



A Single-Center Retrospective Descriptive Cohort Study of 211 Pediatric Patients: Cerebrospinal Fluid Leakage After Fourth Ventricle Tumor Resection

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■ **BACKGROUND:** Cerebrospinal fluid (CSF) leak remains a significant complication of posterior fossa tumor surgery. The goal of this study was to evaluate the wound CSF leakage rate in pediatric patients who underwent fourth ventricle tumor resection in a single-site setting and to explore the association of CSF leakage with the length of stay in the intensive care unit (ICU) and with dural sealant application.

■ **METHODS:** Two hundred and eleven patients who underwent fourth ventricle tumor surgery between 2008 and 2016 were included in this study. Patient data were evaluated retrospectively.

■ **RESULTS:** Postoperative wound CSF leakage was observed in 6 patients (2.8%). One hundred and seventy-six patients (83.4%) stayed in the ICU for ≤ 1 day, and CSF leakage developed in 4 of these patients (2.3%). Thirty-five patients (16.6%) stayed in the ICU for > 1 day, and CSF leakage was observed in 2 of these patients (5.7%). The observed difference was not statistically significant ($P = 0.260$). There were no statistically significant differences in the CSF leakage rates in groups with and without dural sealing before ($n = 2$ [3%] and $n = 4$ [2.8%], respectively; $P = 0.99$) and after ($n = 2$ [3.0%] and $n = 4$ [6.0%], respectively; $P = 0.68$) application of the propensity score matching algorithm.

■ **CONCLUSIONS:** The low CSF leakage rate (2.8%) identified in this study was associated with a certain algorithm

of patient management. There was no strong evidence that the CSF leakage rate was associated with the length of stay in the ICU or with dural sealant application.

INTRODUCTION

Background/Rationale

Surgical wound cerebrospinal fluid (CSF) leakage remains one of the most important and potentially preventable complications in neurosurgery.¹ This problem is often discussed when extended skull base approaches are under consideration.^{2,3} Nevertheless, there are common types of procedures in pediatric neurosurgery that are associated with wound CSF leakage rates of up to 33%. These procedures include resection of posterior fossa (PF) tumors and, most notably, tumors of the fourth ventricle.⁴ Studies have investigated how different surgical techniques can reduce the risk of CSF leakage.^{5,6} However, over the past decade, most studies have focused on the use of additional products to ensure tight dural sealing.^{7,8} Despite the fact that some of these studies had proper methodologic designs and high levels of evidence (prospective, randomized), no reliable answer to the question regarding the most effective methods of postoperative CSF leakage prevention was presented. We have analyzed the available data in the literature and found several major shortcomings that affect the significance of the results obtained in these studies. The most considerable problems of previously published studies on wound CSF leakage in neurosurgery are as follows.

Key words

- Cerebrospinal fluid leakage
- Children
- Craniotomy
- Dural sealant
- Posterior fossa
- Pseudomeningocele

Abbreviations and Acronyms

- CSF: Cerebrospinal fluid
- EVD: External ventricular drain
- ICU: Intensive care unit

PF: Posterior fossa

PSM: Propensity score matching

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- The first is the analysis of various types of surgical procedures associated with different potential risks of CSF leakage in heterogeneous populations. In some cases, patients with supratentorial and infratentorial tumors were analyzed together. In a number of cases, both tumor- and traumatic injury-related disorders were analyzed together.
- The second is multicenter data collection or data obtained from one clinic with a large number of surgeons. It is obvious that the range of surgical techniques is quite wide and has a variable effect on experimental variables. For example, patients with skull base tumors and tumors of the fourth ventricle were compared in the same study as patients who underwent a craniotomy, craniectomy, or other procedures.

To exclude the influence of the aforementioned factors, a study of the effectiveness of postoperative CSF leakage prevention should be carried out on a large homogeneous patient population. The patient population should be operated on within a relatively short period of time by one surgeon whose surgical technique has already been established and has not undergone any fundamental changes during that period. As a preliminary step in planning this type of study, we decided to perform a retrospective analysis of a patient cohort that underwent a resection of PF tumors in our institution.

Objectives

The primary objective of this study was to evaluate the rate of wound CSF leakage in pediatric patients who underwent fourth ventricle tumor resection in a single-site setting.

The secondary objectives were to explore the association of CSF leakage with the length of stay in the intensive care unit (ICU) and with dural sealant application.

METHODS

Study Design and Setting

This study is a retrospective descriptive cohort study of the incidence of wound CSF leakage and the factors that affect it on a homogeneous, large, and consecutive group of pediatric patients operated on by one surgeon (the first author) between 2008 and 2016. The STrengthening the Reporting of OBservational studies in Epidemiology guidelines were followed in this study. This retrospective study was approved by the ethics committee of the institution. Individual patient identification data were not collected when the database was developed, and this is the reason why patient consent was not required for this study. Data analysis was performed at the end of 2017. The follow-up period for every patient was at least 1 year. Literature data and our experience indicate that the risk of postoperative CSF leakage is highest in patients with PF tumors.^{4,9,10} Moreover, PF tumors are the most common neuro-oncologic lesions in pediatric patients.

Participants, Study Size, and Data Sources

We selected subjects who underwent primary resection of fourth ventricle tumors (accounting for up to 80% of all PF tumors in children) as our study exposure cohort. This selection was because of the identical surgical approaches, wide opening of the CSF

pathways during surgery, and stereotypical course of the postoperative period. The time period for patient selection was set between 2008 and 2016 for the following reasons:

- The need to enroll a sufficient number of patients in whom dural sealants were not used because of nonmedical reasons (up to middle of 2012).
- By 2008, the surgeon's experience in pediatric neurosurgery reached 10 years (>3500 operations) and his personal surgical technique had already been worked out. In addition, there were no substantial changes in PF tumor surgery over this time period.
- The size of the analysis group was expected to be at least 200 patients with primary resection of tumors of the fourth ventricle.

The first author has been keeping a prospective register of all operated patients with the procedure types since 1999. The identifiers of all patients who underwent surgical treatment for PF tumors between 2008 and 2016 were exported from this database. Then, the data managers of the hospital selected all the surgery reports ($n = 472$) corresponding to these identifiers from the electronic health record system. After the analysis of surgery reports, it was decided whether patients were eligible for the study. The inclusion criteria were as follows: 1) age under 18 years, 2) predominant location of the tumor in the fourth ventricle, and 3) primary surgery.

The exclusion criterion was death within 1 week after surgery.

Following expert analysis of all of the surgery reports based on the inclusion criteria, the group was reduced to 211 patients.

After selecting the patient population, the data recorded during the course of routine clinical practice (statistical data, case histories, surgery, and procedure reports) were taken from the electronic health record of the hospital. The following clinical and statistical data were included in the analysis: ICU length of stay, data on repeated hospital admissions because of complications, and data on additional surgical procedures. A contextual search of all case notes was performed using the following key words: "CSF leak," "CSF leakage," "CSF accumulation," "meningocele," "pseudomeningocele," and "meningitis." Afterward, the case histories containing the key words were analyzed by the operating surgeon.

The following data were obtained from the surgery reports: 1) information on external ventricular drain (EVD)/shunt placement prior to tumor resection, 2) information on dural closure: primary sutures/dural repair (material), and 3) information on dural suture sealing (and the use of the following products: TachoComb [Takeda Pharmaceutical Company Limited, Tokyo, Japan; here and in the following because of differences in trade names of equal compositions in different countries; TachoComb is equivalent to TachoSil; Takeda Pharmaceutical Company Limited], glues, and drug combinations).

Surgical Technique

All surgical procedures were performed in the sitting position. In cases of an obvious hydrocephalus, an EVD was always placed at the beginning of surgery for the prevention of tension

pneumocephalus during the early postoperative period. A median suboccipital craniotomy was used as access in all cases. No cases of dural tear were registered during the craniotomy. A typical V- or Y-shaped dural incision was used. The approach and tumor resection were performed via the foramen of Magendie dilated by the tumor; if necessary, the foramen was extended via preparation of the choroidal fissure. In all cases, the objective of surgery was to completely remove the tumor. In all cases, the fourth ventricle, cerebral aqueduct, and communication with the spinal subarachnoid space were widely exposed by the end of surgery. Bleeding control was performed using bipolar cautery and application of Surgicel (Ethicon LLC, Bridgewater, New Jersey, USA) to the areas of infiltration. The dura mater was sutured using braided polyglycolic acid 4-0 (RESORBA Wundversorgung GmbH & Co., Nürnberg, Germany) sutures. Depending on the specific situation, intermittent or continuous sutures were used. In all cases, we tried to perform primary closure without the use of dura substitutes. In rare cases in which the occipital sinus was large, suturing for bleeding control purposes resulted in the infeasibility of dural closure without the formation of diastasis or tension. In those cases, a patch from a dura substitute was used to repair the defect (fascia or an artificial product such as Durepair; Medtronic LLC, Minneapolis, Minnesota, USA). Until the middle of 2012, no dural sealants were applied. Since 2012, the fibrin thrombin adhesive system (Tissucol [Baxter LLC, Deerfield, Illinois, USA] or Evicel [Ethicon LLC]) and TachoComb have been used with various frequencies (depending on their availability). The decision related to the use of sealants in this patient group was approved by the physicians' commission of Burdenko Neurosurgical Institute considering the need for the prevention of dangerous complications. During this time period, we did not use the sandwich application for TachoComb. The TachoComb plate was always placed at the top of the dural sutures with an overlap of at least 5 mm. A bone flap was always placed at the end of the surgery and fixed with 4 silk sutures (3-0). The wound was tightly closed layer by layer. Immediately after surgery, patients were transferred to the awakening room of the neurosurgical ICU. After awakening, patients were extubated if their vital signs were stable. In cases with a sufficient level of wakefulness, regardless of local neurologic symptoms, the patient was transferred to a general ward the next morning. To ensure pneumocephalus resolution and CSF clearance during the early postoperative period, and to prevent possible increases in intracranial pressure, the EVD was kept open throughout the entire period that it was present in patients' bodies. The EVD was usually set at +5 cm H₂O. Unloading spinal taps were performed in all patients during the first 2–3 days after surgery; these spinal taps were usually performed the day after surgery and additionally 1 day later for meningism maintenance. In cases with uncomplicated postoperative periods, the drain was removed 4–5 days after surgery. In patients with prolonged stays in the ICU, the drain was kept longer and usually remained until the patient reached the level of general activity at which it was possible to assess the intracranial hypertension clinically after drain removal. All patients underwent regular postoperative visits at 3 months, 6 months, and 1 year after surgery.

During the study period, the surgical technique, suture materials used, and principles of postoperative management of patients remained unchanged, which made it possible to consider the

study group to be the homogeneous in terms of possible uncontrolled factors that possibly affect the reliability of the retrospective study results.

Two subgroups in 1 cohort (N = 211) were identified: a group of patients with no dural sealants used (n = 144) and a group with suture sealants used (n = 67).

We analyzed each patient's postoperative course, with particular attention paid to CSF leakage, pseudomeningocele formation, extracranial complication development, and postoperative length of stay. There were no participants with missing data for each variable of interest.

To compare the CSF leakage rate between cases with dural suture sealing and cases without additional sealant application, propensity score matching (PSM) analysis was carried out to select subgroups that were balanced by factors that potentially affected the outcome and to minimize the selection bias. Statistical data analysis was carried out in the R software environment for statistical computation (version 3.3.2; R Foundation, <https://www.r-project.org/foundation/>). For comparisons between groups, the Fischer exact test and Mann-Whitney U test were used when appropriate. The differences between groups were considered statistically significant if $P < 0.05$.

RESULTS

Descriptive Data

The main characteristics of the population examined are presented in **Table 1**. The age and distribution of histologic types indicate that our cohort can be considered to be representative compared with the data from the literature.¹¹

Table 1. Patient Characteristics (N = 211)

Variable	Number of Patients (%)
Sex	
Male	134 (63.5)
Female	77 (36.5)
Age (years)	
<1	8 (3.8)
1–3	46 (21.8)
3–10	107 (50.7)
10–18	50 (23.7)
Histology	
Astrocytoma	46 (21.8)
Medulloblastoma	100 (47.4)
Atypical teratoid rhabdoid tumor	9 (4.3)
Ependymoma	45 (21.3)
Choroid papilloma	7 (3.3)
Other	4 (1.9)
EVD placement	154 (73)
EVD, external ventricular drain.	

Outcome Data and Main Results

Postoperative wound CSF leakage was observed in 6 patients (2.8%), and 4 (1.87%) of them also developed pseudomeningocele of various severity. Another 5 patients (2.4%) developed clinically significant subcutaneous CSF accumulation during the early postoperative period. The overall rate of CSF leakage was 5.2%. CSF leakage developed 6–17 days after surgery. In all cases, CSF leakage was eliminated by spinal taps or placement of an external lumbar drain. After the elimination of meningitis, one patient required a ventriculoperitoneal shunt implantation. Another patient developed CSF leakage during the third week after surgery (after discharge from the hospital) together with a superficial abscess of the soft tissues that required rehospitalization, drainage of the abscess, and implantation of an external lumbar drain. In 5 patients with pseudomeningocele without CSF leakage, subcutaneous CSF accumulation was observed 3–13 days after surgery. In 4 cases, these accumulations resolved after several spinal taps. In one case, pseudomeningocele was a symptom of nonresorptive hydrocephalus and required ventriculoperitoneal shunt implantation placement 13 days after primary surgery.

The duration of postoperative stay is known to reflect the severity of the patient's condition after the surgery, and the development of complications that include CSF leakage. We used a length of stay at the ICU >1 day as an indicator of severe postoperative conditions. Based on this parameter, we divided patients into 2 groups: uncomplicated postoperative course (length of stay at the ICU ≤1 day) or complicated postoperative course (length of stay at the ICU >1 day). Most patients, 176 (83.4%), stayed at the ICU for <1 day. Among them, 4 patients developed CSF leakage (2.3%). The mean postoperative length of stay in these patients was 17.0 ± 6.2 days compared with 9.6 ± 4.5 days for patients without CSF leakage; the differences were statistically significant in a small number of observations (Mann-Whitney 2-tailed test, $P = 0.008$). Thirty-five patients (16.6%) stayed at the ICU for >1 day. CSF leakage was observed in 2 cases (5.7%) in this subgroup. The mean postoperative lengths of stay in these patients and patients without CSF leakage were 38.0 ± 11.3 and 24.1 ± 16.1 days, respectively. The difference was not statistically significant (Mann-Whitney 2-tailed test, $P = 0.086$). The tendency of higher CSF leakage rates in patients with severe postoperative courses (5.7% vs. 2.3%) was not statistically significant (2-sided Fisher exact test, $P = 0.260$), probably because of the small number of events in the sample and unbalanced groups.

The group without dural sealing treatments consisted of 144 patients (68.2%). CSF leakage was observed in 4 cases (2.8%). In 3 cases (2.1%), there was symptomatic pseudomeningocele without CSF leakage. In the group with suture sealants (TachoComb, fibrin-thrombin glue in various combinations, $n = 67$ [31.8%]), 2 patients (3%) had CSF leakage, and there were 2 cases (3%) of pseudomeningocele without CSF leakage. There were no statistically significant differences in the frequencies of CSF leakage and pseudomeningocele (Fisher exact test; $P = 0.99$ and $P = 0.654$, respectively).

Among the 35 patients with a severe postoperative course, TachoComb with fibrin-thrombin glue was applied in 13 cases (37.1%) and CSF leakage developed in 1 case (7.7%). In 22 cases, no additional sealant was used and CSF leakage developed in 1

case (4.5%); there were no differences in the CSF leakage rates between groups (2-sided Fisher exact test, $P > 0.999$).

One patient with a severe postoperative course who stayed on mechanical ventilation died in the ICU on day 8 as a result of sudden development of cardiovascular failure. Sixteen patients developed extracranial complications related to the surgery. The data on these complications are presented in Table 2. It is important that in all patients with complicated wound healing, no dural sealants were used. No allergic reactions to dural sealants were observed. These observations provide additional evidence about the safety of dural sealants in pediatric neurosurgery.

Other Analyses

To determine the difference in the postoperative CSF leakage rate dependent on dural sealants, patients with dural sealing (group A) and without dural sealing (group B) were compared using the PSM method. Sex, age, tumor histologic type, intraoperative dural closure, EVD placement, and length of stay starting from admission to the operation day were considered as covariates in the PSM.

After PSM algorithm analysis, the group with dural sealing (group A), consisting of 67 patients, was matched with the group without dural sealing (group B), consisting of 67 patients, by propensity scores. TachoComb was used as the sealant in 64 patients (95.5%) from group A, and fibrin-thrombin glue was used in 53 (79.1%) patients. There were no significant differences between the A and B groups in sex ($P = 0.99$), age ($P = 0.38$), histologic diagnosis ($P = 0.89$), dural closure rate ($P = 0.37$), EVD placement rate ($P = 0.99$), and length of stay before surgery ($P = 0.79$). The CSF leakage rate was comparable in both groups (2 [3.0%] in group A and 4 [6.0%] in group B, $P = 0.68$), as was the pseudomeningocele rate (3 [4.5%] in group A and 4 [6.0%] in group B, $P = 0.99$) (Table 3).

Table 2. Extracranial Complications Related to the Surgery

Complication	Number of Patients
Pressure injury of wound/postoperative scar	2
Pneumothorax	1
Pneumocephalus	2
Tumor bed hematoma	2
PF epidural hematoma	1
Meningitis	1
Epidural hematoma	1
Wound necrosis	1
Shunt infection	2
Subcutaneous abscess	1
Tumor hemorrhage after EVD	1
Anemia	1
Total	16

PF, posterior fossa; EVD, external ventricular drain.

Table 3. Subgroup Analysis After Propensity Score Matching Algorithm Application

Variable	Group A (with Dural Sealing) (n = 67)	Group B (without Dural Sealing) (n = 67)	P Value
Sex			1
Male	39 (58.2)	39 (58.2)	
Female	28 (41.8)	28 (41.8)	
Age (years)	5.6 ± 4.1	6.3 ± 4.3	0.38
Histologic diagnosis			0.89
Astrocytoma	6	5	
Atypical teratoid rhabdoid tumor	6	3	
Medulloblastoma	30	34	
Other	2	2	
Choroid papilloma	2	1	
Ependymoma	21	22	
Dural closure rate	4	1	0.37
EVD placement rate	45	46	1
Length of stay before operation (days)	2.1 ± 2.2	2.0 ± 1.6	0.79
CSF leak rate	2 (3.0)	4 (6.0)	0.68
Pseudomeningocele rate	3 (4.5)	4 (6.0)	1

Values are mean ± SD, number of patients (%), number of patients, or as otherwise indicated.
EVD, external ventricular drain; CSF, cerebrospinal fluid.

DISCUSSION

The problem of postoperative CSF leakage still remains relevant because this complication leads to additional patient suffering and doubles the cost of treatment.^{1,12} In pediatric neurosurgery, patients with a high risk of postoperative CSF leakage traditionally include those who underwent PF surgery.^{4,5,13} Among the methods that reduce the risk of CSF leakage in the literature, various modifications of surgical techniques and application of sealants and materials to the dural suture are considered.^{5,8,14}

In our practice, the dural sealants (TachoComb, fibrin-thrombin glue) have become intermittently available since 2012. Their use was not selective and was based on their availability in the operating room, which determined the peculiarities of the compared subgroups regarding a certain unpredictability of the application process. However, to minimize the selection bias in this retrospective study, we applied the so-called pseudorandomization algorithm (PSM) to determine the differences in the postoperative CSF leakage rates and pseudomeningocele between the groups with sealant application and without sealant application because of unavailability.

The frequency of CSF leakage in PF tumors in children varies from 4% to 33% in different clinical series.^{4,5} Our data (2.8%) are

consistent with the minimum levels of postoperative CSF leakage described in the literature. This low CSF leakage rate in our cohort can be explained by a number of reasons. The most important reason is likely related to the technique used to indicate CSF leakage. Of course, retrospective analysis of medical records is likely to lead to underestimates. Moreover, in a number of studies, all cases of pseudomeningocele (including asymptomatic data and all magnetic resonance imaging findings) were referred to as complications, which appears to be controversial.⁴ A small pseudomeningocele without CSF leakage does not actually affect the clinical course of the disease, the timing of the patient's discharge from the hospital, or the need for additional manipulations. Another important factor was performing craniotomy (not craniectomy) in all patients. This technique was shown to decrease the percentage of CSF leakage in pediatric neurosurgeries from 27% to 4%.⁵ In addition, this study also demonstrated the lowest published percentage of CSF leakage after PF tumor surgery provided that craniotomy was performed. Another possible reason for the low CSF leakage rate in our cohort is the widespread use of external ventricular drainage in the perioperative period, which is an unloading lumbar puncture in all patients (i.e., a certain algorithm of patient management aimed at CSF clearance and an effective CSF pressure decrease). CSF draining through the EVD via intermittent spinal taps allows for more rapid CSF clearance and also effectively reduces CSF pressure within the first 4–5 days after surgery, ensuring natural sealing of the wound in the course of its healing. Studies demonstrating that the problems of CSF leakage and pseudomeningocele are related to CSF circulation rather than dural sealing confirm our viewpoint.^{5,15} Therefore, it is not surprising that we did not observe any additional effects after the use of sealants (TachoComb and fibrin-thrombin glue). Other studies, including prospective randomized studies, also failed to demonstrate the efficacy of suture sealant use.^{7,8,16} Despite the formally high degree of evidence in these studies (prospective and randomized), they have a significant number of shortcomings that did not allow them to assess the effective prevention of postoperative CSF leakage. This applies to a very heterogeneous range of surgical procedures associated with completely different risks of CSF leakage. Another problem is the multicenter nature of patient selection (e.g., 200–300 cases from 50–60 surgeons working in 20 clinics could be used in the analysis). In this case, a factor related to the surgical technique may play an important role.

When planning and performing this retrospective analysis, we attempted to consider the shortcomings of published studies and exclude or minimize these shortcomings in our study. The use of a solely retrospective data analysis is a fundamental limitation of our study. A low CSF leakage rate, on one hand, indicates the advantages of our strategy of perioperative patient management. On the other hand, it does not allow us to reliably assess the effect of dural suture sealing.

Future studies in this field should consider the potentially preventable nature of the problem and its importance in the overall treatment results of neuro-oncology patients. Given the socioeconomic component of the problem, the cost of searching for effective means can be expected to be paid off quickly.^{1,12}

CONCLUSIONS

Early CSF leakage remains a relevant problem of PF tumor surgeries and can double the postoperative length of stay. Our strategy of perioperative patient management is associated with a low rate of postoperative CSF leakage (2.8%). The low rate of CSF leakage and relatively small sample size did not provide sufficient power to evaluate the possible effects of the additional use of dural sealants (TachoComb and fibrin-thrombin glue) on the rate of CSF leakage. It is possible that in a clinic with more complications, this effect will be noticeable. This problem deserves further study in carefully planned studies on

adequately homogeneous patient populations. It is also important to identify groups of patients with an increased risk of CSF leakage who can benefit the most from the use of additional dural sealants.

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REFERENCES

- Grotenhuis JA. Costs of postoperative cerebrospinal fluid leakage: 1-year, retrospective analysis of 412 consecutive nontrauma cases. *Surg Neurol*. 2005;64:490-493.
- Di Vitantonio H, De Paulis D, Del Maestro M, et al. Dural repair using autologous fat: our experience and review of the literature. *Surg Neurol Int*. 2016;7:463-468.
- Taha ANM, Almefty R, Pravdenkova S, Almefty O. Sequelae of autologous fat graft used for reconstruction in skull base surgery. *World Neurosurg*. 2011;75:692-695.
- Steinbok P, Singhal A, Mills J, Cochrane DD, Price AV. Cerebrospinal fluid (CSF) leak and pseudomeningocele formation after posterior fossa tumor resection in children: a retrospective analysis. *Childs Nerv Syst*. 2007;23:171-174.
- Gnanalingham KK, Lafuente J, Thompson D, Harkness W, Hayward R. Surgical procedures for posterior fossa tumors in children: does craniotomy lead to fewer complications than craniectomy? *J Neurosurg*. 2002;97:821-826.
- Heymanns V, Oseni AW, Alyeldien A, et al. Sandwich wound closure reduces the risk of cerebrospinal fluid leaks in posterior fossa surgery. *Clin Pract*. 2016;6:824.
- George B, Matula C, Kihlstrom L, Ferrer E, Tetens V. Safety and efficacy of TachoSil (absorbable fibrin sealant patch) compared with current practice for the prevention of cerebrospinal fluid leaks in patients undergoing skull base surgery: a randomized controlled trial. *Neurosurgery*. 2017;80:847-853.
- Green AL, Arnaud A, Batiller J, et al. A multicentre, prospective, randomized, controlled study to evaluate the use of a fibrin sealant as an adjunct to sutured dural repair. *Br J Neurosurg*. 2015;29:11-17.
- Houdemont SP, De Carli E, Delion M, et al. Short-term neurological outcome of children after surgery for brain tumors: incidence and characteristics in a pediatric intensive care unit. *Childs Nerv Syst*. 2011;27:933-941.
- Lassen B, Helseth E, Egge A, Due-Tønnessen BJ, Rønning P, Meling TR. Surgical mortality and selected complications in 273 consecutive craniotomies for intracranial tumors in pediatric patients. *Neurosurgery*. 2012;70:936-943.
- Albright A, Pollack IF, Adelson PD. *Principles and Practice of Pediatric Neurosurgery*. 3rd ed. New York, NY: Thieme; 2015.
- Piek J, Weber C, Kundt G, et al. Pharmacoeconomic consequences of postoperative CSF leaks after intracranial surgery - a prospective analysis. *J Neurol Surg A Cent Eur Neurosurg*. 2012;73:25-28.
- Mehta AI, Mohrhaus CA, Husain AM, et al. Dorsal column mapping for intramedullary spinal cord tumor resection decreases dorsal column dysfunction. *J Spinal Disord Tech*. 2012;25:205-209.
- Kshetry VR, Lobo B, Lim J, Sade B, Oya S, Lee JH. Evaluation of non-watertight dural reconstruction with collagen matrix onlay graft in posterior fossa surgery. *J Korean Neurosurg Soc*. 2016;59:52-57.
- Hosainey SAM, Lassen B, Helseth E, Meling TR. Cerebrospinal fluid disturbances after 381 consecutive craniotomies for intracranial tumors in pediatric patients. *J Neurosurg Pediatr*. 2014;14:604-614.
- Hutter G, von Felten S, Sailer MH, Schulz M, Mariani L. Risk factors for postoperative CSF leakage after elective craniotomy and the efficacy of fleece-bound tissue sealing against dural suturing alone: a randomized controlled trial. *J Neurosurg*. 2014;121:735-744.

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