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Neurosurgery in the Sitting Position: Retrospective Analysis of 692 Adult and Pediatric Cases

Oturur Pozisyonda Nöroşirürji: 692 Erişkin ve Çocuk Olgunun Retrospektif Analizi

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ABSTRACT

AIM: The sitting position is routinely used in many centers, although its use remains controversial and appears to be diminishing because of the risk of venous air embolism (VAE).

MATERIAL and METHODS: This is a retrospective analysis of 601 adult and 91 pediatric cases underwent neurosurgery from January 1995 through December 2010 in the sitting position. The incidence of VAE and other complications related to the sitting position has been determined. VAE was defined as a sudden and sustained decrease of end-tidal carbon dioxide (ETCO2) ≥0.7kPa.

RESULTS: The incidence of VAE in children and adults were found to be 26.3% (n=24) and 20.4% (n=123) consecutively but the difference was not significant. The incidence of positioning induced hypotension was more in adults (37.6%) compared to children (18.6%, p=0.00001). The presence of COPD (p=0.04) and ASA status (p=0.03) showed a correlation with 'hypotension with positioning'. There was no peroperative mortality.

CONCLUSION: The study provides a significant body of data on neuroanesthesia for the sitting position and our results suggest that if the sitting position is a neurosurgical necessity it can be used with vigilant follow up throughout the procedure to detect any occurrence of VAE by ETCO2 monitoring if you do not have the chance to use more sensitive tools.

KEYWORDS: Complications, Air embolism, Monitoring, End tidal carbon dioxide, Position, Sitting

ÖZ

AMAÇ: Oturur pozisyon, venöz hava embolisi (VHE) riski nedeniyle gitgide daha az kullanılıp tartışmalı bir konu olmayı sürdürse de, pek çok merkezde rutin olarak kullanılmaktadır.

YÖNTEM ve GEREÇLER: Bu yazı, Ocak 1995 ile Aralık 2010 tarihleri arasında oturur pozisyonda ameliyat edilen 601 erişkin ve 91 çocuk olgunun retrospektif analizidir. Bu çalışmada VHE ve oturur pozisyonla ilişkili diğer komplikasyonlar tespit edilmiştir. VHE'si tanısı, end tidal karbondioksit (ETCO2) düzeyinde ani ve sürekli bir şekilde 0,7 kPa'dan fazla düşüşle konmuştur.

BULGULAR: VHE insidansı çocuklarda %26,3 (n=24) ve erişkinlerde %20,4 (n=123) bulunmuştur, fakat bu fark anlamlı değildir. Oturur pozisyonun oluşturduğu hipotansiyon insidansı erişkinlerde (%37,6) çocuklardan fazladır (%18,6, p=0,00001). KOAH hastası olma (p= 0,04) ve yüksek ASA skoru (p=0,03) pozisyonun oluşturduğu hipotansiyon ile ilişkili bulunmuştur. Ameliyat sırasında ölen hasta yoktur.

SONUÇ: Bu çalışma, oturur pozisyonda nöroanestezi uygulaması açısından oldukça fazla sayıda veri içermektedir. Eğer oturur pozisyon cerrahi bir gereklilikse ve daha gelişmiş bir monitörizasyon olanağınız yoksa sadece ETCO2 monitörizasyonu ile VHE oluşumu ihtiyatli bir şekilde takip edilerek uygulanabilir.

ANAHTAR SÖZCÜKLER: Komplikasyonlar, Hava embolisi, Monitorizasyon, End tidal karbondioksit, Pozisyon, Oturur

INTRODUCTION

The sitting position provides optimum access to midline lesions in the posterior fossa and cervical spine, improves venous and cerebral spinal fluid drainage, decreases intracranial pressure, lowers airway pressure, and improves access to the endotracheal tube and ability to observe the face for signs of cranial nerves stimulations (2,8,17,20,23). There are also significant complications of the sitting position including hemodynamic instability, VAE, paradoxical air embolism (PAE), pneumocephalus, peripheral neuropathy, tetraplegia and macroglossia (2,8,17,20,23). Although there is an ongoing debate about the use of sitting position in neurosurgery and its use is generally declining, it is routinely used in many centers and in our institution.

In this study, we evaluated 692 sitting position cases retrospectively and determined the complications related to this position.

We analysed a relatively large series with one of the highest number of patients in the literature. Our aim was to call attention to the use of the sitting position in neurosurgery while comparing complications between adults and children in spite of lacking most sensitive monitoring facilities.

MATERIAL and METHODS

This is a retrospective analysis of 692 cases that underwent neurosurgical interventions from January 1995 through December 2010 in the sitting position. After approval from the ethics committee data were collected from preoperative evaluation charts and anesthesia records.

Data included patient's age, sex, body weight, height, history of hypertension, cardiac disease, asthma and chronic obstructive pulmonary disease (COPD), ASA physical status, diagnosis and incidence of hemodynamic changes induced by positioning. Hypotension was defined as 20% or more reduction of systolic blood pressure from preoperative values. Bradycardia was defined as a heart rate lower than 50 per minute in adults, 60 per minute in children. Tachycardia was defined as a heart rate greater than 90 per minute in adults and 110 per minute in children. Oxygen desaturation was defined as an arterial oxygen saturation lower than 90 %. The occurrence of VAE was defined as a sudden and sustained decrease of $ETCO_2 \geq 0.7$ kPa. The incidence of VAE and VAE induced hypotension, hypoxia, tachycardia, bradycardia, arrhythmia, PAE, air aspiration from central venous catheter, repeated episodes of VAE as well as the time of VAE (during pin head holder fixation, during cranio (tomy) ectomy, during the procedure, during closure), the requirement for a change in position and manipulation associated hemodynamic changes were recorded. Blood loss, blood replacement, urine output and duration of surgery were noted. Peroperative mortality and postoperative mechanical ventilation requirement were recorded.

The anesthetic technique changed over time with the standards of practice. Most of the patients received intravenous or oral midazolam for premedication. Anesthesia was induced with propofol or thiopental for adults, thiopental for co-operative children and inhalation for uncooperative children. In the first years of analysed period, anesthesia was maintained with pancuronium or vecuronium with 0.5 MAC of halothane or isoflurane in oxygen/air and fentanyl or morphine. Halothane was commonly used for children until sevoflurane was introduced into our practice. From the year 2000 cisatracurium, sevoflurane, and remifentanil were used. Total intravenous anesthesia was used in few patients. Minute ventilation was adjusted to achieve a mild hypocapnia ($PaCO_2$: 4.2-4.5 kPa).

Adults and children older than 12 years old were volume loaded with 10 ml per kg of a colloid solution prior to positioning. Children below12 years old were given up to 10 ml per kg of a crystalloid solution. Standard intra-operative monitoring included 5 lead electrocardiography, capnography, pulse oximetry, invasive and non-invasive arterial blood pressures, body temperature and urine output. Elastic bandage or anti-thrombosis socks were used to prevent venous pooling in the lower limbs. Central venous catheters were used for all patients and multi-lumens preferred if available. Preoperative echocardiography was not routinely performed to detect patent foramen ovale.

Treatment of a suspected VAE included washing the surgical area with saline, application of bone wax, ventilation with 100% O_2, bilateral neck vein compression, applying positive end–expiratory pressure (PEEP) up to 10 cmH_2O, intravenous fluids to increase venous pressure and air aspiration from central venous catheter.

Most of the patients were extubated in the operation room at the end of the surgery if their breathing was adequate and gag reflex present. All patients were transferred to the neurosurgical intensive care unit postoperatively.

Statistical analysis

Chi-square tests were used to compare the incidence of VAE, VAE induced hemodynamic changes, positioning induced hemodynamic changes between adults and children. Student "t" test was used to compare duration of surgery between adults and children. The incidence of VAE in children younger than 9 years were compared with 9 - 16 years old and adult patients. Chi-square tests were used to analyze the incidence of VAE and manipulation related hemodynamic changes among patients according to the site of surgery (cervical, posterior fossa and supratentorial). Chi-square tests were also used to analyze the relationship between postoperative mechanical ventilation requirement and occurrence of air embolism. The relationship among ASA status of patients, history of hypertension, cardiac disease, asthma and COPD and the development of hemodynamic changes induced by positioning were assessed using multivariant analysis. A probability value less than 0.05 was considered to be statistically significant.

RESULTS

Six hundred ninety two patients including 601 adults and 91 children (ages≤ 16 yr) were available for analysis in this study. Demographic features of patients and other preoperative characteristics are presented in Table I.

Hypotension, bradycardia and tachycardia with positioning were more common in adults but only hypotension with positioning reached statistical significance. Difference in manipulation-related hemodynamic changes between adults and children did not reach statistical significance. Mean bleeding volume, the number of patients who required transfusion and the amount of transfused blood are presented in Table II.

VAE, diagnosed by $EtCO_2$ occurred in a total of 147 patients and accounted for 21.2%. The incidence figures of VAE in

Table I: Summary of Preoperative Factors in Children and Adults

Factor	Adult (n = 601)	Children (n = 91)	p value
Age (years, mean ± SD)	43.8 ± 14.2	8.1 ± 4.4	N/A
Gender (n, M/F)	263/338	50/41	0.04
Body weight (kg, mean ± SD)	71.2 ± 13.9	30.2 ± 17.7	N/A
Height (cm, mean ± SD)	164.3 ± 14.0	146.1 ± 22.1	N/A
History of hypertension (n)	63 (10.4 %)	0	0.00001
History of asthma (n)	6 (0.9 %)	0	1.0
History of cardiac disease (n)	17 (2.8 %)	1 (1.0 %)	0.48
History of COPD (n)	15 (2.4 %)	0	0.14
ASA physical status (n)			0.00001
I	289 (48.0 %)	62 (68.1 %)	
II	163 (27.1 %)	9 (9.8 %)	
III	82 (13.6 %)	10 (10.9 %)	
IV	67 (11.1 %)	10 (10.9 %)	

N/A: *Not applicable.*
n: *number*
COPD: *Chronic Obstructive Pulmonary Disease*
ASA: *American Society of Anesthesiology*

Table II: Summary of Intraoperative Factors Related to Cardiovascular System in Children and Adults

Factor	Adult (n = 601)	Children (n = 91)	p value
Hypotension with positioning, n (%)	226 (37.6)	17 (18.6)	0.00001
Tachycardia with positioning, n (%)	53 (8.8)	12 (13.1)	0.18
Bradycardia with positioning, n (%)	63 (10.4)	5 (5.4)	0.18
Bleeding volume (mL, mean ± SD)	236.0 ± 296.3	132.9 ± 133.7	N/A
Number of patients transfused n (%)	31 (5.1)	9 (9.8)	0.08
Amount of blood transfusion (mL, mean ± SD)	595 ± 315	280 ± 175	N/A
Urine output per hour (mL, mean ± SD)	75.0 ± 63.7	66.9 ± 54.8	N/A
Haemodynamic changes*, n (%)	229 (38.1)	28 (30.7)	0.20

n: *number*
**Manipulation related haemodynamic changes.*
N/A: *Not applicable.*

children and adults were found to be 26.3 % (n = 24) and 20.4 % (n = 123) respectively, but the difference was not significant. Incidences of hypotension, hypoxia, bradycardia, tachycardia, arrhythmia in those who suffered VAE were higher in adults but the difference was not significant. Likewise air aspiration from central venous catheter and repeated episodes of VAE were insignificantly more common in adults. Only two adult patients necessitated a change to supine position due to VAE induced hypotension and bradycardia. The majority of VAEs were seen 'during craniotomy or craniectomy' and 'during the procedure' in both groups, but the difference was not significant (Table III).

Sitting position in our series was most commonly used for posterior fossa procedures in both adults and children without any significant difference. Space occupying lesions including tumors and vascular pathologies were the most common causes of surgery and more common in adults ($p<0.007$). The duration of surgery was not different between adults and children (Table IV).

The incidence of VAE was 24.5 % (13/53), 28.9 % (11/38), and 20.4 % (123/601) in children less than 9 years old, those between 9 and 16 years old, and adults respectively, the differences were not significant (Table V).

There was no peroperative mortality and no unexplained morbidity in the patients with VAE that would be related to PAE.

Multivariate analysis

Multivariate analysis demonstrated that presence of COPD ($p = 0.04$) or ASA status ($p = 0.03$) have a correlation with

Table III: Summary of Intraoperative Events Related to Incidence of Venous Air Embolism (Vae) in Children and Adults

Factor	Adult (n = 601)	Children (n = 91)	p value*
No. of patients with VAE, n (%)	123 (20.4)	24 (26.3)	0.21
VAE with hypotension, n (%)	51 (41.4)	11 (45.8)	0.76
VAE with hypoxia, n (%)	1 (0.8)	0	1.0
VAE with bradycardia, n (%)	19 (15.4)	6 (6.5)	0.23
VAE with tachycardia, n (%)	27 (21.9)	6 (6.5)	0.69
VAE with arrhythmia, n (%)	19 (15.4)	5 (20.8)	0.43
VAE with air aspiration, n (%)	101 (82.1)	19 (79.1)	0.67
Repeated episodes of VAE, n (%)	16 (13.0)	2 (8.3)	0.71
Position changes required, n (%)	2 (1.6)	0	1.0
Timing of VAE , n (%)			0.26
Head holder fixation	1 (0.1)	0	
Crani(otomy)ectomy	72 (11.9)	10 (10.9)	
During the procedure	48 (5.3)	12 (13.1)	
During closure	2 (0.3)	2 (2.1)	

n: *number*
**P values were calculated based on the number of patients with venous air embolism in adults (n = 123) and children (n = 24).*

Table IV: Summary of surgical factors in children and adults

Factor	Adult (n = 601)	Children (n = 91)	p value
Surgical site, n (%)			0.15
Supratentorial	21 (3.4)	1 (1.09)	
Posterior fossa	527 (87.6)	86 (94.5)	
Spinal	53 (8.8)	4 (4.3)	
Radiological diagnosis, n (%)			0.007
Tumors	447 (74.3)	81 (89.0)	
Vascular lesions	33 (5.4)	2 (2.1)	
Compression**	121 (11.8)	8 (8.7)	
Duration of surgery* (minute)	307.7 ± 103.52	306.3 ± 82.3	0.88

n: *number*
**Student "t" test.*
***This group included any compression in the craniocervical junction by congenital or acquired anomalies including Arnold-Chiari syndrome.*

Table V: The Incidence of Venous Air Embolism in Children Younger than 9 Years, 9 - 16 Years Old Children and Adult Patients

Factor	< 9 years (n = 53)	9-16 years (n = 38)	P value
No. of patients with VAE, (%)	13 (24.5)	11 (28.9)	0.63
Factor	**< 9 years (n = 53)**	**Adults (n = 601)**	**P value**
No. of patients with VAE, (%)	13 (24.5)	123 (20.4)	0.48

'hypotension with positioning'. The occurrence of VAE was more likely in posterior fossa procedures (p = 0.04) than upper spinal and supratentorial procedures. The occurrence of VAE did not increase the need for the postoperative mechanical ventilation in this series (p = 0.11) since only 3 patients required postoperative mechanical ventilation following VAE during surgery. The site of surgery did not show any relationship with manipulation-related hemodynamic changes (p = 0.35).

DISCUSSION

The use of the sitting position remains controversial and appears to be diminishing due to the risk of VAE, but it is already in use in many centers.

The sitting position may cause cardiovascular instability and hypotension. The reported incidence of hypotension associated with the sitting position ranges from 5 to 32 %

(2,17,22,27). Positioning the patient with flexion of the hips, elevating the knees, and wrapping lower extremities with elastic bandages and volume loading before positioning aims to prevent hypotension with positioning (20). We found that the incidence of hypotension with positioning is 37.6 % in adults and 18.6 % in children. Moreover there is a correlation between high ASA physical status and hypotension with positioning in the present study. Although hypotension associated with the sitting position is significantly more in adults than children, we could not find any data in previous studies to make comparisons. We explained this data with higher ASA scores in adults than children in our series. Due to vasodilator properties of antihypertensive drugs and as hypertensive patients are already volume depleted, hypotension is a common finding following induction of anesthesia in hypertensive patients. Although we could not demonstrate a relationship between 'history of hypertension' and 'hypotension with positioning', the history of hypertension may have an additional effect on 'hypotension with positioning' in adults.

Occurrence of VAE may not be well tolerated in patients with COPD which is a relative contraindication of the sitting position (4). We showed that there is a correlation between presence of COPD and hypotension with positioning in present study. Therefore, the sitting position in patients with COPD and high ASA scores need more attention.

The reported incidence of VAE during neurosurgery in the sitting position ranges from 7 to 76% in adults (1,5,6,15,17,19,22,23,26,27) and from 9.3 to 33% in children (1,3,11,18,25). The incidence of VAE widely varies between studies due to sensitivity differences of the various techniques for detecting VAE. Transosephageal echocardiography (TOE) and precordial Doppler are the most sensitive methods (8). $EtCO_2$ is a monitor of intermediate sensitivity for detecting VAE (16). The incidences of VAE detected by $EtCO_2$ are 20.4 % in adults and 26.3% in children in our series. These results are consistent with most of the reported series that detected VAE by $EtCO_2$ (1,3,6,18,27).

Harrison and colleagues (11) reviewed 407 children who underwent neurosurgery in the sitting position and found a lower incidence of VAE in children (9.3%), detected by $EtCO_2$, than our study and previous studies (1,18). They explained this finding with higher dural sinus pressures in children than in adults. Iwabuchi and co-workers (13) suggested that children younger than 9 years may not be susceptible to VAE due to their positive dural sinus pressure, even in upright position. We studied the incidence of VAE discriminately in children below 9 years due to the physiological differences suggested by Iwabuchi and co-workers. The incidence of VAE in children younger than 9 years was compared with 9 - 16 years old children and adults, but we could not find any difference. Our series included less children (n= 91) than Harrison's study (11), but we showed that the incidence of VAE was similar between children and adults, as in the study by Bithal and colleagues (1). Matjasco and colleagues (17) reported the incidence of VAE was 62% in children and 23% in adults, but this study included 541 adults and only 13 children.

It was speculated that the volume of air entered the venous circulation is equal it would be relatively larger for the blood and cardiac volume of the children than adults, therefore the incidence of VAE induced hypotension in children might be higher (3). While some study results support this argument (3,18), some others do not (7). No significant differences were found in the incidence of VAE induced hypotension in adults and children in the present study.

VAE may lead to serious complications with eventual morbidity and mortality. Gale and Leslie (8) reported that large volumes of VAE may cause hypoxia secondary to increased dead space. We did not see any relationship between VAE and postoperative mechanical ventilation requirement. There is no peroperative mortality due to VAE in the present study.

The use of a central venous catheter (CVC) is recommended by several workers (2,12), but some clinicians do not use it routinely (5,11). In this study, air was successfully aspirated via CVC in 82.1% of cases in adults and 79.1% in children following VAE. We therefore believe that CVC is a very important tool to treat VAE.

Even if there are some concerns about the technique of jugular venous compression, such as cerebral venous outflow obstruction, leading to brain swelling, carotid artery compression and bradycardia, we commonly use intermittent neck compression to enable the surgeon to detect the site of venous bleeding and prevent VAE. Moreover, Toung and co-workers (24) claimed that intermittent neck compression should be used as a prophylactic measure to prevent VAE.

Woorbies and colleagues (26) have used PEEP for the prevention and treatment of VAE while Jaffe and colleagues (14) had stressed the probable increase of PAE by PEEP. Schmitt and co-workers (21) showed that VAE can occur during the release of PEEP and hypothesized that the sudden decrease of PEEP might have decreased the right atrial pressure and subsequently increase venous return from cerebral veins. We used PEEP in physiological levels (5 cm H_2O) and increased it up to 10 cmH_2O to prevent VAE and we gradually decreased PEEP to physiological levels following dural opening.

The presence of a patent foramen ovale (PFO) can be detected by the use of preoperative echocardiography. The risk of PAE is not restricted to the presence of PFO as there are case reports of paradoxical emboli in patients without cardiac shunts (10). We cannot routinely perform preoperative echocardiography and did not experience any cerebrovascular accident that would suggest a paradoxical air embolism in our patients during the early postoperative period.

The diagnosis of PAE without TOE is difficult but sometimes the surgeon can observe air bubbles in cerebral arteries and diagnose PAE. There was no unexplained peroperative morbidity or mortality in the patients with VAE that would be related to PAE in the present study.

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The occurrence of VAE was more likely in case of posterior fossa procedures in comparison to upper spinal and supratentorial procedures in the present study. In the study reported by Leslie and colleagues (15) (n=100) VAE is more common in patients undergoing posterior fossa surgery than in those undergoing cervical surgery, but the difference is not significant. In another study (n=58) there was no difference between the incidences of VAE at various surgical sites (5). These differences might be explained by the limited sample sizes of previous studies.

There were two pregnant patients in this case series. The first one was 37 years old and gestational age was 22 weeks. She underwent surgery for cerebellopontine angle menengioma. The second patient was 33 years old and gestational age was 27 weeks. She was operated for craniocervical ependimoma. Both of them had swallowing problems, so we could not wait until the Ceasarean section, programmed for the 35th week. Fetal heart rate was monitored during and following the operation in both cases. Although we infused 500 mL of colloid solution prior to positioning, the sitting position caused severe hypotension and tachycardia in the second case, and was promptly treated by 5 mg iv bolus ephedrine. We did not detect any VAE episodes by $EtCO_2$ during surgery in both cases. They were extubated at the end of operation and transferred to the ICU. Subsequent obstetric and ultrasound controls were normal and Ceasarean sections were performed during the 35th gestational week and babies were born with an APGAR score of 8-9. We can probably speculate that anesthesia and sitting position for neurosurgery can be performed during the second and third trimester of pregnancy, as it is in Giannini and Bricchi's report (9).

Black and colleagues (2) suggested that preoperative blood loss was less in the sitting position when compared to supine, the average blood loss was 359 mL in their 333 cases. The mean bleeding volume was 236 mL in the adult population (n=601) of our series.

The present study has some limitations. Firstly this is a retrospective observational study and it may cause underestimation of the true results. The second limitation is that $EtCO_2$ monitoring may not be sensitive enough to detect all incidences of VAE accurately. The third limitation is our inability to access the ICU records of all patients; unfortunately we could not determine the incidences of postoperative pneumocephalus, peripheral neuropathy, etc. Despite these limitations the present study provides a significant body of data with one of the highest number of patients in the present literature on neuroanesthesia for the sitting position.

In conclusion, the incidence of VAE was 20.4% in adults and 26.3% in children and there was no peroperative mortality due to VAE in the present study. The results of this study suggest that if the sitting position is a neurosurgical necessity it can be used with vigilant follow up throughout the procedure to detect any occurrence of VAE by $ETCO_2$ monitoring if you do not have the chance to use more sensitive tools.

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