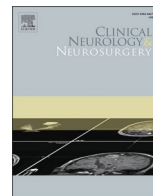


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Pediatric posterior fossa tumors outcomes: Experience in a tertiary care center in the Middle East

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ABSTRACT

Background: Among all childhood cancers, brain tumors are second only to leukemia in incidence and are the most common solid pediatric tumors. More than 60 % of pediatric brain tumors are infra-tentorial. The first-line treatment for most infra-tentorial tumors in pediatric patients is surgical resection, with the goal of gross-total resection, relief of symptoms and hydrocephalus, and increased survival. The proximity to the fourth ventricle, and therefore, the cerebrospinal fluid (CSF) pathways, predisposes children with posterior fossa tumors to the development of obstructive hydrocephalus and multiple other co-morbidities pre and post-surgery.

Objectives: This study aims to present our series of pediatric posterior fossa tumor surgeries in the Neurosurgical Department at the American University of Beirut Medical Center (AUBMC) and perform internal quality control for our single-institution consecutive series as one of the largest referral and tertiary care centers in the region. The second purpose of this retrospective study is to weigh the risks of surgery against the presumed advantages and to have specific knowledge about the complication rates, especially those related to the CSF pathway, comparing our results to those in the literature.

Methods: All pediatric patients (< 18 years of age), referred to our center from different regions in the middle east, and surgically treated for a posterior fossa tumor from June 2006 to June 2018 at the American University of Beirut Medical Center were included. A thorough review of all medical charts was performed to validate all the database records.

Results: The patient sample consisted of 64 patients having a mean age of 6.19 ± 4.42 years and 59.37 % of whom were males. The most common tumor pathology was pilocytic astrocytoma (40.62 %) followed by medulloblastoma (35.93 %) and ependymoma. The most common type of tumor that was seen in patients that developed mutism postoperatively (n = 6, 9.37 %) was medulloblastoma (n = 4, 66.66 %). In this patient sample, 12.28 % (n = 7) of the patients developed hydrocephalus postoperatively. Midline tumors were more associated with the development of mutism (OR = 4.632, p = 0.306) and hydrocephalus (OR = 5.056, p = 0.135) postoperatively, albeit not statistically significantly. The presence of a preoperative shunt was shown to be protective against the development of CSF leak (OR = 0.636, p = 0.767), as none of the patients that came in with CSF diversion developed a CSF leak after their surgery.

Conclusion: This study from a single center experience accompanied by a thorough literature review sheds light on the complications frequently encountered after posterior fossa tumor surgery in children. These included transient cerebellar mutism, CSF leak, and hydrocephalus as seen in some of our patients. Our findings highlight the need for prospective studies with well-defined protocols directed at assessing novel ways and approaches to minimize the risk of these complications.

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1. Introduction

Primary CNS (Central Nervous system) tumors are the second most common childhood malignancies following hematologic malignancies and are the most common solid pediatric tumors comprising 40 %–50 % of all tumors. In the United States, the estimated incidence of childhood primary nonmalignant and malignant CNS tumors is approximately 5–6 cases per 100,000 population [1]. Malignant CNS tumors account for approximately 15–20% of all childhood malignancies and are considered a leading cause of cancer death in children between 0 and 14 years of age.

In childhood, primary CNS tumors predominate and more than half of them are present in the posterior fossa, i.e. the infratentorial space. On the other hand, adult brain tumors are mainly supratentorial, metastatic and only 15–20% are in the posterior fossa [2,3].

Clinical presentation differs according to the tumor location. These tumors may manifest with several nonspecific signs and symptoms that may be seen in more common and less serious childhood illnesses [4]. Headache is the most common presenting symptom followed by any sign of increased intracranial pressure such as nausea and vomiting.

In this review, we retrospectively studied our patient population characteristics and their surgical outcome along with pertinent literature review clarifying the standard of care in the surgical management of pediatric posterior fossa tumors.

2. Methods

After obtaining institutional review board (IRB) approval, we retrospectively reviewed the medical charts of all pediatric patients with brain tumors operated between 2006 and 2018 at a single institution (American University of Beirut Medical Center) and selected all patients with posterior fossa tumors. Patient consent was not required for this study, which was a retrospective chart review with anonymized patient data.

We included patients below the age of 18 who had a posterior fossa tumor. We studied multiple variables including demographics (age, gender), tumor histology, and development of complications post-operatively such as CSF leak, collection, hydrocephalus, and mutism. We summarized our findings and put them in context with a thorough literature review.

3. Results

3.1. Patient characteristics

Our patient sample consisted of 64 patients having a mean age of 6.19 ± 4.42 years and 59.37 % of whom were males (Table 1). The majority of these patients ($n = 57$, 89.06 %) underwent primary surgery for their tumors while the remaining seven (10.93 %) underwent a secondary surgery on a recurring tumor, having undergone their primary surgery at an outside hospital. A craniotomy and tumor removal were done on fifty-nine patients (92.18 %) while the other five patients (7.81 %) had a biopsy. The most common tumor pathology observed was pilocytic astrocytoma ($n = 26$, 40.62 %), followed by medulloblastoma ($n = 23$, 35.93 %), ependymoma ($n = 6$, 9.37 %), anaplastic astrocytoma ($n = 4$, 6.25 %), and others ($n = 5$, 7.81 %). The most common presenting symptom for our patients was vomiting (34.37 %), followed by dysequilibrium (25 %), headache (25 %), and focal weakness (4.68 %) (Table 2).

Different tumor types encountered among our patients appeared to be more associated with certain ages more than others (Table 3). Most notably, patients with ependymoma had the youngest age upon presentation on average (3.2 years). On the other hand, patients with medulloblastoma and pilocytic astrocytoma presented at an older age on average (5.5 and 7.4 years, respectively). They had, however, a more wide-spread range of ages at presentation, reaching a maximum of 14

Table 1
Patient characteristics.

Patients	n	%	
Gender	Female	26	40.62
	Male	38	59.37
Age	≤ 3 years	22	34.37
	> 3 years	42	65.62
	Mean	6.19 ± 4.42	
Type of surgery	Primary	57	89.06
	Secondary	7	10.93
Surgery performed	Biopsy	5	7.81
	Craniotomy	59	92.18
	Ependymoma	6	9.37
Pathology	Pilocytic Astrocytoma	26	40.62
	Medulloblastoma	23	35.93
	Anaplastic Astrocytoma	4	6.25
Preoperative CSF Shunt	Other	5	7.81
	Yes	7	10.93
Permanent postoperative diversion	No	57	89.06
	Yes	18	28.12
Total	No	46	71.87
		64	100

Table 2
Patients' presenting symptoms.

Presentation	n	%
Vomiting	22	34.37
Disequilibrium	16	25
Headache	16	25
Focal Weakness	3	4.68
Cranial Nerve Palsy	2	3.12
Fatigue	1	1.56
Other	9	14.06

Table 3
The mean age of patients at the time of surgery for each tumor pathology encountered.

Tumor Pathology	Minimum age	Maximum age	Mean (\pm SE)
Ependymoma	2.0	5.0	$3.167 (\pm 1.169)$
Medulloblastoma	0.6	14.0	$5.504 (\pm 3.612)$
Pilocytic astrocytoma	0.8	17.0	$7.415 (\pm 5.211)$
Astrocytoma	1.0	7.0	$4.750 (\pm 2.872)$
Other	2.0	15.0	$7.800 (\pm 5.167)$

years for medulloblastoma and 17 years for pilocytic astrocytoma.

Seven patients (10.93 %) presented for surgery with a VP shunt already in place (done in another institution) and referred to our center for continuity of care. Among the patients that did not have a VP shunt, 30 (52.63 %) required an intraoperative EVD, seven of whom requiring a permanent shunt postoperatively. In addition, four patients that did not have a VP shunt originally or an intraoperative EVD ended up requiring a permanent shunt postoperatively (Fig. 1). Thus, 11/57 patients (19.29 %) continued to have hydrocephalus or leaked postoperatively ultimately requiring a VP shunt, whereas 18/64 patients (28.12 %) in total had a VP shunt.

3.2. Factors associated with mutism in patients postoperatively

Among our sample of patients, only six patients (9.37 %) developed mutism postoperatively (Table 4). All of these patients had their tumors located in the midline (i.e. the fourth ventricle or cerebellar vermis). The most common type of tumor that was seen in patients that developed mutism was medulloblastoma ($n = 4$, 66.66 %), the other two types were ependymoma and pilocytic astrocytoma. Using Fisher's exact test and the odds ratios, statistical significance was calculated for different variables in association with the development of mutism (Table 4). Based

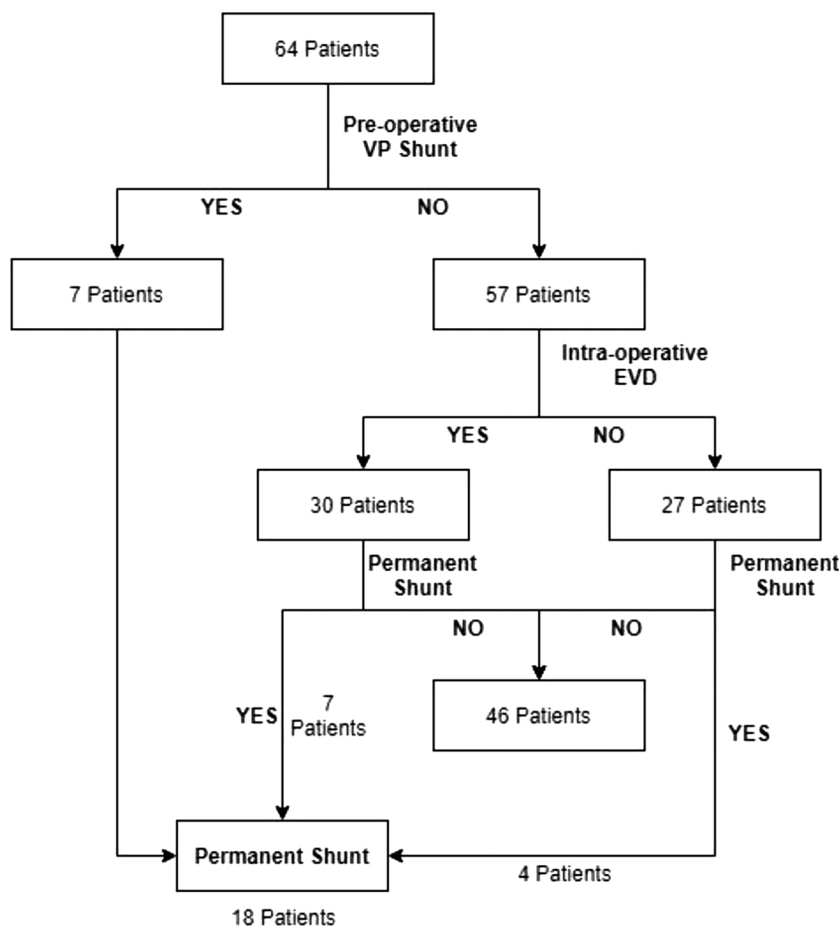


Fig. 1. Flowchart showing the number of patients that presented to their surgery with or without CSF diversion, with the type of initial diversion and whether they required a permanent diversion postoperatively or not.

Table 4
The characteristics of the patients that developed mutism postoperatively.

Mutism	n	%	
Pathology	Medulloblastoma	4	66.66
	Ependymoma	1	16.66
	Pilocytic Astrocytoma	1	16.66
Tumor location	Midline	6	100
	Complete resection	3	50
Extent of resection	Partial	3	50
	Total	6	100

on the odds ratios, it appeared that midline tumors were more associated with the development of mutism postoperatively (OR = 4.632, p = 0.306), however, it was not statistically significant.

3.3. Factors associated with hydrocephalus and CSF leak in patients postoperatively

Eleven patients (17.18 %) developed CSF leak. These CSF leaks were

Table 5
The types and incidences of CSF leaks observed in patients postoperatively.

CSF Leak	n	%	
Gender	Male	7	
	Female	4	
Type	Pseudomeningoceles without percutaneous CSF drainage	5	8
	Percutaneous CSF leak	6	9
Total	11	17	

classified into 2 types: pseudomeningoceles without percutaneous CSF drainage (n = 5, 7.81 %) or percutaneous CSF leak (n = 6, 9.37 %) (Table 5). Using Fisher’s exact test and the odds ratios, statistical significance was calculated for different variables in association with the development of CSF leak. None of the patients that presented with a preoperative VP shunt in place developed a leak postoperatively, however, no statistical significance was found (OR = 0.636, p = 0.767). Also, age above 3 years appeared to be more associated albeit not statistically significant with the development of CSF leak postoperatively (OR = 9.111, p = 0.055).

Moreover, fourteen patients (21.87 %) from our sample had hydrocephalus requiring a shunt, whether preoperatively or postoperatively. Fisher’s exact test and the odds ratios were used also to calculate statistical significance for different variables in association with the development of hydrocephalus. Midline tumors were positively associated with persistent hydrocephalus (OR = 5.056, p = 0.135) although this was not statistically significant. Besides, age above 3 years appeared to be less associative with the development of hydrocephalus (OR = 0.445, p = 0.256).

4. Discussion

The most common pediatric posterior fossa tumors include astrocytomas, medulloblastomas, ependymomas, and brainstem gliomas [5,6]. They tend to culminate during the first decade of life [5,7]. Cerebellar astrocytomas are the most common pediatric posterior fossa tumors, with an incidence varying between 30 % and 40 % [8,9] and the most prevalent histologic subtype is juvenile pilocytic astrocytoma [8]. Within the cerebellum, they most commonly occur in the hemispheres

[10–13]. On the other hand, medulloblastomas, which are second after astrocytomas, tend to develop in the vermis of the cerebellum (midline) with extension into the fourth ventricle [8,14–16]. The third most common tumors are ependymomas constituting 8–15% of these tumors in children [8,14,15]. Brainstem gliomas are fourth and correspond to gliomas originating in the medulla oblongata, pons, and midbrain. They comprise 10–20% of all brain tumors in children [17,18].

Posterior fossa surgeries carry a remarkable risk of complications. In this review, we cite many, of which we emphasize posterior fossa syndrome, pseudomeningocele, and cerebrospinal fluid (CSF) leak and postoperative hydrocephalus, among others.

Before we address the subject of posterior fossa syndrome (cerebellar mutism syndrome), we should first distinguish between cerebellar mutism as a sign and as a syndrome. Cerebellar mutism is defined as the inability to speak following cerebellar lesions, most commonly triggered by surgical interventions for posterior fossa tumors [19–21], trauma to the cerebellum [22,23], resection of arteriovenous malformations [24, 25], and miscellaneous infections [26,27]. Cerebellar mutism occurs in the setting of a conscious patient, devoid of cranial nerve palsies and long tract signs, and emerges few days after a cerebellar insult, but usually lasts up to four months before recovery [28]. The recovery period is marked by a fluctuating level of dysarthria which can either resolve completely and spontaneously, and this seldom occurs [19,20], or more frequently cause longstanding dire consequences such as slurred or slow speech [29–31].

In contrast to cerebellar mutism, posterior fossa syndrome (PFS), also known as cerebellar mutism syndrome (CMS) [8,20,32,33], first described in 1985 [34], corresponds to a constellation of manifestations that ensue after posterior fossa tumor resection. It includes cerebellar mutism, hypotonia, ataxia, neurobehavioral perturbations, emotional lability, cranial nerve palsies, oropharyngeal apraxia and speech disorders, and long-term neurocognitive complications [8,19,30,35–37].

The incidence of this syndrome fluctuates between 11 and 29 % [20, 29,38–41], with more than 400 cases reported to date [36], and the cerebellar vermis being the most frequently affected structure [36, 42–47]. Nevertheless, the advances made in the surgical resection of posterior fossa tumors and the growing knowledge about this syndrome are contributing to the rise in its identification and reporting [28,36,48]. There appears to be no gender preference for the syndrome [32,38,48, 49], but it is more preponderant in childhood [20,28,36].

Among all posterior fossa tumors, medulloblastoma is the most commonly associated with PFS, particularly when the tumor size exceeds 5 cm [20,32,33,37,38,50]. Other important risk factors for the development of this syndrome are brainstem involvement and the midline location of a tumor; namely the fourth ventricle and cerebellar vermis [8,20,33,37,38,50]. The pathophysiology of PFS is not well understood, but multiple theories have attempted to explain this syndrome [8,28,36]. The involvement of the dento-thalamocortical pathways (DTC) is one of the most widely accepted theories [8,22,28,31,36,43,46, 51], although some studies confirmed the diagnosis of PFS albeit the presence of intact dentate nuclei [52]. Other theories include cerebellar spasm and hypoperfusion [43,53–55], postoperative edema [49], possible alterations in neurotransmitters levels and their release [56], surgical splitting of the inferior vermis [36,44], among others.

The management of PFS has not been well established, and more research is needed [28,36]. Previous work included a trial of medications such as nimodipine [47] and speech therapy [36]. The prognosis of patients suffering from PFS is unpredictable, and even if speech is regained, the other long-term sequelae previously mentioned can persist [8,28,43,44,56–58].

Other two well established postoperative complications of posterior fossa tumor resection in children are pseudomeningocele and CSF leak [59–62]. Pseudomeningocele is defined as the enclosed accumulation of CSF in the epidural space following surgery or less commonly because of congenital or traumatic dural defects [63]. It can be diagnosed clinically or radiographically using computed tomography (CT) or magnetic

resonance imaging (MRI) [62]. In contrast, CSF leak is the visible escape of cerebrospinal fluid through a wound, ear (otorrhea), or nose (rhinorrhea) [61].

The incidence of pseudomeningocele and CSF leak ranges between 7.1 % and 33 % [59,61,62,64,65]. The pathogenesis is not quite elucidated [65], yet, several factors are thought to be implicated; we cite poor wound closure, hydrocephalus, subarachnoid scarring, incomplete dural closure, and performing a craniectomy rather than a craniotomy [59,60, 66–68]. These CSF related complications are not merely cosmetic, as they can predispose to surgical site infections, aseptic meningitis, CSF fistula, and intracranial hypotension, all requiring prompt measures to be taken [62,69].

Although various techniques (the use of dural grafts, external ventricular drainage, and tissue glue) have been devised to avert the occurrence of pseudomeningocele and CSF leak, none has proven to be beneficial [62], except for the substitution of a craniectomy with craniotomy [60].

Pseudomeningocele is a self-limiting condition, resolving in few weeks to few months postoperatively, hence the first-line treatment is conservative, consisting of observation, bed rest, and pressure dressing [59,64,67]. Invasive procedures (e.g. CSF diversion) should be reserved for patients who fail conservative measures, those who develop CSF leak or hydrocephalus, and those with expanding pseudomeningocele [69].

In addition to all the complications discussed earlier, one of the most important features shared by the pediatric posterior fossa tumors remains the formation of hydrocephalus, which can be the presenting sign of a tumor or a postoperative complication [14,70,71]. Numerous studies have reported high rates of hydrocephalus associated with posterior fossa tumors, extending between 70 % and 90 % [59,72–74]. The etiology of hydrocephalus in these tumors can be either be related to obstructed CSF flow (most prevailing etiology) or impaired absorption [71,75]. Whatever the cause, prompt detection and management of hydrocephalus and subsequently increased intracranial pressure is paramount to the patient's survival [8].

Nevertheless, the management of hydrocephalus in pediatric posterior fossa tumors remains an area of debate and controversy [72,76]. Treatment of hydrocephalus is categorized into pre-resection and post-resection options, as well as, the resection of the tumor obstructing the CSF flow [72]. These options comprise procedures that assist in either temporary or permanent CSF diversion: they include ventriculoperitoneal (VP) shunt, endoscopic third ventriculostomy (ETV), and external ventricular drainage (EVD).

At present, a widely used approach is the resection of the tumor preceded by EVD placement either preoperatively, or intra-operatively, and the patient is then put on a weaning trial postoperatively [75,77]. This technique mitigates the gratuitous need for prophylactic ETV which exposes 70 % of children to hazardous outcomes [78,79].

Up to 40 % of patients experience postoperative persistent hydrocephalus [73,75,79,80]. For this reason, a multivariate model for stratifying the patient's risk for developing persistent hydrocephalus, namely the Canadian Preoperative Prediction Rule for Hydrocephalus (CPRH) [81], was created and recently modified (mCPRH) [78]. This model serves to categorize patients, preoperatively, into low-risk and high risk-patients for post-resection hydrocephalus, thereby abating the risk of unnecessary procedures and the accompanying morbidity and mortality [75,82–84]. Factors included in the modified model are scored between 1 and 3, with a maximal score of 10. The higher the score, the higher the likelihood of developing postoperative hydrocephalus [75]. These factors encompass age less than 2 years (score of 3), radiographic evidence of transependymal flow (score of 1), preoperative moderate/severe hydrocephalus (score of 2), presence of cerebral metastasis (score of 3), and estimated tumor type: medulloblastoma (score of 1), ependymoma (score of 1), and dorsally exophytic brainstem glioma (score of 1) [78]. Based on this model, low-risk patients (score \leq 4) can be managed without permanent CSF diversion, and either not placing EVD at all or only intraoperative placement of EVD in case of moderate

to severe pre-resection hydrocephalus. As for high-risk patients (score > 4), preoperative or postoperative permanent CSF diversion using VP shunt or ETV, or intraoperative placement of EVD, remain the options neurosurgeons adopt in the absence of level I evidence for the preferred method of treatment, in addition to very frequent close follow-up of patients [70,73,75,85,86].

Additionally, numerous studies emphasize on the importance of administering steroids preoperatively [11,14,75,77,79,87] to reduce the tumor and hydrocephalus related edema, along with the earliest possible resection of the obstructing tumor to reduce the risk of hydrocephalus formation [72,88–91].

In this review, we report a single center experience in the surgical management of pediatric posterior fossa tumors. We retrospectively reviewed 64 patients, surgically treated by the senior author between 2006 and 2018. The most common tumor pathology observed was pilocytic astrocytoma (40.62 %), followed by medulloblastoma (35.93 %). Less commonly we encountered ependymoma (9.37 %), anaplastic astrocytoma (6.25 %), and other rare tumors (7.81 %). Our numbers are grossly comparable to the literature concerning tumor pathology distribution [8,14]. Our population of interest had a male predominance (59.37 %) and age ranging mainly between 3 and 10 years old.

Only six of our patients developed transient mutism after surgery (9.37 %) with the most common type of tumor associated with mutism being medulloblastoma (66.66 %). This finding is consistent with the numbers found in the literature [50,92]. All our patients who developed mutism had tumors located in the midline (Table 4). This finding is also concordant with the series described in the literature [20,33,37]. The tumor size was not well specified in all the reviewed charts, which limited our ability in this study to find a correlation between mutism and tumor size, as stated in other studies [49–51]. To note that due to the small number of patients with mutism, we were incapable of establishing a significant association between certain patient's characteristics and the development of mutism postoperatively. To reduce the incidence of mutism, the senior author has followed the strategy of avoiding retraction on cerebellar hemispheres during surgery and minimizing bipolar cauterization of venous bleeds resulting from tumor dissection next to deep cerebellar nuclei, resorting to the application of gel foam/cottonoids to control the bleeds. Most of the mutism cases were noted in the early rather than later phase of the series.

Another prominent complication in posterior fossa surgery is CSF leak, whether a contained pseudomeningocele or percutaneous leak. In their retrospective study of 174 pediatric posterior fossa operations, Steinbok et al., reported a 33 % rate of CSF leak [62]. They concluded that using tissue glue, dural grafts, and external ventricular drainage do not statistically reduce the rate of pseudomeningocele formation or postoperative CSF leak.

Similarly, Parizek et al. stated up to a 28 % rate of pseudomeningocele [93]. Further, Santamarta et al., in their retrospective review of 71 patients with 84 operations, found a 14.3 % (12/84) CSF leak and 7.1 % (6/84) pseudomeningocele. According to their numbers, only tumor size was statistically significant in influencing the manifestation of CSF related complications [61].

From our sample, only 11/64 patients, that is 17.18 %, had CSF leak, with the following detailed incidence: 7.81 % pseudo meningocele without percutaneous CSF drainage and 9.37 % percutaneous CSF leak (Table 4). We treated CSF leak with conservative management (pressure dressing-head of bed elevation) and in-hospital observation in 6 cases that were almost self-limiting, 1 case was treated with a lumbar drain that was successfully removed 5 days later with resolution of the collection. The rest needed to be shunted (4 cases). On the other hand, none of the patients who presented with preoperative VP shunt in place developed a leak postoperatively ($p = 0.767$). Likewise, age above 3 years seemed to be more associated, albeit not statistically significant, with the development of CSF leak postoperatively ($p = 0.055$). Our findings are consistent with the results of Steinbok et al., where pseudomeningocele/CSF leaks were more commonly seen in midline located

tumors compared to off midline tumors [62]. In contrast, Hosainey et al. studied CSF disturbances in all intracranial tumors in pediatric patients ($n = 381$) and concluded that younger age was significantly associated with CSF leak [94]. Our results may be explained by the higher number of patients operated on above the age of 3 years ($n = 42$), versus those who are lesser than 3 years of age ($n = 22$).

In addition to the above-mentioned complications, hydrocephalus, as previously stated, is one of the main concerns facing surgeons in pediatric posterior fossa surgery. As reported in the literature, persistent hydrocephalus after surgery and tumor resection can range between 10–36 % of the cases with a global average of 30 % [81].

Santos de Oliveira et al. in his study of 64 patients concluded that midline location, younger age, and a higher ventricular index at presentation are risk factors for postoperative hydrocephalus [79]. In addition, Bogner et al. ($n = 180$) established that tumor location, the extent of resection and postoperative CSF leak were not significantly associated with postoperative hydrocephalus. By contrast, younger age, tumor histology, and preop ventricular drainage were predictive of postoperative need for CSF diversion [73]. Further, Morelli et al. ($n = 160$) proposed that medulloblastoma histology and preoperative hydrocephalus are risk factors for postoperative hydrocephalus [84].

Many studies tried to predict clinical factors affecting the need for postoperative CSF diversion taking into consideration factors such as age, presence of metastasis, hydrocephalus among others. These efforts were oriented towards dividing patients into low risk and high risk for postoperative hydrocephalus, thus the need for CSF diversion pre-resection [75,78]. However, there is no class I evidence concerning pre-resection CSF diversion in pediatric posterior fossa tumors despite the highlighted data above.

In our study, 7/57 (12.28 %) patients had persistent hydrocephalus requiring a VP shunt postoperatively, and another 4 shunted for persistent CSF leak, raising the shunted group postoperatively to 11/57 or 19.29 %. If we include the 7 referred patients who had a preoperative VP shunt, a total of 18/64 (28.12 %) patients were shunted. While falling short of being statistically significant, midline tumors were positively associated with the development of hydrocephalus (OR = 5.056, $p = 0.135$). To note, none of the shunted patients preoperatively had CSF leak with an adequately healed wound and no collection. Furthermore, none of our patients who had preoperative ventriculoperitoneal shunt developed mutism. As per the senior author, this may be mainly due to a relaxed cerebellum intraoperatively, minimal to no retraction on the cerebellum and easier access to the tumor. We further noted that 4/7 preoperatively shunted patients turned out to have medulloblastoma (57.14 %), and 7 out the 11 shunted postoperatively had medulloblastomas (63.63 %). In total, we had 23 medulloblastomas and 11/23 were shunted, that is 47.82 %. Additionally, 11/18 of the shunted patients had medulloblastomas (61.11 %). Given the above data and the high percentage of medulloblastomas needing to be shunted, inquisitive questions may arise. Does having a high suspicion of medulloblastoma and hydrocephalus on preoperative MRI justify inserting a preoperative shunt or any type of permanent CSF diversion (ETV)? Does this reduce the chance of cerebellar mutism and postoperative CSF leaks and help avoid a prolonged period of external CSF diversion and its complications? Should this become a new standard practice and is it cost-effective knowing the known complications associated with VP shunts ranging from infection to failed shunts and the need for a reoperation? [95–97].

4.1. Limitation

Although this study provides a general overview of the postoperative complications of posterior fossa tumors in children both in the literature and in a large referral center in the region, limitations are inevitable. First, it's a retrospective study meaning that it does not permit the addition of certain variables which might reveal statistically significant relations affecting the outcomes, in our case, it is the tumor size. Second,

our studied population was limited to 64 eligible patients which might limit possible statistical significance.

5. Conclusion

Posterior fossa tumors are among the most common childhood cancers. Surgery with safe resection remains the mainstay of treatment. This study from a single center experience with a thorough literature review discusses the characteristics of childhood posterior fossa tumors and the outcomes of pediatric patients undergoing surgical procedures for these tumors with special emphasis on the complications frequently encountered postoperatively. Of all complications, and as seen in the literature, we experienced transient cerebellar mutism, CSF leak, and hydrocephalus in some of our patients. These unfavorable outcomes can profoundly affect the lives of these young patients, given that they occur at relatively high rates. Despite the many developed gradings and protocols, pre-resection CSF diversion remains a debate with no level I evidence for the standard of care. Future prospective studies with well-defined protocols are needed and should be directed at assessing novel ways and approaches to minimize the risk of these complications.

Credit author statement

The authors state that they have all contributed to the work equally. As for their most relevant roles, the first and second authors (Drs Mousalem and Ftouni) contributed most to Writing the original draft, third and fourth authors (Drs Abou Mrad and Amine) contributed most to Investigation and Methodology, sixth and seventh authors (Drs Bali and Baasiri) contributed most to Conceptualization and Data curation, and the fifth and last authors (Drs Hamideh and Najjar) in Supervision and Review/editing.

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