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ORIGINAL RESEARCH

Medicine Science International Medical Journal

Medicine Science 2018;7(3):524-7

Incidence of venous air embolism and blood gas changes seen in infratentorial surgeries operated in sitting position

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Received 06 December 2017; Accepted 01 March 2018
Available online 17.05.2018 with doi: 10.5455/medscience.2018.07.8807

Abstract
Our aim was to find out the rate and timing of venous air embolism (VAE), other complications associated with sitting position and changes on arterial blood gas during and after VAE. We analyzed retrospectively files of 124 patients who underwent posterior fossa surgery in department of Neurosurgery of our institute between January 2004 and April 2014. The incidence of emboli was 76,3% in the first 3 hours of the surgery while it was 38.2% in the first 2 hours in total. VAE was seen in a total of 21 patients (16.9%) and it was detected by a sudden drop of minimum 2mmHg of end-tidal CO_2 ($EtCO_2$)(25.38 ± 3.28 mmHg) in all cases (100%). The pH, PaO_2 and $PaCO_2$ values of the patients with and without emboli were evaluated pre and post-operatively and no significant difference was found ($p>0.05$). Precordial doppler ultrasonography is the most sensitive non-invasive monitoring device for accurate detection of even small VAE which are not clinically relevant. The most sensitive technique for detection of VAE is transoesophageal echocardiography but it is expensive, invasive and can cause some serious complications. In our study, emboli were most frequently seen in the 3rd hour of the surgery which coincide with tumor resection, thus proposing anaesthesiologists to be more cautious about VAE and EtCO2 during the tumor resection period.

Keywords: Sitting position, venous air embolism, cranial surgery, arterial blood gas analysis

Introduction

Although providing a perfect surgical sight for especially lesions in midline brain, fascilitating drainage of cerebrospinal fluid and venous blood, and better ventilation supply; sitting position in the infratentorial operations has a potential of serious complications like venous air embolism (VAE), tension pneumocephalus, intraoperative hemodynamic instability, lingual or laryngeal edema. VAE is one of the most important and life-threatening complications in sitting position. The veins above the level of right atrium have lower intravascular pressure than central venous pressure. The pressure of neck and head veins become subatmospheric when the patient's head position is more than 65° up. As a result of these veins' opening out, air absorbed into the veins and VAE occurs [1,2]. It is shown that the VAE incidence varies between 7% to 76% of the patients undergoing neurosurgery in sitting position, due to the sensitivity of the follow-up techniques. The most sensitive techniques are transoesophageal echocardiography (TEE) and precordial Doppler ultrasonography (PD) for VAE detection. Monitorisation of central venous and pulmonary arterial pressures, expired gas analysis ($EtCO_2$, N), intracardiac echocardiography (ICE), transcutaneous oxygen, and usage of oesophageal stethoscope are the other methods for VAE detection [3]. The precordial doppler and $EtCO_2$ monitoring are the suggested monitors for VAE detection. If air can be quickly taken under control and a limited amount of air entered into the veins, the effects of VAE may be subclinical [4]. It may result in obstruction on right ventricle outlet, decrease in cardiac output, decrease in arterial blood pressure, ischemia of myocardium and brain, and even death; although the volume of absorbed air is little [5].

In this study, we analyzed retrospectively files of 124 patients who underwent posterior fossa surgery in Department of Neurosurgery of our institute between January 2004 and April 2014 to find out the rate and timing of VAE, other complications associated with sitting position and changes on arterial blood gas during and after VAE.

Materials and methods

Following approval of Ethics Committee of our institute, the records of 124 patients who underwent posterior fossa craniotomy in the sitting position between January 2004 and April 2014 were reviewed retrospectively. Demographic data, preoperative and

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intraoperative arterial blood gas analysis, anesthetic technique and intraoperative hemodynamic variables were recorded. Standard monitoring included an electrocardiogram, invasive arterial blood pressure, pulse oximeter, capnography, temperature, central venous pressure and urine output. VAE was detected by a sudden drop of 2 mmHg in end-tidal CO_2 as in the study of Mirski et al. [5] and verified simultaneously by arterial blood gas analysis.

Statistical Analysis

For evaluation of the quantitative measurements, we used descriptive statistics of mean ± standard deviation (SD), median, minimum and maximum values, and number and percentage of qualitative data. Distribution of data was assessed by the Shapiro Wilk's test, was found in accordance with the normal distribution of data. To compare preoperative and postoperative measurements, a t-test was performed. A p-value of less than 0.05 was considered significant. 21.0 version of SPSS (Statistical Package of Social Science) for Windows was used for statistical analysis.

Results

The files of 124 patients who underwent posterior fossa craniotomy in sitting position between 2004-2014 were evaluated. Demographic variables and the mean duration of surgeries are shown in table 1. The incidence of emboli was 76,3% in the first 3 hours of the surgery while it was 38.2% in the first 2 hours (table 2).

VAE was seen in a total of 21 patients (16.9%) and it was detected by a sudden drop of $EtCO_2$ (25.38 ± 3.28 mmHg) in all cases (100%). The pH, PaO_2 and $PaCO_2$ values of the patients with and without emboli were evaluated pre and post-operatively, and no significant difference was found (p>0.05) between the groups (table 3).

The incidence of emboli according to preferred anaesthesia technique (total intravenous anesthesia {with propofol and remifentanil, air, O_2 } or inhalation {desflurane mixed in air, O_2 with remifentanil}) for maintenance had no significant difference between the groups of "with emboli" and "without emboli" (p>0.05) (table 4).

The mean value of arterial blood pH was 7.42 ± 0.06, PaO2 was 153.71 ± 53.74, PaCO2 was 37.54 ± 7.87 and EtCO2 was 25.38 ± 3.28 when the emboli occurred (table 5).

All the patients were hemodynamically stable both at the time of VAE and following aspiration of the air via the central venous catheter. Neither mortality nor morbidity due to VAE has seen.

Table 1. Demographic variables (age, body weight, sex and duration of surgery)

Variables	Mean ± SD (median)
Age (year)	41.47 ± 16.81 (40.5)
Body weight (kg)	70.69 ± 13.29 (70)
Sex (F / M)	69 / 55 (55.6% / 44.4%)
Duration of surgery (hours)	5.6± 1.88 (5)

Table 2. Timing of emboli

Time	%
1. hour of surgery	4.8%
1.5. hour of surgery	4.8%
2. hour of surgery	28.6%
3. hour of surgery	38.1%
4. hour of surgery	19%
5. hour of surgery	4.8%

Table 3. Preoperative and postoperative pH, PaO_2, $PaCO_2$ values of patients with or without emboli

	With emboli		Without emboli		p-value	
With emboli	**Preoperative**	**Postoperative**	**Preoperative**	**Postoperative**	**Preoperative**	**Postoperative**
pH (mean ± SD (median)	7.40 ± 0.05 (7.41)	7.41 ± 0.04 (7.40)	7.41 ± 0.04 (7.42)	7.40 ± 0.04 (7.41)	0.415	0.246
PaO_2 (mean±SD) (median)	203 ± 61,00 (216)	194.4 ± 60.2 (210)	189,9 ± 51,9 (196)	198.7 ± 44.6 (200.50)	0.308	0.067
$PaCO_2$ (mean±SD) (median)	35.5 ± 5.21 (34)	35.23 ± 4.15 (34)	34.02 ± 4.3 (34)	34.85 ± 3.85 (34)	0.234	0.394

Table 4. Emboli incidence according to method of anesthesia

	Total Intravenous Anaesthesia (TIVA) n, %	Desflurane-Remifentanyl n, %	Total	p value
With emboli	10, 8.07 %	11, 8.87 %	21 (16.94%)	0.635
Without emboli	55, 44.35 %	48, 38.71 %	103 (83.06%)	

Discussion

Although the sitting position for posterior fossa surgeries has some advantages for the surgeon, also has a high risk for VAE. Complications due to the position of the patient, myocardial or cerebral ischemia in consideration of hypotension, and paradoxical arterial air embolism may also be seen. The largest studies between 1978 and 2002 that reporting incidence of VAE in the sitting position indicated that VAE can be seen 6% to 30%. Only 1% to 6% of them were serious as producing hypotension [3]. The detection of VAE depends on the sensitivity of monitoring methods that are used during the surgery. It is reported 6% to 82,5% up to the sensitivity of used detection technique of VAE [5]. İşçimen et al reported the incidence of VAE 27.6% with PD and in 70.6% of these cases $EtCO_2$ reduction detected (19.5% of total patients) [6]. In a study of ICE usage for detection of VAE, 82.5% of VAE incidence reported by Schafer et al. [7]. Bithal et al reported the incidence as 22% in children and 28% in adults with the sole monitorization of end tidal CO_2 of total 430 patients (96 children and 334 adults) that underwent posterior fossa surgery in sitting position [8]. Korkmaz Dilmen et al analyzed 692 adult and pediatric patient underwent neurosurgery in sitting position and monitored with EtCO2 retrospectively. They found the VAE incidence 26.3% on children and 20.4% on adults [9]. Duke et al retrospectively analyzed 432 cases of vestibular schwannoma surgeries in sitting and supine positions and determined that the incidence of VAE was 5% in supine and 28% in the sitting position [10]. In a study which included 600 patients undergoing neurosurgical operations in the sitting position, Ganslandt et al reported that the overall incidence of VAE was 19 % (114 of the cases) and incidence of the severe VAE with a drop of end-tidal CO_2 was 10.2 %. They also figured that the incidence of VAE was more frequent in cerebellar fossa surgeries than cervical spine surgeries (21% and 11% respectively)[11]. In a meta-analysis of published 28 studies between 1972 and 2007 including 4806 patients who underwent neurosurgery in sitting position, Fathi et al indicated that VAE occurred 38.6% of posterior fossa surgeries and 11.8% of cervical surgeries [12]. Black et al reviewed 579 posterior fossa surgeries and found incidence as 45% in sitting position group versus 12% of prone position group [13] Leslie et al studied prospectively on 100 patients operated in the sitting position and monitored with EtCO2, they found an incidence of 9%. None of the patients had significant desaturation or hypotension [14]. Saladino et al analyzed 425 patients who underwent neurosurgical procedures in sitting position and detected VAE incidence of 21 %. From the first incision of skin to the end of the dural opening, 55.6 % of VAE occurred. The 33% of VAE occurred during tumor resection [15]. This finding is similar to our results.

All the patients planned for surgery in sitting position were catheterized by a 7 F subclavian catheter to aspirate the air from the right atrium in case of VAE. Similar to the literature results, the incidence of VAE was 16,9 % (21 patients). We accepted a sudden drop of 2 mmHg of EtCO2 as VAE and confirmed with the simultaneous arterial blood gas analysis. And blood was aspirated from the catheter as soon as a drop of 2 mmHg in $EtCO_2$ is seen. The VAE can be detected by the more sensitive techniques (like TEE, ICE or PD) than $EtCO_2$ in the lack of any drop of $EtCO_2$. In the similar studies using $EtCO_2$ for VAE detection, the authors reported 2 to 4 mmHg sudden drop for suspicion of VAE [5,6,11] In our study, the sudden drop of 2mmHg on $EtCO_2$ supported with simultaneous arterial blood gas analysis and also aspiration of the air from right atrium via subclavian venous catheter.

There was no significant difference between pre and postoperative pH, $PaCO_2$, and PaO_2 between with and without emboli groups. Also, there was no difference in the occurrence of VAE between total intravenous anesthesia group and inhalation anesthesia with desflurane group. The 38.2% of VAE occurred in the first 2 hours of surgeries when the 38.1% were occurring in the 3rd hour of surgery. Thus VAE is mostly seen during resection of tumor and secondly during the opening of the cranium. All of the patients were hemodynamically stable both at the time of VAE and following aspiration of the air via the central venous catheter. Neither mortality nor morbidity was seen due to VAE.

Conclusion

PD is the most sensitive non-invasive monitoring device for accurate detection of even small VAE which are not clinically relevant. The most sensitive technique for detection of VAE is transoesophageal echocardiography but it is expensive, invasive and can cause some serious complications as a tracheal laceration. As VAE results in an increase in dead space ventilation, it causes a decrease in the level of end-tidal CO_2 [1].

In case of lack of precordial doppler, careful monitoring of end-tidal CO_2 can be considered as a reliable method for early detection of VAE. In case of 2 mmHg sudden reduction of $EtCO_2$, it should alert the anesthesiologist for VAE [5]. It provides enough time for aspiration of the air via the central venous catheter with the tip in the right atrium, thus preventing further air passage to the pulmonary artery [16].

In our study, venous air emboli were most frequently seen in the 3rd hour of the surgery which coincides with tumor resection, thus proposing anaesthesiologists to be more cautious about VAE and $EtCO_2$ during the tumor resection period.

Competing interests
The authors declare that they have no competing interest.

Financial Disclosure
The financial support for this study was provided by the investigators themselves.

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