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ORIGINAL ARTICLE

Prone versus sitting position in pediatric low-grade posterior fossa tumors

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Abstract

Purpose The choice between sitting and prone position to access the infratentorial space in a suboccipital craniotomy is still a matter of debate. The comparisons in terms of complications and outcome of both positions are scarce, and the pediatric population is indeed more infrequent in these in scientific reviews. In this paper, we assess intraoperative and postoperative complications and neurological outcome in pediatric patients undergoing posterior cranial fossa surgery for pilocytic astrocytoma in sitting and prone position respectively.

Methods We retrospectively analyzed 30 consecutive patients undergoing surgery for cerebellar pilocytic astrocytoma at the two neurosurgical units referring to the University of Padova Medical School from 1999 to 2017. Preoperative, intraoperative, and postoperative data were retrieved from our medical archives.

Results The statistical analysis did not show any differences between the two groups in terms of preoperative, intraoperative, and postoperative data. The neurological status at last follow-up was similar in both groups of patients.

Conclusions Our results suggest that both sitting and prone position can be considered safe in suboccipital craniotomies. Further studies are needed to show if there are possible differences between these positions for other frequent pediatric tumors such as medulloblastomas and ependymomas.

Keywords Surgical positions · Complications · Outcome · Pilocytic astrocytoma · Children

Abbreviations

PA	Pilocytic astrocytoma
PCFT	Posterior fossa cerebral tumor
VAE	Venous air embolism
PICU	Pediatric intensive care unit
PFO	Patent foramen ovale
TEE	Transesophageal echocardiography
PP	Prone position
SP	Sitting position
PPG	Prone position group
SPG	Sitting position group
EVD	External ventricular drainage
CSF	Cerebrospinal fluid
MRC	Medical research council
SD	Standard deviation

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Introduction

Surgical positioning is a mandatory step in surgical planning, considering the length of surgery and the obliged trajectories that the surgeon must follow in order to be anatomically and functionally respectful. The advantages and disadvantages of both positions are widely described in literature. The sitting position provides an improved surgical field and an anatomical orientation with an easier instrumental access to the rostral part of the posterior cerebral fossa; it decreases bleeding and improves CSF and blood drainage. Moreover, it allows a direct access to the airways and bloodlines and facilitates intraoperative neuro-monitoring. Nevertheless, several complications have been described such as an increased incidence of venous air embolism (VAE) and hemodynamic instability, which are the reasons beyond the more frequent use of prone position in the last decades [11]. Many reports investigated the adverse events observed in each position [4–8, 10, 12–18, 20, 21, 23, 24, 28, 30, 31, 36–40, 42, 45] but few of them compare the differences in term of incidence, postoperative improvement, and long-term outcome of both prone and sitting position [5, 30, 39]. Children who underwent surgery in the sitting position are even more infrequent in scientific reviews and, considering that the infratentorial neoplasms represent the 45–70% of all brain tumors in children [34], it is surprising that only one article focused the discussion of surgical positioning on this population so far [30]. Furthermore, there is a lack of homogeneity in patients' selection and procedures undermining the comparison among previous studies.

Materials and methods

In order to focus our experience on a homogeneous group of patients and comparable procedures, we retrospectively analyzed 30 consecutive patients undergoing surgery for cerebellar pilocytic astrocytoma (PA) at the two neurosurgical units referring to the University of Padova Medical School from 1999 to 2017. These neurosurgical units have a solid tradition to perform posterior fossa craniotomies in prone and in sitting position respectively. Preoperative data collected included age (years), sex, weight (kg), ASA physical, history of severe cardiac or respiratory diseases, history of previous posterior cerebral fossa tumor (PCFT), symptoms of PCFT, presence of hydrocephalus and its treatment, time to diagnosis (days), and radiological classification (according to Pencalet et al. [33]).

Intraoperative data collected included surgical difficulties (according to the operative report), anesthesia technique, the occurrence of clinically significant venous air embolism (VAE), cardiac dysrhythmias, hemodynamic instability, duration of surgery (min), blood loss and transfusions (mL), number of complications, and number of patients with complications.

Postoperative data collected included pneumocephalus, tension pneumocephalus, fistula, coma, hemorrhage, reintervention for complications, residual tumor, neurological outcomes (mental status, eye injury, seizures, motor deficit, sensory deficit, cranial nerves status), extubation difficulties/failure, number of complications, number of patients with complications, duration of hospitalization (days), stay in pediatric intensive care unit (PICU, hours), and status at discharge from the hospital.

All surgical procedures were performed under general anesthesia according to a standardized protocol. Moreover, anesthetic technique and monitoring were similar between the two groups. Routine monitoring included ECG, pulse oximetry, urine output (though urinary catheterization), $SaO2$, end-tidal $PCO2$, central venous pressure, body temperature measurement, and blood-gas analysis. Mechanical ventilation was adjusted to achieve a $SaO2 > 99\%$; continuous monitoring of end-tidal $PCO2$ was used throughout the surgical procedure to detect significant episodes of VAE; finally, serial blood samples were obtained during surgery for measurement of blood-gas tension, fluid, and electrolyte status. Intraoperative transesophageal echocardiography (TEE) was adopted for those patients who had patent foramen ovale (PFO) previously detected with transthoracic echocardiogram and/or with bubble test. Care was taken with positioning all the patients, with special attention to pad any potential pressure point and to avoid excessive head flexion or turning. In all cases, compression pants were used. Both centers have similar protocols for patient's positioning safety guidelines.

Long-term follow-up data included clinical and neuroradiological status at time of last neurosurgical or oncological follow-up.

Statistical analysis

Results are presented as mean ± SD, or as number of cases and percentage: $p < 0.05$ is considered statistically significant. Student's t test is used to compare means of normally distributed data, Mann-Whitney test was adopted for not normally distributed data, and Fisher's exact test was used for categorical variables and/or in the analysis of contingency tables.

Results

Preoperative data

Thirty pediatric patients were included; 16 of them underwent surgery in prone position (prone position group, PPG) and 14 in sitting position (sitting position group, SPG). Preoperative data are shown in Table 1. Mean age at surgery was slightly lower for patients in the PPG but not significantly (Student's t test). In this series, the main symptoms at presentation were headache and vomit in both clinical records. Other signs and symptoms referred by patients were diplopia, vertigo, postural instability, nystagmus, tinnitus, VII c.n. deficit, head deviation, and hemiparesis. Two patients per group were already known for previous PCFT. Time to diagnosis was extremely variable, probably related with the slow growth rate of PA. Seven patients in both groups (44% and 50%) presented with severe to moderate hydrocephalus requiring preoperative external ventricular drainage (EVD) in two cases respectively. In the SPG, two patients had PFO diagnosed by bubble test with trivial shunt whereas none of the PPG patients' presented with signs or symptoms imputable to PFO. Globally, the preoperative characteristics of the two groups of patients did not show statistically significant differences.

Table 1 Preoperative data

	Prone position ($n = 16$)	Sitting position ($n = 14$)
Age (years)	7.8 ± 3.9	9.9 ± 5.0
Gender (M/F)	9/7	6/8
ASA physical status	2.38 ± 0.72	1.92 ± 0.5
ASA 1 (*n*)	1 (6%)	2 (14%)
ASA 2 (*n*)	9 (56%)	10 (71%)
ASA 3 (*n*)	5 (31%)	2 (14%)
ASA 4 (*n*)	1 (6%)	0 (0%)
Patent foramen ovale	–	2
Previous PFT (*n*)	2 (13%)	2 (14%)
Signs or symptoms of PFT (*n*)	15 (94%)	12 (86%)
Headache (*n*)	10 (63%)	10 (71%)
Vomit (*n*)	8 (50%)	3 (21%)
Diplopia (*n*)	3 (19%)	4 (29%)
Vertigo (*n*)	4 (25%)	4 (29%)
Postural instability (*n*)	5 (31%)	5 (36%)
Papilledema (*n*)	2 (13%)	3 (21%)
Hydrocephalus (*n*)	7 (44%)	7 (50%)
Time to diagnosis (days)	99 ± 93	59 ± 58
Radiological classification		
Solid (*n*)	5 (31%)	5 (36%)
Cystic, enhancing wall (*n*)	6 (38%)	3 (21%)
Cystic, non enhancing wall (*n*)	5 (31%)	6 (43%)
Vermis (*n*)	7 (44%)	3 (21%)
Hemisphere (*n*)	4 (25%)	5 (36%)
Transitional (*n*)	5 (31%)	6 (43%)

Intraoperative data

Anesthetic technique was analogous in both groups in terms of anesthetic agents, pre-medications, ventilation, and monitoring. To evaluate the occurrence of hemodynamic changes, arterial hypertension or hypotension was defined as a modification of 20% or more in the systolic blood pressure. The surgical procedure was comparable in both groups, performed by the senior surgeon (DdA for PPG and PL for SPG). Clinical significant VAE occurred only in one patient in the SPG, causing a decrease in SaO2 and a modest hemodynamic instability. A patient in the PPG had a hypertensive peak treated by sodium nitroprusside. The volume of blood transfused during surgery was higher in the PPG but not significantly; we could not analyze the blood loss because of an incomplete set of data. There were no significant differences between the two groups in terms of overall intraoperative complications. Intraoperative data are shown in Table 2.

Postoperative data

There were no cases of tension pneumocephalus, macroglossia, face or salivary glands swelling, pulmonary embolus, coma, and quadriparesis. In PPG, we found two cases of ischemic lesion in the cerebellar hemisphere supplied by postero-inferior cerebellar artery and by the anterior-inferior cerebellar artery respectively. CSF fistula was the most common complication, associated to a chronic hydrocephalus requiring shunt placement in half of the patients (one case in the PPG and in two cases in the SPG). In one patient of the PPG, an epidural bleeding due to a head-holder pin-fracture was discovered during postoperative neuroimaging requiring surgical evacuation. Despite cranial nerve dysfunction, motor deficit, and cerebellar syndrome, the 56% of the PPG patients and the 43% of the SPG patients were discharged without neurological deficit. Furthermore, a clear improvement was also recorded at discharge in an additional 38% and 43% of patients respectively, and at last follow-up, the 94% of the PPG patients (15 out of 16) and the 93% of the SPG patients (13 out of 14) did not show any neurological deficit.

One patient from PPG developed a wound infection by Staphylococcus Warneri, treated with antibiotic therapy without any sequelae. Duration of tracheal intubation and stay in PICU was similar in both groups, instead hospital stay was longer for PPG but not significantly. Postoperative data are shown in Table 3.

Table 2 Intraoperative data

	Prone position ($n = 16$)	Sitting position ($n = 14$)	p value
Hemodynamic instability (n)	2 (13%)	1 (7%)	ns
Bradycardia	•		
Hypertension	•		
Hypotension		•	
Clinically significant VAE (n)	0 (0%)	1 (7%)	ns
Difficult hemostasis in closure (n)	0 (0%)	0 (0%)	ns
Duration of surgery (min)	359 ± 98	349 ± 81	ns
Blood loss (ml)*	n/a	124 ± 100.15	ns
Transfusions (ml)	195	133	ns
Diuresis (ml)	1000 ± 545.87	1250 ± 1180.25	ns
Number of complications (n)	2 (13%)	2 (14%)	ns
Number of patients with complications (n)	2 (13%)	1 (7%)	ns
Total excision (n)	16 (100%)	13 (93%)	ns

*Incomplete set of data. *ns* not significantly

Discussion

Hemodynamic instability and blood transfusion

Hemodynamic instability is one of the major sitting position's drawbacks that encouraged the adoption of prone position in the past decades. Arterial hypotension during surgery was described to occur with an incidence from 32 to 5% in adults patients in previous reports [2, 5, 25, 50] and of 5% in both PP and SP in children [30]. None of those clinical records was significantly different between PP and SP. In our series, we found only one episode of hypotension (7%) in SPG, a finding consistent with the literature. Arterial hypertension was previously described in 5 to 10% (SP and PP respectively) of pediatric patients from literature [30] and in one of our patients of PPG (6%) without any postoperative trace. Finally, among our patients, we found an episode of bradycardia in approaching the brainstem requiring a temporary interruption of the procedure. Therefore, despite the physiological changes in patient positioning, with an adequate anesthetic practice and fluid balance precautions, both PP and SP are to be considered safe.

Although the volume of blood transfused was slightly higher in PP group, this finding was not statistically significant. This result is in contrast with previous literature [2, 5, 11, 25, 30, 39, 43, 50] but it could be attributed to our strict patient selection; indeed, the homogeneity from a single-diagnosis could have reduced bias due to different histological lesions with a different impact on both surgical procedure and outcome.

VAE

VAE has been the most important limiting factor of surgical procedures in sitting position. It is difficult to quantify the effective incidence of VAE because of the differences in terms of sensitivity of various monitoring modalities; in literature, it ranges from 7 to 76%, as shown in Table 4 (depending on the technique used for detection, expecting higher values of VAE incidence in those study that adopted TEE) [2, 3, 5, 7, 12, 15, 16, 21, 25, 27, 30, 32, 39, 43, 48]. Moreover, it is important to differentiate VAE from clinically significant VAE, which is associated to clinical signs, and these entities are not always individually analyzed. In our study, only one patient from SPG (7%) presented an episode of clinically relevant VAE with an important decrease of SaO2, without sequelae. In prone position, VAE is rare; and in literature, there are only few cases reported so far [9, 19, 26, 29, 41, 44] (Table 5). In the literature, there is not a reported consensus about the diagnostic criteria for VAE in children. In both centers, the diagnostic criteria for clinical relevant VAE were similar: a sudden and sustained drop of End-TidalCO2 without preceding acute events in associations with signs of shock (i.e., the decrease of mean arterial pressure, tachycardia, raised PCO2, and central venous pressure). From 2010, the TTE for SPG where adopted, making more accurate the diagnosis of VAE. In general, the patients' selection and preoperative cardiological evaluation, the standard anesthesiological and neurosurgical practice, together with the use of TTE in PFO patients, and the use of CO2 field flooding [21] may explain the lower clinically relevant VAE in our series. Beyond that, none of the patients had a PFO associated with a relevant shunt.

Length of surgery, complications, and early reintervention

Length of surgery was similar in both groups according to the report of Black et al. [5]; otherwise, the more recent report by Rath et al. found that less time was taken for surgery in sitting position [39]. A possible reason for this incongruence with

Table 3 Postoperative data

	Prone position ($n = 16$)	Sitting position ($n = 14$)	p value
Cerebellar ischemia (*n*)	2 (13%)	0 (0%)	ns
Fistula (*n*)	2 (13%)	4 (29%)	ns
Reintervention (n)	2 (13%)	3 (21%)	ns
Epidural bleeding	1	0	
Fistula	1	3	
Tumor relapse	0	0	
Wound infection (*n*)	1 (6%)	0 (0%)	ns
Difficult extubation (*n*)	1 (6%)	0 (0%)	ns
Cranial nerve dysfunction (*n*)	3 (19%)	5 (36%)	ns
Motor deficit (*n*)	4 (25%)	2 (14%)	ns
Sensory deficit (*n*)	0 (0%)	1 (7%)	ns
Tension pneumocephalus (*n*)	0 (0%)	0 (0%)	ns
Coma (*n*)	0 (0%)	0 (0%)	ns
Quadriparesis (*n*)	0 (0%)	0 (0%)	ns
Mutacism/mutism (*n*)	2 (13%)	0 (0%)	ns
Mood deflection (*n*)	2 (13%)	1 (7%)	ns
Patients with complications (*n*)	7 (44%)	7 (50%)	ns
Duration of intubation (*h*)	25.50 ± 10.90	25.44 ± 12.96	ns
Duration of ICU recovery (*h*)	67.92 ± 35.04	64.56 ± 39.60	ns
Duration of hospitalization (days)	20 ± 16	15 ± 7	ns
Status at discharge			ns
Neurologically normal (*n*)	9 (56%)	6 (43%)	
Neurologic deficit, improving (*n*)	6 (38%)	7 (50%)	
Neurologic deficit, non-improving (*n*)	1 (6%)	1 (7%)	
Language and speech dysfunction (*n*)	1 (6%)	1 (7%)	

ns not significantly

Table 4 VAE in the sitting position

Ref.	Patients (*n*)	Incidence (%)
Michenfelder et al. 1972	69	32
Albin et al. 1976	180	25
Cucchiara et al. 1982	48 (≤ 12 years)	33
	48 (> 12 years)	45
Voorhies et al. 1983	81	50
Standefer et al. 1984	382	7
Matjasko et al. 1985	354	23
Black et al. 1988	333	45
Papadopoulos et al. 1994	62	76
Orliaguet et al. 2001	60	2
Harrison et al. 2002	407	9
Bithal et al. 2004	430	33–37
Rath et al. 2007	46	15
Ganslandt et al. 2013	355*	26
	245•	9
Longatti et al. 2015	10	70♦
Günther et al. 2017	208	23

*TEE monitoring, • Doppler ultrasound monitoring, ♦ 1–6% of severe VAE

recent literature could be the surgeon's experience and the standardized procedure in PP and in SP performed in both centers.

The most common postoperative complications after posterior cranial fossa surgery are bleeding, CSF leaks, pseudomeningocele, and meningitis [1, 33, 47]. In our series, the main cause of reintervention was CSF fistula with an incidence of 6% and 21% in the PPG and SPG respectively; our finding is slightly higher compared with other report [5, 12, 30] (Tab. 6). In one PPG patient and in two SPG patients, the fistula was sustained by a hydrocephalus requiring shunt.

Table 5 VAE in the prone position

Ref.	Patients (*n*)	Outcome
Shenkin et al. 1969	1	Fatal
Meridy et al. 1974	2	Fatal/non-fatal
Olympio et al. 1994	1	Non-fatal
Kelleher et al. 1995	1	Non-fatal
Dubey et al. 2000	1	Non-fatal
Ting et al. 2001	1	Non-fatal

Table 6 Incidence of early reintervention in the sitting and the prone position

Ref.	Sitting (%)	Prone (%)	Cause
Black et al. 1988	6/333 (1.8%)	6/246 (2.4%)	Bleeding
	2/333 (0.6%)	2/246 (0.8%)	Infection
Orliaguet et al. 2001	2/60 (3.3%)	–	Bleeding
	1/60 (1.7%)	–	Residual tumor
	5/60 (8.3%)	3/19 (15.8%)	Fistula
	–	1/19 (5.3%)	Infection
Ganslandt et al. 2013	14/600 (2.3%)	n/a	Various

Cerebellar ischemia from PICA and AICA was found in two PPG patients (13%) due to surgical manipulation, whereas none of the SPG patients had this vascular complication. These findings were not significantly associated to the position.

Outcome

Cranial nerve dysfunctions were found preoperatively in 19% and 29% and postoperatively in 19% and 36% (PPG and SPG respectively), according to the report by Rath et al. This author observed that the cranial nerves function was more likely to be preserved in the SP, whereas deterioration was more common in PP group, probably imputable to an inadequate surgical exposure in PP group [39]. In our series, we did not find a statistically significant correlation with cranial nerve dysfunction and positioning probably due to the surgeons and centers' experience. Black et al. described new/worse motor deficits in 5% and 6% (SP and PP respectively) and sensory deficits in 2% from both SP and PP groups without statistical association with patient's positioning [5]. In our patients, there was only one case of severe motor deficit in PPG whereas the other five patients with slight motor impairment (4/5 MRC muscle scale) recovered completely.

Postoperative cerebellar mutism is described in 8–31% of children who underwent posterior fossa surgery, mostly related to vermian damage [35, 46, 49]. Our findings about mutism and mutacism (13% in PPG) and mood deflection (13% in PPG and 7% in SPG) were consistent with literature and we did not find any correlation with the patient's positioning.

Patients' selection

In literature, only three authors compare PP and SP for posterior fossa approach [5, 30, 39], among them only one focusing on pediatric population [30]. Their findings showed that intraoperative complications and early interventions were more frequent in PP patients [30]; the duration of surgery was increased in PP group [39] as the tracheal intubation and the stay in PICU [30, 39]. All the authors found an association between PP and blood loss [5, 30, 39] and Rath et al. associated SP with a lower incidence of cranial nerve damage [39]. Black et al. and Rath et al. considered adult and pediatric patients underwent posterior fossa surgery for tumors, Arnold-Chiari malformation, trigeminal neuralgia, arteriovenous malformation, aneurysm, abscess [5, 39] whereas Orliaguet et al. considered only children with posterior fossa tumors [30]. In order to reduce bias imputable to the patients' age and to the diagnosis (tumors/other posterior fossa pathologies), we decided to select only children, as they are more involved in posterior fossa tumors focusing, in PA as a paradigm of this group of pathology.

Conclusions

Perspective in "prone vs sitting" debate

Surgery is the first-line treatment for PA and a total tumor resection coincide with patients healing. Adjuvant therapies such as radiation and chemotherapy are rarely required and generally, 80 to 90% of the children survive following total resection of the tumor. This relatively high survival of patients diagnosed with PA calls for increasing efforts to achieve a lowest number of intraoperative and postoperative complications in order to give back to these patients a long-life expectancy and an adequate quality of life. Historically, two positions were established for the treatment of posterior fossa tumors, and only one report compared the two strategies in pediatric population [30]. Previous studies advocated the need for disease selection [5], for a multicenter involvement [30], for a more homogenous set of procedures [17], and for further studies accessing the benefits and risks of each position [17, 22].

In the present study, the involvement of two distinguished neurosurgical centers in which the two positions are adopted regularly and separately lead us to analyze the single complication without many biases of the previous studies. The results obtained match with those from literature, thus both prone and sitting position are safe. Moreover, the well-known anesthesiological and position-related complications are nowadays easily manageable with a good anesthetic practice, a careful intraoperative monitoring and appropriate precautions in positioning.

Limitations

Interpretation of the results must consider the major limitation of this study. First of all, it is a retrospective and non-randomized study; in addition, anesthetic practice changed over this period, and different anesthesiologist could manage differently the same intraoperative complication. A prospective randomized study would further define risk and benefit related to prone or sitting position, including a larger number of patients and all the other histology related to posterior cranial fossa tumors.

Compliance with ethical standards

Conflict of interest The authors report no conflict of interest concerning the materials or methods used in this study or the findings disclosed in this paper.

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