered possible that cardiac air embolism may occur.

RÉSUMÉ

Depuis plusieurs années, nous nous sommes servis d'un stéthoscope oesophagien comme instrument pour dépister les embolies gazeuses cardiaques dans tous les cas d'anesthésie pour neurochirurgie

Au cours des 26 premiers mois, nous avons diagnostiqué six cas d'embolie gazeuse. Cinq de ces cas sont survenus au cours de la chirurgie pour exploration de la fosse postérieure alors que le malade était en position assise. L'autre cas est survenu au cours d'une décompression de la moelle cervicale et thoracique haute, le malade était en position ventrale. Aucun de ces cas n'est relié à l'usage de la ventilation contrôlée avec pression positive et négative.

Nous avons entendu le bruit de l'embolie gazeuse dans le cœur, chez 5 des 6 cas, au moins 30 secondes avant l'observation de tout autre signe. Dans un cas, le stéthoscope n'était pas en usage pour un moment, lorsque l'embolie est survenue. La porte d'entrée de l'air a été retrouvée dans chaque cas, en faisant ressortir des bulles d'air, soit en augmentant la pression dans le circuit de la machine à anesthésie, soit en comprimant les veines du cou.

Comme traitement, nous avons fermé l'entrée de l'air dans le champ opératoire et nous avons chassé l'air des chambres cardiaques en augmentant le retour du sang veineux venant de la partie inférieure du corps. Pour réaliser ce traitement, il nous a suffi de placer le malade la tête basse et/ou en position latérale. Occasionnellement, nous avons dû recourir à des vasopresseurs pour rétablir la pression artérielle.

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