Cerebrospinal fluid disturbances after 381 consecutive craniotomies for intracranial tumors in pediatric patients

Clinical article

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Object. The aim of this study was to investigate the incidence of CSF disturbances before and after intracranial surgery for pediatric brain tumors in a large, contemporary, single-institution consecutive series.

Methods. All pediatric patients (those < 18 years old), from a well-defined population of 3.0 million inhabitants, who underwent craniotomies for intracranial tumors at Oslo University Hospital in Rikshospitalet between 2000 and 2010 were included. The patients were identified from the authors’ prospectively collected database. A thorough review of all medical charts was performed to validate all the database data.

Results. Included in the study were 381 consecutive craniotomies, performed on 302 patients (50.1% male, 49.9% female). The mean age of the patients in the study was 8.63 years (range 0–17.98 years). The follow-up rate was 100%. Primary craniotomies were performed in 282 cases (74%), while 99 cases (26%) were secondary craniotomies. Tumors were located supratentorially in 249 cases (65.3%), in the posterior fossa in 105 (27.6%), and in the brainstem/diencephalon in 27 (7.1%). The surgical approach was supratentorial in 260 cases (68.2%) and infratentorial in 121 (31.8%). Preoperative hydrocephalus was found in 124 cases (32.5%), and 71 (86.6%) of 82 achieved complete cure with tumor resection only. New-onset postoperative hydrocephalus was observed in 9 (3.5%) of 257 cases. The rate of postoperative CSF leaks was 6.3%.

Conclusions. Preoperative hydrocephalus was found in 32.5% of pediatric patients with brain tumors treated using craniotomies. Tumor resection alone cured preoperative hydrocephalus in 86.6% of cases and the incidence of new-onset hydrocephalus after craniotomy was only 3.5%.

key Words • craniotomy • complications • intracranial tumor • external ventricular drain • endoscopic third ventriculostomy • hydrocephalus • surgical mortality • oncology

Intracranial brain tumors are the most common solid tumors occurring in the pediatric population. According to the Central Brain Tumor Registry of the US, approximately 2000 children and adolescents under the age of 20 are diagnosed with primary CNS malignancies each year in the US.8

First-line treatment for pediatric patients with intracranial tumors is resection, with the goal of gross-total resection to obtain tissue diagnosis, relieve symptoms, and increase survival. However, craniotomies do not come without inherent risks, be they postoperative CSF leaks/

Abbreviations used in this paper: CI = confidence interval; DNET = dysembryoplastic neuroepithelial tumor; ETV = endoscopic third ventriculostomy; EVD = external ventricular drain; OR = odds ratio; PNET = primitive neuroectodermal tumor; VP = ventriculo-peritoneal.

This article contains some figures that are displayed in color online but in black-and-white in the print edition.
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disturbances in our patients by reviewing our prospective-ly collected database on craniotomies performed between 2000 and 2010 on those patients less than 18 years old.

Methods

Study Population

The defined pediatric neurosurgical catchment area for Oslo University Hospital-Rikshospitalet is the southwest, west, south, and eastern health region of Norway, consisting of 0.7 million inhabitants under the age of 18. The hospitals’ data protection officials approved the study.

Our prospectively collected database was used to identify all patients less than 18 years old who underwent a craniotomy for an intracranial tumor in the period of 2000–2010 at Oslo University Hospital-Rikshospitalet. Patients who underwent stereotactic or endoscopic biopsy were not included. A total of 413 craniotomies were identified, but because 32 patients with preexisting ventricular shunts were excluded from this study, the cohort consisted of 381 craniotomies.

Data Collection

The following patient data were recorded: age, sex, primary or secondary (repeated) resection, main tumor location (supratentorial, infratentorial, or brainstem/diencephalon), specific tumor location, histology, surgical approach (supratentorial or infratentorial, and whether the resection was transventricular/intraventricular or not), preoperative hydrocephalus, choice of treatment of preoperative hydrocephalus, presence of postoperative hydrocephalus, treatment mode of postoperative hydrocephalus, time of postcraniotomy shunt placement, surgical intervention for a postcraniotomy CSF leak, meningitis, and lastly, tumor resection radicality.

Specific tumor locations were cerebrum, cerebellum, brainstem/diencephalon, intraventricular, pituitary gland, cranial nerve, cranium, and meninges. Furthermore, they were classified according to histology as: glioma of WHO Grades I–IV, primitive neuroectodermal tumor (PNET), dysembryoplastic neuroepithelial tumors (DNET), germinoma, ependymoma, craniopharyngioma, plexus tumor, other benign tumor, and other malignant tumor. For odds ratio (OR) analysis, WHO Grade I was used as the reference category unless otherwise stated.

Primary craniotomy was defined as the first craniotomy in a specific location, while all subsequent craniotomies in the same location were defined as secondary. Thus, 1 patient could have more than 1 primary craniotomy, if undergoing an operation in more than 1 location. The degree of resection was evaluated by reviewing all the postoperative MR images: complete resection was defined as no visible residual tumor, subtotal resection was defined as less than 10% residual tumor, and partial resection as anything less than 90% resection. The senior author (T.R.M.) thereafter carefully reviewed all the charts and MR images to validate the database.

Preoperative hydrocephalus was defined as ventriculomegaly and the presence of symptoms and/or signs of raised intracranial pressure. Regarding the treatment mo-
Complete resection was achieved in 184 cases (48.3%), subtotal resection in 177 (46.5%) cases, and in 20 cases (5.2%) a partial resection/biopsy was performed. A supratentorial approach was used in 260 cases (68.2%) and an infratentorial surgical approach in 121 cases (31.8%; Table 2). In 127 craniotomies (33.3%), the approach entered the ventricular system.

### Preoperative Hydrocephalus

**Incidence and Treatment.** There were 124 cases (32.5%) with preoperative hydrocephalus (Fig. 1, Table 2). Of these 124 cases, 8 (6.5%) underwent ETV prior to craniotomy, 33 (26.6%) received an EVD either prior to (n = 9) or simultaneously with tumor resection (n = 24), while 82 patients (66.1%) underwent tumor resection alone (Fig. 1). One patient had a ventriculoperitoneal (VP) shunt inserted at the same time as this patient underwent a craniotomy.

**Risk Factors.** In the univariate analysis, risk factors for preoperative hydrocephalus included: younger age (OR 1.1, 95% confidence interval [CI] 1.1–1.2; p < 0.001); primary craniotomy (OR 3.9, 95% CI 2.1–7.2; p < 0.001); main tumor location infratentorial (OR 8.1, 95% CI 4.9–13.6; p < 0.001); specific tumor location in brainstem/diencephalon (OR 4.5, 95% CI 1.7–11.7; p < 0.01), intraventricular (OR 8.5, 95% CI 4.5–16.7; p < 0.001), and in cerebellum (OR 11.1, 95% CI 5.2–25.0; p < 0.001), and histology (p < 0.001; Table 3, Fig. 2).

Using multivariate analysis, the risk factors for preoperative hydrocephalus included younger age (OR 1.1, 95% CI 1.0–1.2; p < 0.05), primary craniotomy (OR 3.9, 95% CI 2.0–8.2; p < 0.001), main tumor location infratentorial (OR 3.3, 95% CI 1.9–5.8; p < 0.001), and histology (p < 0.01; Table 3).

### Persisting Postoperative Hydrocephalus

**Incidence and Treatment.** Of the 124 cases with preoperative hydrocephalus, 24 (19.4%) had persisting postoperative hydrocephalus. Of these 24 patients, 20 required early VP shunt placement and 4 required late VP shunt placement (Fig. 3).

**Risk Factors.** Only meningitis was associated with increased risk of postoperative hydrocephalus in both univariate and multivariate analysis, (OR 7.0, 95% CI 1.1–55.7, p < 0.05; and OR 9.5, 95% CI 1.3–85.8, p < 0.05, respectively). Age, sex, primary/secondary resection, main tumor location, specific tumor location, histology, and surgical approach were not statistically significant.

### New-Onset Postoperative Hydrocephalus

**Incidence and Treatment.** Of the 257 patients without hydrocephalus preoperatively, a total of 9 patients (3.5%) developed hydrocephalus after surgery, of whom 7 were boys. Five patients required early VP shunt placement and 4 required late VP shunt placement.

**Risk Factors.** Only male sex (OR 4.0, 95% CI 1.5–11.2; p < 0.01), main tumor location infratentorial (OR 6.2, 95% CI 1.4–27.4; p < 0.05), and infratentorial surgical approach (OR 5.6, 95% CI 1.4–23.6; p < 0.05) were significantly associated with increased risk of developing new-onset postoperative hydrocephalus. Age, primary/secondary resection, specific tumor location, histology, and meningitis did not reach any significance.

In the multivariate analysis, only infratentorial tumor...
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**TABLE 2: Craniotomy characteristics***

<table>
<thead>
<tr>
<th>Tumor Cerebri</th>
<th>Primary Craniotomies (n = 282, 74.0%)</th>
<th>Secondary Craniotomies (n = 99, 26.0%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Preop Hydrocephalus</td>
<td>Preop Hydrocephalus</td>
</tr>
<tr>
<td>supratentorial (n = 249, 65.3%)</td>
<td>140 (49.7%)</td>
<td>40 (14.2%)</td>
</tr>
<tr>
<td>infratentorial (n = 105, 27.6%)</td>
<td>19 (6.7%)</td>
<td>63 (22.3%)</td>
</tr>
<tr>
<td>brainstem/diencephalon (n = 27, 7.1%)</td>
<td>13 (4.6%)</td>
<td>7 (2.5%)</td>
</tr>
</tbody>
</table>

* One patient had a brainstem tumor extending superiorly, resulting in it being located both in the brainstem and supratentorially.

location (OR 5.1, 95% CI 1.3–21.3; p < 0.05) was significantly associated with developing new-onset postoperative hydrocephalus. Age, sex, specific tumor location, surgical approach, and meningitis were not significantly associated with developing new-onset postoperative hydrocephalus.

**Overall Incidence of Postoperative Hydrocephalus**

**Incidence and Treatment.** A total of 33 (8.7%) of 381 patients had hydrocephalus after surgery (Fig. 3). Of these 381 patients, 24 (6.3%) had persistent postoperative hydrocephalus, of whom 20 required early VP shunt placement and 4 required late VP shunt placement. Nine patients (2.4%) had new-onset postoperative hydrocephalus, of whom 5 required early VP shunt placement and 4 required late VP shunt placement (Fig. 3).

**Risk Factors.** The risk factors in the univariate analysis included younger age (OR 1.1, 95% CI 1.0–1.2; p < 0.01), main tumor location infratentorial (OR 2.2, 95% CI 1.0–4.8; p < 0.05), PNET histology (OR 2.4, 95% CI 1.0–5.8; p < 0.05), infratentorial surgical approach (OR 2.2, 95% CI 1.1–4.5; p < 0.05), untreated preoperative hydrocephalus (OR 6.6, 95% CI 3.0–14.7; p < 0.001), and meningitis (OR 11.5, 95% CI 2.2–59.5; p < 0.01).

In the multivariate analysis, younger age (OR 1.1, 95% CI 1.0–1.2; p < 0.05), untreated preoperative hydrocephalus (OR 4.8, 95% CI 2.2–11.6; p < 0.001), and meningitis (OR 7.7, 95% CI 1.3–47.4; p < 0.05) were significantly associated with an increased risk of developing postoperative hydrocephalus.

**CSF Leaks**

**Incidence and Treatment.** There were 24 patients with postoperative CSF leaks (6.3%). Of these 24 patients, 2 were successfully treated with compression bandages, 2 with secondary skin sutures, 5 by lumbar punctures, 4 required postoperative EVD placement, and 2 patients underwent endoscopic fenestration. Only 9 patients (2.4%) required postoperative VP shunt placement, of whom 7 were treated early whereas 2 were treated within 3 months postoperatively.

**Risk Factors.** In univariate analysis, the following factors were significantly associated with an increased risk of postoperative CSF leak: younger age (OR 1.2, 95% CI 1.1–1.3; p < 0.001), main tumor location infratentorial (OR 3.8, 95% CI 1.6–9.4; p < 0.01), infratentorial surgical approach (OR 3.3, 95% CI 1.4–7.6; p < 0.01) and existing preoperative hydrocephalus (OR 4.6, 95% CI 1.9–11.1; p < 0.01).

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![Flow chart showing the diagnosis and treatment of preoperative hydrocephalus (HC). *One patient included in this group had VP shunt insertion simultaneously with craniotomy. pt = patient.](image-url)
In multivariate analysis, only younger age (OR 1.2, 95% CI 1.1–1.3; p < 0.01), main tumor location infratentorial (OR 3.0, 95% CI 1.2–7.9; p < 0.05), and new-onset postoperative hydrocephalus (OR 5.6, 95% CI 2.1–14.8; p < 0.01) were significantly associated with postoperative CSF leaks. Sex, primary/secondary resection, specific tumor location, histology, and surgical approach did not reach significance.

**TABLE 3: Risk factors for developing untreated preoperative hydrocephalus using univariate and multivariate regression analysis**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate Analysis</th>
<th>Multivariate Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>age (continuous variable)</td>
<td>1.1†</td>
<td>1.1–1.2</td>
</tr>
<tr>
<td>sex</td>
<td>M 1</td>
<td>F 0.8</td>
</tr>
<tr>
<td>primary craniotomy</td>
<td>3.9†</td>
<td>2.1–7.2</td>
</tr>
<tr>
<td>secondary craniotomy</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>main tumor location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>supratentorial</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>infratentorial</td>
<td>8.1†</td>
<td>4.6–13.6</td>
</tr>
<tr>
<td>brainstem/diencephalon</td>
<td>1.5</td>
<td>0.6–3.8</td>
</tr>
<tr>
<td>histology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WHO Grade I</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WHO Grade II</td>
<td>0.4</td>
<td>0.1–1.2</td>
</tr>
<tr>
<td>WHO Grade III</td>
<td>0.2‡</td>
<td>0–0.9</td>
</tr>
<tr>
<td>WHO Grade IV</td>
<td>0.5</td>
<td>0.1–1.4</td>
</tr>
<tr>
<td>PNET</td>
<td>3.2†</td>
<td>1.6–6.2</td>
</tr>
<tr>
<td>DNET</td>
<td>(5.1 x 10⁻⁸)†</td>
<td>NC, 0.2</td>
</tr>
<tr>
<td>germinoma</td>
<td>0.4</td>
<td>0.1–1.6</td>
</tr>
<tr>
<td>ependymoma</td>
<td>0.8</td>
<td>0.3–1.7</td>
</tr>
<tr>
<td>craniopharyngioma</td>
<td>0.2‡</td>
<td>0.1–0.9</td>
</tr>
<tr>
<td>plexus tumor</td>
<td>1.4</td>
<td>0.5–3.5</td>
</tr>
<tr>
<td>other benign tumor</td>
<td>0.1†</td>
<td>0–0.2</td>
</tr>
<tr>
<td>other malignant tumors</td>
<td>(5.1 x 10⁻⁸)‡</td>
<td>NC, 0.7</td>
</tr>
</tbody>
</table>

* NC = zero or less than zero, and thus not able to be calculated.
† p < 0.001.
‡ p < 0.05.
§ p < 0.01.

In multivariate analysis, only younger age (OR 1.2, 95% CI 1.1–1.3; p < 0.01), main tumor location infratentorial (OR 3.0, 95% CI 1.2–7.9; p < 0.05), and new-onset postoperative hydrocephalus (OR 5.6, 95% CI 2.1–14.8; p < 0.01) were significantly associated with postoperative CSF leaks. Sex, primary/secondary resection, specific tumor location, histology, and surgical approach did not reach significance.

**Meningitis**

*Incidence and Treatment.* Six patients developed postoperative meningitis (1.6%), in 2 cases secondary to CSF leaks. These patients were treated successfully with intravenous antibiotics and suffered no long-term effects. Untreated preoperative hydrocephalus was present in 5 of these 6 patients, 3 of whom needed ventricular shunting due to postoperative hydrocephalus (2 at an early stage and 1 at a late stage).

**Risk Factors.** In univariate analysis, intraventricular approach (OR 10.4, 95% CI 1.2–89.7; p < 0.01), untreated preoperative hydrocephalus (OR 5.3, 95% CI 1.0–29.3; p < 0.05), CSF leak (OR 8.0, 95% CI 1.4–46.2; p < 0.05), and new onset postoperative hydrocephalus (OR 11.5, 95% CI 2.2–59.5; p < 0.01) were significant risk factors for developing postoperative meningitis. In multivariate analysis, CSF leakage (OR 10.2, 95% CI 1.2–70.5; p < 0.05) and new-onset postoperative hydrocephalus (OR 13.6, 95% CI 2.2–87.7; p < 0.05) were significantly associated with postoperative meningitis. Age, sex, primary versus secondary resection, and preoperative hydrocephalus were not significantly associated with a risk of developing postoperative meningitis.

**Surgical Mortality**

There were 2 deaths within 30 days after surgery, giving a surgical mortality rate of 0.5%. The first patient died 3 days postcraniotomy after a resection of a large PNET in the temporoparietal region. The second patient died 30 days after primary surgery due to a massive cerebral infarction secondary to central venous thrombosis. The patient had undergone a primary subtotal resection of a pilocytic astrocytoma in the brainstem.
Complication studies are of importance to the practicing neurosurgeons as they can lead to an increased awareness of complications and possibly thereby lead to improved patient care. Traditionally, most studies on perioperative complications in surgery for pediatric brain tumors have focused on the posterior fossa. Although most complications regarding CSF circulation and dynamics may be related to disturbance of CSF flow in the posterior fossa territory, it is important to also include supratentorial tumors as they account for up to two-thirds of all pediatric tumors.\textsuperscript{23,29,31} Unfortunately, there are few published case series on CSF disturbances that include both infra- and supratentorial tumors.

**Preoperative Hydrocephalus and Its Treatment**

In this study of 381 consecutive craniotomies for supra- and infratentorial pediatric brain tumors, 32.5\% presented with preoperative hydrocephalus. Numerous series have reported rates of hydrocephalus prior to surgery ranging from 69\% up to 92\%, although most of these studies concerned tumors in the posterior fossa region.\textsuperscript{2,4,9,19,25,34}

We found that younger patient age and infratentorial tumor location were the two most important risk factors for preoperative hydrocephalus (Table 3), which is in accordance with results from previous studies.\textsuperscript{34} With respect to patient age, this might partially be explained by an immaturity of the arachnoid granulations (pacchionian bodies) for CSF reabsorption in the young, as they only reach functionality in the late infantile period.\textsuperscript{37}

With respect to tumor histology, PNETs were significantly associated with a higher risk of preoperative hydrocephalus compared with WHO Grade I tumors (Table 3). This is in accordance with the published literature, although the main focus of these studies has been restricted to tumors located in the posterior fossa and less attention

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**Fig. 2.** Graph of the results of the univariate analysis of risk factors for preoperative hydrocephalus. “Yes and No” refers to the presence or absence of hydrocephalus, respectively.
has been given to the precise significance of tumor histopathology.\textsuperscript{17,18}

Of our 124 cases with preoperative hydrocephalus, 82 were treated using tumor resection only, and 11 of these patients went on to require shunt surgery for hydrocephalus, yielding a cure rate of 86.6\% (Fig. 1). Other series report persistent hydrocephalus postoperatively in approximately 10\%–30\% of cases, even though these studies reflect the rates of posterior fossa tumors only.\textsuperscript{3,25,33,35} Our results are on the lower end of this scale, in part possibly due to our inclusion of both supra- and infratentorial tumors.

In our study, only 1 patient early in the series received a VP shunt concomitant with tumor craniotomy (0.3\%). In a recent study by Wong et al.,\textsuperscript{39} the authors demonstrated a trend toward less shunting prior to, or simultaneously with, craniotomy, from 17.6\% in the early 1970s to 2.7\% in the period 2001–2008. Precraniotomy shunting has been largely abandoned and replaced by preoperative ETV or EVD as effective modalities for CSF diversion in more contemporary series.\textsuperscript{1,9,13,16,25,33,36,39}

Feng et al.\textsuperscript{11} concluded in their series of 58 patients (including both children and adults) that ETV prior to surgery is a most effective treatment for cases of preoperative obstructive hydrocephalus caused by aqueductal stenosis and space-occupying lesions. In the same study, shunt independence after ETV was achieved in 82\% of patients with tumor-related obstructive hydrocephalus. In a Swiss series by de Ribaupierre et al.\textsuperscript{1} with 48 pediatric patients (0–18 years old), 24 had preoperative ETV because of obstructive hydrocephalus. Of these, 8 patients experienced failure of the ETV, of whom 5 eventually needed a VP shunt. In a study by Houdemont et al.,\textsuperscript{19} 22 (38.6\%) of 57 patients with preoperative hydrocephalus had an ETV before surgery, and none of these patients needed postoperative shunt placement. Sainte-Rose et al.\textsuperscript{33} reported in their series of 196 pediatric patients that only 3 (6.4\%) of 47 patients with preoperative hydrocephalus treated by ETV needed postoperative shunting, compared with 16 (19.5\%) of 82 patients without preoperative ETV. Other series have reported similar high ETV success rates,\textsuperscript{2,32,33} although these series involved pediatric patients with posterior fossa tumors. In our study, 8 (6.5\%) of 124 cases underwent ETV prior to craniotomy for relief of preoperative hydrocephalus, none of whom went on to require an early VP shunt after craniotomy (Fig. 1). In addition, our study demonstrates a similar high success rate of ETV in both supra- and infratentorial tumors, albeit in a very limited number of patients. Previous studies have conflicting recommendations as to routine preoperative ETV, with some authors recommending it as a first choice for obstructive hydrocephalus caused by tumors,\textsuperscript{10,33} whereas others discourage it.\textsuperscript{3,12} Nonetheless, we believe that careful patient selection for ETV prior to surgery may have a great impact on postoperative outcome.

Placement of an EVD to treat preoperative hydrocephalus is commonly used in neurosurgical practice and numerous studies have shown its effectiveness with respect to postoperative outcome.\textsuperscript{4,26,36} Most often the EVD is inserted simultaneously during tumor resection and the EVD is subsequently weaned after surgery. If this fails, placement of a permanent VP shunt is performed.\textsuperscript{7} In our study, 33 (26.6\%) of 124 cases received an EVD to treat preoperative hydrocephalus, 24 of which were incidental to the craniotomy (Fig. 1).

The success rate of the EVD (63.6\%) was less than
that of preoperative ETV (87.5%) or craniotomy alone (86.6%), because 12 of 33 patients subsequently received VP shunts because of persistent hydrocephalus postoperatively, either early (10 patients) or within the first 3 months after the craniotomy (2 patients; Fig. 1).

Bognár et al. reported that 41% of patients with preoperative (13 of 27), intraoperative (2 of 27), and postoperative (12 of 27) EVD placement underwent postoperative shunt placement in their series of 180 pediatric patients with posterior fossa tumors. Similarly, Culley et al. reported a shunt insertion rate of 33% in children who received an EVD either preoperatively (18/81) or at the time of surgery (63/81) in a series of 117 pediatric patients. Our study of both supratentorial and infratentorial tumors showed a postoperative shunt placement rate of 36.4%, which is within the same range of the aforementioned studies. Possible explanations for the lower success rate of perioperative EVD insertion compared with preoperative ETV or tumor resection alone might include a negative selection bias and an increased risk of infections and complications related to the drainage of CSF, which have been shown by numerous studies in the past.

In the aforementioned study by Bognár et al., 28 (15.6%) of 180 patients received a shunt postoperatively, 6.7% within the first 6 weeks postoperatively, and 8.9% between 2 and 83 months after surgery. Furthermore, 15.3% of children who showed hydrocephalus on their admission CT scan underwent postoperative shunt placement, producing a shunt-free treatment success rate of 84.7%. In another similar study by Fritsch et al., 46 (88.5%) of 52 patients did not require permanent CSF diversion (neither VP shunt placement nor EVD/ETV). We report a similar high postoperative shunt-free success rate of 86.6% after tumor resection only (Fig. 1).

New-Onset Postoperative Hydrocephalus

Of the 257 patients with no preoperative hydrocephalus, only 9 patients (3.5%) developed new-onset hydrocephalus postoperatively. In the same study mentioned earlier by Bognár et al., 7 (16%) of 43 patients without preoperative hydrocephalus developed shunt-dependent hydrocephalus postoperatively. Santos de Oliveira et al. reported in their retrospective study of 64 patients that 2 (40%) of 5 patients without preoperative hydrocephalus developed new-onset postoperative hydrocephalus, both of whom received shunts. In the study by Culley et al., 3.1% of patients had new-onset postoperative hydrocephalus requiring shunting. Similarly, Morelli et al. reported new-onset postoperative hydrocephalus in 4.3%

Most studies have not identified significant risk factors associated with new-onset postoperative hydrocephalus. In our study, male sex, main tumor location infratentorial, and infratentorial surgical approach were significantly associated with an increased risk of developing new-onset postoperative hydrocephalus. Interestingly, in comparison with the risk factors for postoperative hydrocephalus in the overall analysis, younger age did not reach statistical significance in the univariate analysis (OR 3.9, p < 0.065). Seven of the 9 patients with new-onset postoperative hydrocephalus were boys, suggesting that younger boys have a particularly high risk of developing new-onset postoperative hydrocephalus. This result is in accordance with the study of Lassen et al., who reported that boys have a higher risk of postoperative CSF leakage, a well-known risk factor.

Overall Postoperative Hydrocephalus

In our study, a total of 33 patients had postoperative hydrocephalus, of whom 24 (6.3%) had persistent postoperative hydrocephalus and 9 (2.4%) had new-onset postoperative hydrocephalus (Fig. 3). Younger age (OR 1.1), preoperative hydrocephalus (OR 4.8), and meningitis (OR 7.7) were highly associated with a risk of postoperative hydrocephalus. In a study by Riva-Cambrin et al. in 343 pediatric patients with posterior fossa tumors, younger patient age and degree of hydrocephalus preoperatively were significant predictors of postoperative hydrocephalus. Culley et al. and Papo et al. also found that younger children had a higher incidence of postoperative shunt placement, presumably because of postoperative hydrocephalus. In contrast to our study, Culley et al. did not find preoperative hydrocephalus to be a significant risk factor for predicting the need for postoperative shunt placement. However, in our study, young age and untreated preoperative hydrocephalus were also significantly associated with developing postoperative CSF leaks, in accordance with results from previous studies by Lassen et al. and Bognár et al., which further strengthen the association between young age and untreated preoperative hydrocephalus as risk factors for developing postoperative hydrocephalus.

The univariate analysis in our study showed that patients with PNETs (OR 2.4) have an increased risk of developing postoperative hydrocephalus. Past studies have reported significant correlations between postoperative shunting due to persisting postoperative hydrocephalus and patients with medulloblastomas. Medulloblastomas occur mostly infratentorially in the posterior fossa and can obstruct CSF pathways. Another factor that may explain the possibility of developing hydrocephalus postoperatively is their potential for metastasis intracranially before the tumor is surgically removed. Both PNETs and infratentorial tumor location were significantly associated with postoperative hydrocephalus overall in the univariate analysis of our study, but in the multivariate analysis they did not reach significance. For persisting postoperative hydrocephalus, only meningitis was a significant risk factor in both univariate and multivariate analysis.

With regard to shunt treatment of postoperative hydrocephalus, 20 patients required early VP shunt placement while 4 required late VP shunt placement in our study (Fig. 3). In a recent study of craniotomies in 641 pediatric patients, von Lehe et al. reported that 27.0% of craniotomies for tumor cases required shunts or ETV due to permanent hydrocephalus, more often performed in younger children (p < 0.05). Other risk factors for permanent hydrocephalus included low preoperative Karnofsky Performance Scale scores, infratentorial surgery (40.4% vs. 2.6% for supratentorial surgeries), intraxial or subdural surgery, and emergency surgery. Other patient series have postoperative hydrocephalus rates ranging from 10% to 35%, although these series are
restricted to posterior fossa tumors. The overall rate of postoperative hydrocephalus with subsequent VP shunt placement in our study is relatively low, even though we included all patients regardless of tumor location and state of preoperative hydrocephalus. The literature states that approximately 30% are in need of permanent shunt placement due to postoperative hydrocephalus, but these rates reflect posterior fossa tumors.24 In the aforementioned study by Wong et al.,19 their rate of postoperative ventricular shunting was 31.1% in the period from 2001 to 2008, yielding a success rate with postoperative shunt independence of 68.9%, whereas in our series the success rate is higher than 80% in the past decade.

CSF Leakage and Meningitis

Our postoperative CSF leak rate was 6.3%. This rather high rate of CSF leaks might partially be explained by how leakage was defined; we have included all identified leaks, including hygromas and leakage of CSF fluid along EVD lines, and not only those requiring operative treatment. Most of the aforementioned series have not specified the term “CSF leakage.” Nevertheless, our rate is in the midrange of previously published series, in which 2.0%–10.3% of children undergoing craniotomies developed CSF leakage according to Lassen et al.23 In the aforementioned study by Houdemont et al.,19 which included 117 pediatric and adolescent patients (age range 0.3–21.4 years), 1.7% of cases were complicated by meningitis. Lassen et al.23 reported a postoperative meningitis rate of 1.8%. Our rate of postoperative meningitis was 1.6% compared with other reported series.1,4,13 As previous studies have shown, CSF leaks are closely related to postoperative infections and prolonged hospital stay.7,20,21 For instance, Houdemont et al.19 reported that infected patients stayed 4 times longer in the pediatric intensive care unit than those without infection. Furthermore, financial costs and hospital stays increase considerably with CSF leaks and it is of importance to be aware of cost-effectiveness regarding CSF complications. In a prospective study by Piek et al.27 performed in 545 patients with a variety of different intracranial procedures, costs per case nearly doubled because of complications regarding postoperative CSF leakage.

With CSF infections contributing greatly to increased morbidity and even mortality, it is important to select patients carefully to undergo perioperative EVD placement. In such settings, we therefore recommend antibiotic-impregnated EVD catheters rather than standard EVD catheters due to their safety profile, although other factors such as the duration of EVD placement must also be taken into account. However, in a recent study by Pople et al.,28 the use of antibiotic-impregnated EVD catheters did not significantly reduce the risk of EVD infection compared with standard EVD catheters.

Strengths of the Study

The strengths of this study lie in its setting, design, and follow-up. The data were restricted to 1 health center only (Rikshospitalet), thereby reducing the possible confounding effect of differences in access to health care services between health centers. Thus, we have avoided the selection bias inherently present in large multicenter studies, as there is only 1 neurosurgical unit performing these surgeries within a geographically well-defined area. Our series includes both supratentorial and infratentorial tumors, thereby reflecting the panorama of brain tumors observed in a pediatric neurosurgical practice. Furthermore, the study includes both primary and secondary craniopties, also reflecting a common clinical setting. Our study design is a retrospective analysis of a prospectively registered database. As the study includes all craniopties performed for a histologically verifiable brain tumor within the study period, there is no selection bias. With respect to data quality, we only used easily verifiable endpoints. In addition, every single complication registered in the database was verified by a thorough retrospective chart review by 2 independent reviewers (S.A.M.H. and T.R.M.). Lastly, we obtained a 100% follow-up rate. To the best of our knowledge, our study is the largest study with regard to postoperative CSF disturbances after craniopties for pediatric brain tumors.

Limitations of the Study

The first limitation of the study is the retrospective analysis of patient outcome with respect to CSF leaks and meningitis, as these data were not systematically registered in the database and were identified by chart reviews. Second, although this is a large series, the total number of patients may still be so low that a statistical Type II error (i.e., failure to identify a true prognostic factor) may occur when performing the multivariate analyses. Third, most contemporary patient series conducted in pediatric brain tumors in the neurosurgical literature comprise tumors located in the posterior fossa territory, which makes them challenging for direct comparisons to our study. Lastly, the statistical analyses may have been affected unfavorably by including patients who underwent multiple craniopties.

Conclusions

Preoperative hydrocephalus was found in 32.5% of pediatric patients with brain tumors treated using craniopties. Tumor resection alone cured preoperative hydrocephalus in 86.6% of cases, and the incidence of new-onset hydrocephalus after craniotomy was only 3.5%. In general, complication rates are low with regard to perioperative CSF disturbances. Further studies are needed for better understanding and alleviation of these complications. The authors’ data could be used as a benchmark for future studies.

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Disclosure

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


34. Santos de Oliveira R, Jucá CE, Valera ET, Machado

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