Venous Air Embolism Associated Morbidity and Mortality in Patients Undergoing Neurosurgical Procedures in the Sitting Position

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Abstract

Objectives: To identify the morbidity and the mortality related to Venous Air Embolism (VAE) during posterior fossa surgery in the sitting position.

Methods: This study was conducted at Jordan University Hospital, Amman, Jordan. Records of 73 patients undergoing posterior fossa surgery in the sitting position from 1990 to 2005 were retrospectively reviewed to determine the incidence of VAE, the nature of perioperative morbidity and mortality and their relation to VAE.

Results: The incidence of VAE was 13.5%. Intraoperative hypotension secondary to VAE was (9.6%). Intraoperative hypotension was 19% during the positioning of patients and 29% during the procedures. Patients who received blood transfusion were 10 (19.2%) children and 5 (9.6%) adults. Average blood transfusion in children was 200 mls and 360 mls in adults.

Postoperatively, six (11.5%) patients were electively intubated and ventilated. Postoperative evacuation of posterior fossa haematoma was performed in seven (13.5%) patients. Six (11.5%) patients died within one month after surgery. There was no intraoperative or postoperative morbidity or mortality related to VAE.

Conclusion: Our results indicate the absence of morbidity and mortality related to VAE. With early detection and prompt treatment of VAE, the sitting position is safe for neurosurgical procedures.

Keywords: posterior fossa surgery, anesthesia, venous air embolism.

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Introduction

The sitting position for posterior fossa surgery was popular in 1960s and 1970s. [1-3] However, the popularity of this position declined in 1980s and 1990s. [4, 5] Venous Air Embolism (VAE) has been considered the major deterrent to the use of sitting position. [6] Postoperative quadriplegia and neurological dysfunction secondary to VAE and paradoxical air embolism has resulted in dramatic decline in the use of sitting position for neurosurgery in the United Kingdom and in the United States. [7, 8] Several retrospective studies reported various incidences of VAE in the case of sitting position depending upon the monitoring technique. The incidence ranges from 7% to 76%, and the detection techniques were transoesophageal echocardiography (TOE), precordial Doppler, end tidal carbon dioxide ($ETCO_2$) analysis, pulmonary artery pressure and right atrial pressure monitoring. [9- 11, 25, 26] These reports demonstrated low morbidity and no serious consequences of VAE.

The aim of this study is to report our experience on the operative morbidity and mortality related to VAE in posterior fossa surgery in the case of sitting position using $ETCO_2$ monitoring to detect VAE.

Patients and Methods

Seventy three patients who underwent posterior fossa surgery in the sitting position at Jordan University Hospital between 1990 and 2005 were included in this study. Patients who underwent extra cranial surgery like cervical laminectomy in the sitting position were excluded from this study.

Preoperative data were collected on each patient including age, sex, review of the medical and neurosurgical status, history of previous neurosurgical procedures in the sitting position, diagnostic computerized tomography and magnetic resonance imaging neurostudies.

Each patient was classified clinically according to the clinical classifications of the American Society of Anesthesiologists (ASA). Intraoperative data collected include anesthesia management, monitoring during the procedure, hemodynamic changes, blood replacement, occurrence of venous air embolism and surgical histopathology.

Postoperative data collected were about neurosurgical status, cardiopulmonary complications, surgical complications and the outcome.

Induction of general anesthesia was inhalational in small children and intravenous in other patients. After endotracheal intubation, balanced anesthesia was achieved using fentanyl and vecuronium or atracurium and low inspired concentrations of isoflurane or sevoflurane delivered in nitrous oxide/ oxygen mixture. Controlled ventilation of the lungs was adjusted to achieve end tidal CO_2 tension approximately 30 mm Hg.

After the induction of anesthesia, patients were brought gradually to the sitting position over 5-10 minutes and intravenous (I.V) crystalloids and/or vasopressors were given according to changes in blood pressure.

Monitoring techniques during surgery consisted of electrocardiography, pulse oximetry, capnography, direct arterial blood pressure measurements and central venous pressure measurements. Nasopharyngeal temperature, arterial blood gases, blood loss and urine output were also monitored.

The lower extremities of all patients were wrapped with compression bandages. Intraoperatively, $ETCO_2$ partial pressure changes was used to diagnose VAE; a decrease of ≥ 5 mmHg in $ETCO_2$ tension in the absence of hypovolaemia was diagnosed as an episode of VAE. Changes in the systolic blood pressure of $\geq$ 10% from the baseline value during positioning, during the procedures and during VAE were recorded.

General therapeutic measures were applied promptly whenever VAE was suspected and diagnosis was made. It included switching nitrous oxide off, ventilation with 100% oxygen, informing the surgeon who flushed the surgical field with saline, coagulation of the opened blood vessels and applying bone wax.

Postoperatively, patients were extubated or electively ventilated and sent to the intensive care unit for more observation and management.

Results

Records of 73 patients who underwent neurosurgical procedures in the sitting position at Jordan University Hospital were studied. They were 33 children and 40 adults, the age distribution of patients is shown in Figure (1).

Sixty four (78%) patients were in the ASA class 1 and ASA class 2. Thirty four (46.5%) patients needed ventriculo-peritoneal (V-P) shunt insertion before surgery to decrease intracranial pressure (ICP) and to treat hydrocephalus. Summery of clinical data is given in Table (1).

Venous air embolism was detected in 10 (13.7%) patients, eight (11%) were children and 2 (2.7%) were adults (Table 2).

Hypotension ≥ 10% of the preoperative systolic blood pressure occurred in twenty (27%) patients during positioning, in 16 (22%) patients during the procedures and in 7 (9.6%) during episodes of VAE. The severity of hypotension were similar during VAE, during positioning and during procedures.

Severe hypotension during VAE occurred only in one 12-year-old patient during the resection of 4^{th} ventricular highly vascular ependymoma tumor; the reduction in ETCO2 was more than 10 mmHg and the systolic blood pressure reached 50 mmHg, patient responded promptly to treatment, then the position was changed to lateral and was surgery abandoned in the sitting position. The patient made full postoperative recovery without neurological deficits (Table 3).

None of the patients with venous air embolism sustained intraoperative or postoperative complications. Blood transfusion was given to 5 (6.8%) adults and 12 (16%) children patients. The average blood volume transfused in adults was 360 ml and in children it was 200 ml.

Postoperative evacuation of posterior fossa haematoma occurred in seven (9.6%) patients. Three (4%) patients died within one month of surgery.

The first case was a five-year-old female patient who was having a big posterior fossa ependymoma tumor. She underwent posterior fossa surgery in the sitting position in July 2000. Recurrence of the tumor occurred early and a redo posterior fossa surgery in the sitting position was done in December 2000. Next day after surgery, the child developed disseminated intravascular coagulopathy, and a very high intra-cranial pressure (ICP) after evacuation of posterior fossa hematoma, and then she died.

The second case was a thirty-year-old female patient who was suffering from an advanced posterior fossa tumor. She underwent posterior fossa surgery in the sitting position with partial excision of the tumor. Postoperatively, she sustained a posterior fossa heamtoma which was evacuated and kept ventilated due to very high ICP. The patient died 5 days after the initial surgery.

The third patient was a ten-year-old female patient who had a huge brain stem glioma tumor with absent gag reflex. She underwent partial excision of the tumor in the sitting position and died twenty days later from aspiration pneumonia. None of the patients who died in this study had episodes of VAE.

There were no complications associated with the sitting position like postoperative airway obstruction, tension pneumocephalus, peripheral nerve injuries or others. The average stay of patients in hospital was sixteen days (range 5 to 58 days).

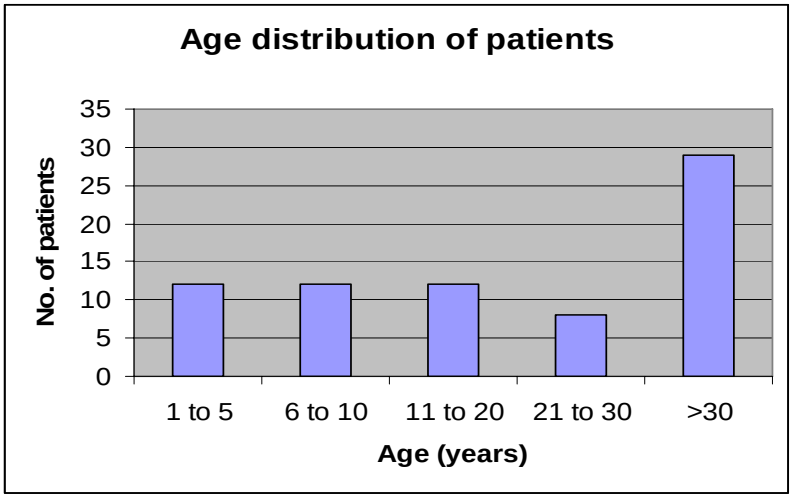

Figure 1

Table 1: Preoperative clinical data of 73 patients who underwent posterior fossa surgery in the sitting position.

Age (years)	***Mean: 30 (Range 3 to 73)***	
Male/ Female	***3/4***	
	Number of patients	***(%)***
History of Cardiac disease	*6*	*(8.2%)*
History of Respiratory disease	*4*	*(5.5%)*
History of other diseases	*4*	*(5.5%)*
History of previous posterior fossa surgery	*11*	*(15 %)*
Ventricular peritoneal (V-P) Shunt insertion	*34*	*(46.5%)*
ASA clinical status*		
Class 1	*26*	*(35.6%)*
Class 2	*38*	*(52%)*
Class 3	*7*	*(9.6%)*
Class 4	*2*	*(2.7%)*

****American Society of Anesthesiologists clinical classification:***

- ***Class 1: No organic, physiologic, biochemical or psychiatric disturbance.***
- ***Class 2: Mild to moderate systemic disease or disturbance.***
- ***Class 3: Severe systemic disease or disturbance.***
- ***Class 4: Severe systemic disturbance that is life threatening.***

Table 2: Intraoperative complications of 73 patients during posterior fossa surgery in the sitting position.

Systolic Hypotension:	***Number of patients***	***(%)***
During positioning of patients	*20*	*27%*
During the procedures	*16*	*22%*
During episodes of VAE	*7*	*10%*
Blood transfusion ≤ two units	*17*	*23%*
Increase in intracranial pressure	*2*	*2%*
Venous air embolism	*10*	*14%*

Table 3: Clinical data of patients who had episodes of venous air embolism during posterior fossa surgery in the sitting position.

Case No.	*Age (years) sex*	*Duration of surgery*	*Surgical pathology*	*Reduction in ETCO2 partial pressure*	*Change in systolic blood pressure*	*Outcome*
1	*15 female*	*345 minutes*	*Arachnoid cyst*	*8 mm Hg*	*No change*	*Full recovery*
2	*3 female*	*365 minutes*	*Glioma*	*6 mm Hg*	*No change*	*Full recovery*
3	*12 male*	*300 minutes*	*Ependymoma*	*15 mm Hg*	*>50% reduction*	*Full recovery*
4	*7 female*	*480 minutes*	*neuroblastoma*	*10 mm Hg*	*10-20% reduction*	*Full recovery*
5	*18 male*	*420 minutes*	*inflammatory lesion*	*10 mm Hg*	*10-20% reduction*	*Full recovery*
6	*50 female*	*510 minutes*	*astrocytoma*	*10 mm Hg*	*10-20% reduction*	*Full recovery*
7	*5 female*	*240 minutes*	*10-20% reduction*	*8 mm Hg*	*10-20% reduction*	*Full recovery*
8	*6 male*	*300 minutes*	*medullo-blastoma*	*10 mm Hg*	*No change*	*Full recovery*
9	*2.5 female*	*300 minutes*	*medullo-blastoma*	*6 mm Hg*	*10-20% reduction*	*Full recovery*
10	*13 male*	*435 minutes*	*medullo-blastoma*	*6 mm Hg*	*10-20% reduction*	*Full recovery*

Discussion

The use of sitting position for neurosurgical procedure has many advantages. It promotes cerebral venous blood and cerebrospinal fluids (CSF) drainage by the effect of gravity, so; it lowers ICP. [3, 13] Also, it causes the accumulated blood in the surgical field to drain away facilitating rapid access to the bleeding points, allowing by this the procedure to be technically easier than in the horizontal position.

In the meantime, the sitting position has many potential complications; these include increased incidence of venous air embolism, increase in haemodynamic instability, and an increase in postoperative bleeding. [6] Quadreparesis and compressive peripheral neuropathology had also been reported in association with the sitting position. [14] Debate continues about the use of sitting position in neurosurgery. [5] Several retrospective studies addressed the problems related to sitting position focusing on the risk of VAE and heamodynamic instability.

These reports confirm the lack of intraoperative or postoperative mortality associated with the occurrence of VAE. [9, 10, 15, 16]

Gill et al. [15] in a study of 60 children patients whose surgery was operated in the sitting position and in 19 children patients in the prone position, found that intraoperative complications as well as the severity of perioperative complications were more frequent in the prone position.

Young et al. [16] reported in a retrospective study of 225 patients who underwent neurosurgical procedures in the sitting position that the incidence of VAE was 30% and most of the complications were related to the operative procedures rather than to venous air embolism.

Black et al. [5] reported in a comparative study of the outcome following posterior fossa craniectomy in both the sitting and horizontal positions in 579 patients that VAE occurred significantly more in the sitting position (45%

versus 12%)when using precordial Doppler monitoring and no morbidity or mortality was attributed to VAE.

Harrison et al. [9] reported their experience in the use of sitting position in pediatric patients and using $ETCO_2$ monitoring for the detection of VAE, they found low incidence of VAE (9.3%) and no VAE-associated mortality.

$ETCO_2$ monitoring was utilized in the present study and has shown that venous air embolism occurred in 10 (13.7%) patients. The incidence is 8 of 33 (30%) in children and 2 of 40 (5%) in adults. Using the same end-tidal CO2 monitoring, other authors have found the frequency of VAE to be from 6% to 40%. [12, 17, 18] This difference in rate of VAE could be attributed to the state of operative hydration, which was demonstrated by Gottdiener et al. [24] who detected the presence of air by echocardiogram whenever the central venous pressure was low.

Capnography is not as sensitive as transoesophageal echocardiography (TOE) or precordial Doppler for the detection of VAE. [11, 20, 27, 28] Mammoto et al. [21] reported that capnography is a satisfactory method for the detection of VAE.

English JB et al. [20] found that changes in $ETCO_2$ occurs before changes in blood pressure during VAE. In our study, one patient sustained severe hypotension during an episode of VAE which was due to large volume of air sucked into the circulation, this could have been prevented had TOE or Doppler ultrasonic monitors been used. VAE can occur any time during surgery when the surgical field is above the heart level. It is important on the part of the operating surgeon to secure the opened blood vessels to prevent aspiration of air into the circulation.

VAE causes hypoxia secondary to the increase in dead space and hypotension from increased right ventricular after load due to air obstruction.

VAE can cause Paradoxical Arterial Air Embolism (PAE) in patients with patent foramen ovale which may result in quadriplegia. [22, 23]

Mammoto et al. found that PAE is associated with large VAE which indicates the importance of preventing the growth of VAE by using sensitive monitors that detect small amounts of air entering into the circulation.

Blood transfusion in our study was given to 17 patients, 12 of them were children and the blood transfused was to restore the preoperative hemoglobin level in these lengthy procedures rather than to treat acute blood loss.

One limitation of this study was that the number of patients over a long period was small due to the fact that the new generation of neurosurgeons in our hospital prefer prone position for posterior fossa surgery.

To conclude, our study demonstrates the absence of morbidity and mortality related to VAE during posterior fossa surgery in the sitting position which added further support to the literature.

$ETCO_2$ monitoring is efficient in the detection of VAE but it is more safe to use further sensitive monitors, since the crucial factor in preventing VAE complications is early detection and prevention of further entrance of large volume of air into the circulation.

Table 4: Postoperative complications of 73 patients operated in the sitting position.

Posterior fossa haematoma	*7*	*(9.6%)*
Wound dehiscence	*2*	*(3%)*
Cerebrospinal fluid leak	*3*	*(4%)*
Brain abscess	*1*	*(1.5%)*
Pseudomeningocele.	*1*	*(1.5%)*
Death within 30 days after surgery	*3*	*(4%)*

Table 5: Postoperative neurological outcome of 73 patients operated in the sitting position.

	Number of Patients	***(%)***
Improvement in headache and vomiting	*40*	*(55%)*
Improvement in sensory function	*11*	*(15%)*
Improvement in motor function	*8*	*(11%)*
Improvement in mental status	*3*	*(4%)*
New neurological deficits	*2*	*(3%)*
Worsening of neurological deficits	*8*	*(11%)*
Coma	*4*	*(5.5%)*

Table 6: Posterior fossa tumors histopathology of 73 patients operated in the sitting position.

	Number of Patients	***(%)***
Medulloblastoma	*20*	*(27%)*
Astrocytoma	*19*	*(26%)*
Ependymoma	*5*	*(7%)*
Meningioma	*4*	*(5.5%)*
Glioma	*3*	*(4%)*
Haemogioblastoma	*3*	*(4%)*
Pineoblastoma	*3*	*(4%)*
Acoustic neuroma	*3*	*(4%)*
Inflammatory lesions	*2*	*(3%)*
Arachnoid cyst	*2*	*(3%)*
Neuroblastoma	*2*	*(3%)*
****Others***	*7*	*(9.5%)*

****Chondrosarcoma, Cholesteotoma, Secondary metastasis, Vascular malformation, Ganglion cell tumor, Chordoma, Syringobulba.***

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معدل الحالات المرضية والوفيات المصاحبة للوصمات الهوائية الوريدية في عمليات جراحة الأعصاب في وضع الجلوس

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الملخص

الهدف: تحصل الوصمات الهوائية الوريدية في عدة أنواع من العمليات الجراحية، ولكنها تحصل بنسبة عالية في العمليات الجراحية في وضع الجلوس. هدف هذه الدراسة هو معرفة الحالات المرضية والوفيات المصاحبة للوصمات الهوائية الوريدية في أثناء العمليات الجراحية العصبية للتجويف الخلفي من المخ في وضع الجلوس.

الطريقة: قمنا بدراسة 73 ملفاً لمرضى أجريت لهم عمليات جراحية عصبية للتجويف الخلفي من المخ في وضع الجلوس في مستشفى الجامعة الأردنية من 1990 إلى 2005.

قمنا بدراسة نسبة حدوث الوصمات الهوائية الوريدية عند هؤلاء المرضى وطبيعة الحالات المرضية و الوفيات التي حصلت في أثناء الجراحة والتخدير ومدى علاقة هذه الحالات بالوصمات الهوائية الوريدية.

النتيجة: نسبة حدوث الوصمات الهوائية الوريدية كانت 13.7 % من عدد المرضى، ونسبة هبوط ضغط الدم الشرياني نتيجة الوصمات الهوائية الوريدية في أثناء العملية كانت 9.6 %، ونسبة هبوط ضغط الدم الشرياني في أثناء تحريك المريض إلى وضع الجلوس كانت 7 %، ونسبة هبوط ضغط الدم الشرياني في أثناء العملية الجراحية في وضع الجلوس كانت 22 %، ونسبة حالات نقل الدم في أثناء الجراحة كانت 23 %، ونسبة عدد الوفيات خلال شهر من العملية كانت 4 %، ونسبة عدد الحالات التي تم معها تفريغ تجمع دموي من مؤخرة الرأس بعد العملية كانت 9.6 %. ولم نجد حالات مرضية أو وفيات نتيجة الوصمات الهوائية الوريدية.

خاتمة: لم نجد في هذه الدراسة حالات مرضية أو وفيات ناتجة عن الوصمات الهوائية الوريدية في أثناء وضع الجلوس. والكشف المبكر عن الوصمات الهوائية الوريدية بواسطة أجهزة مراقبة حساسة لحدوثها بالإضافة إلى علاجها المبكر، يجعل إجراء عمليات التجويف الخلفي للمخ في وضع الجلوس أكثر سلامة.

الكلمات الدالة: عمليات جراحة الأعصاب في وضع الجلوس، التخدير، الوصمة الهوائية الوريدية .