Effect of the Degree of Head Elevation on the Incidence and Severity of Venous Air Embolism in Cranial Neurosurgical Procedures in the Semi-sitting Position

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INTRODUCTION

Despite the significant decline in its use over the past 20 years, the semi-sitting position (SSP) still has a unique and irreplaceable role in neurosurgery, especially in posterior fossa surgery. This position allows better gravitational drainage of cerebrospinal fluid and blood from the surgical field, offering the neurosurgeon a clean and unobstructed exposure of the lesion.. Intraoperative VAE can be defined as an obstruction of the vascular circulation by air introduced into the venous system from the surgical field or from other interventions to the venous system during surgery. Changing the position of the patient from supine to semi-sitting brings the venous pressure at heart level below the atmospheric pressure, thereby placing the patient at particular risk of rapid air inflow into the venous circulation. Still, the reason for the surprisingly large variation in rates of VAE between studies, from 1.6% to 76%, is still unknown. This range is too wide to be explained only by different detection methods and is probably the result of different positioning techniques, as there is no standardized angle of elevation of the patient’s head. Moreover, none of the studies is prospective. To the best of our knowledge, there are currently no data that define the relationship between the degree of head elevation and the rate and severity of VAE.

In this study, we compared data regarding VAE in patients undergoing elective infratentorial neurosurgical procedures in the SSP. We compared data from two groups, one having 30 degrees of head elevation and the other having 45 degrees. We also defined a standard protocol for perioperative management of patients undergoing surgery in the SSP.

MATERIAL AND METHODS

One hundred patients undergoing an elective infratentorial craniotomy in the semi-sitting position were included, and patients were divided into two groups. In group 1, each patient’s head was elevated 30 degrees; in group 2, head elevation was 45 degrees. Patients were assigned to groups according to the location of their lesion. During surgery, the standard anesthetic protocol was used with total intravenous anesthesia, and transesophageal echocardiography was used to detect air in the blood circulation. Any air embolism seen on the echocardiography screen was classified as grade 0 to 4. If multiple events occurred, the worst graded attack was used for statistical analysis. During hemodynamic changes caused by emboli, fluid and vasopressor requirements were recorded. Surgical and anesthetic complications were also recorded. In the literature, the rate of VAE for various degrees of head position has been reported in a wide range, from 1.6% to 76%.¹⁹ According to our experience and clinical relevance, however, the rate of VAE for two different degrees of head position ranged from 15% to 40%. According to power analysis, 49 patients per group were calculated with $\alpha = 0.05$, $\beta = 0.20$, and power = 0.80 to show a reduction in the rate of VAE from 40% to 15% between two different degrees of head position. To compensate for potential exclusions or withdrawals, we decided to include 50 patients in each group. The two groups were compared with regard to demographics of the patients, number of patients with hemodynamic changes requiring treatment after positioning from supine to SSP, and the rate and severity of VAE detected on the TEE screen. A p value < 0.05 was considered statistically significant.

RESULTS

There was a statistically significant difference between groups for the total rate of venous air emboli detected on transesophageal echocardiography: 22.0% (n=11) in group 1 and 62.5% (n=30) in group 2 ($p < 0.0001$). The rate and severity of air embolism were significantly lower in group 1 than in group 2 ($p < 0.001$). The rate of clinically important venous air embolism (grades 2, 3, and 4: venous air embolism with decreased end-tidal carbon dioxide levels and/or hemodynamic changes) was 8.0% (n=4) in group 1, and 50.0% (n=24) in group 2 ($p < 0.0001$). There was no association between the rate and severity of venous air embolism with patients’ demographics ($p>0.05$). There was association, however between the rate of venous air embolism and the type of surgical pathology ($p< 0.001$). The venous embolism was more frequent in patients with meningiomas. There were no major surgical or anesthetic complications related to the patients’ position during the postoperative period.

TABLE 2. Characteristics of the study groups (% (n))

	Group 1 (n=50)	Group 2 (n=48)	P value
Female/male ratio (n)	26/24	31/17	0.2903
Age (years)	37 ± 21	41 ± 17	0.3038
Weight (kg)	73 ± 9	76 ± 8	0.0848
ASA status (I/II) (n)	36/14	27/21	0.1568
Surgical pathology (%(n))			
neuroepithelial tumors	50.0% (25)	39.6% (19)	0.4047
meningiomas	18.0% (9)	22.9% (11)	0.6205
schwannomas	26.0% (13)	18.8% (9)	0.4709
cavernous malformations	4.0% (2)	10.4% (5)	0.2636
epidermoid cysts	2.0% (1)	4.2% (2)	0.6134
germ cell tumors	0% (0)	4.2% (2)	0.2373
Number of patients with hemodynamic changes requiring treatment	0% (0)	8.3% (4)	0.0539

TABLE 3. Comparison of the rate and severity of venous air embolism between groups (% (n))

	Group 1 (n=50)	Group 2 (n=48)	OR	95% CI	P value
Grade 0	64.0% (39)	37.5% (18)	5.90	2.43-14.36	0.0001*
Grade 1	14.0% (7)	12.5% (6)	1.14	0.35-3.67	0.999
Grade 2	8.0% (4)	45.8% (22)	0.10	0.031-0.33	< 0.0001*
Grade 3	0	4.2% (2)	0.18	0.00-3.94	0.237
Grade 4	0	0			1
Clinically important venous air embolism†	8.0% (4)	50.0% (24)	0.08	0.02-0.27	< 0.0001*
Total venous air embolism	22.0% (11)	62.5 (30)	0.16	0.06-0.41	0.0002**

†The severity of the venous air embolism ≥ grade 2

*There was a statistically significant difference between groups ($p < 0.0001$).

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CONCLUSION

For patients in the semi-sitting position, an increase in the degree of head elevation is directly related to a higher rate of venous air embolism. With 30 degrees of head elevation and our standardized technique of positioning the semi-sitting position can be utilized safely in neurosurgical practice.