A hospital-based analysis of pseudomeningoceles after elective craniotomy in children: what predicts need for intervention?

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OBJECTIVE In pediatric patients, the development of a postoperative pseudomeningocele after an elective craniotomy is not unusual. Most will resolve with time, but some may require intervention. In this study, the authors analyzed patients who required intervention for a postoperative pseudomeningocele following an elective craniotomy or craniectomy and identified factors associated with the need for intervention.

METHODS An institutional operative database of elective craniotomies and craniectomies was queried to identify all surgeries associated with development of a postoperative pseudomeningocele from January 1, 2010, to December 31, 2017. Demographic and surgical data were collected, as were details regarding postoperative events and interventions during either the initial admission or upon readmission. A bivariate analysis was performed to compare patients who underwent observation with those who required intervention.

RESULTS Following 1648 elective craniotomies or craniectomies, 84 (5.1%) clinically significant pseudomeningoceles were identified in 82 unique patients. Of these, 58 (69%) of the pseudomeningoceles were diagnosed during the index admission (8 of which persisted and resulted in readmission), and 26 (31%) were diagnosed upon readmission. Forty-nine patients (59.8% of those with a pseudomeningocele) required one or more interventions, such as lumbar puncture(s), lumbar drain placement, wound exploration, or shunt placement or revision. Only race ($p < 0.01$) and duraplasty ($p = 0.03$, OR 3.0) were associated with the need for pseudomeningocele treatment.

CONCLUSIONS Clinically relevant pseudomeningoceles developed in 5% of patients undergoing an elective craniotomy, with 60% of these pseudomeningoceles needing some form of intervention. The need for intervention was associated with race and whether a duraplasty was performed.

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KEYWORDS pseudomeningocele; elective craniotomy; intervention; treatment; risk factors; hydrocephalus

A PSEUDOMENINGOCELE is defined as an abnormal collection of CSF bounded by extradural soft tissue. It is a well-known possible sequela of any intradural cranial or spinal surgery. For example, in a randomized trial of 229 adults undergoing elective craniotomy, the pseudomeningocele rate ranged from 9.7% to 17.2%, with diabetes mellitus, elevated preoperative C-reactive protein level, and duraplasty being positively associated with pseudomeningocele occurrence.⁹ A recent systematic review reported a pseudomeningocele rate of around 8%.¹⁰

In recent years, several attempts have been made to identify patient or surgical factors that influence the patient's risk of developing a pseudomeningocele following cranial surgery. Numerous variables have been examined, including surgical location and technique, use of various dural grafts or tissue sealants, patient demographics, and presurgical diagnoses.^{4,5,7,11,13,14,16,18,21,22} The results of these studies have been largely inconclusive, with craniectomies being the most commonly cited predictor of pseudomeningocele development.^{4,5,7,14} However, previous studies have

ABBREVIATIONS ETV = endoscopic third ventriculostomy.

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almost exclusively focused on a specific anatomical location, namely the posterior fossa.^{4–7,11,13,14,16,18,21,22} Additionally, few studies have focused on the pediatric population.

Most pseudomeningoceles are self-limiting.^{15,23} However, those that are large, growing, or symptomatic with concomitant hydrocephalus will likely require one or more interventions, including lumbar puncture, surgical drainage and repair, and shunt placement. Tu et al. explored physician preferences with regard to pseudomeningocele treatment.²³ Although overall there was no consensus or standardized protocol as to the type and timing of treatment, the majority of respondents wait at least 7–14 days before exploring a posterior fossa pseudomeningocele following tumor resection.

To our knowledge, predictors of pseudomeningocele intervention—as opposed to development—have not been previously investigated. The purpose of this study was to explore the association between previously cited variables, in addition to several novel ones, and the need to treat a clinically significant pseudomeningocele in the hospital setting.

Methods

Database Creation

An institutional (Le Bonheur Children's Hospital) operative database of elective craniotomies and craniectomies that is retrospectively maintained on a regular basis was queried to identify all surgeries associated with the development of postoperative pseudomeningoceles from January 1, 2010, to December 31, 2017. An index operation was defined as any independent elective (i.e., nonurgent or emergent) craniotomy or craniectomy. As such, one patient may have had more than one index operation. In order for patients to be included in this analysis, their pseudomeningocele(s) must have been diagnosed within the first 90 days of their index surgery, whether during the initial hospitalization or during readmission, or both. As such, each patient had at least one index surgery and 0–3 readmissions.

Variables and Definitions

A pseudomeningocele was defined as a “clinically significant” (i.e., visible or palpable by physical examination, as documented in the electronic medical record) CSF collection, contained within extradural cranial or upper cervical soft tissues, with or without a CSF-cutaneous fistula (i.e., CSF leak through the recent skin incision). Clinically insignificant or irrelevant subcutaneous fluid collections were defined as those that were not detectable by physical examination (i.e., diagnosed by imaging only). Our primary outcome was need for treatment, defined as any and all procedures (bedside or in the operating theater) directed at reducing the size and ultimately eliminating the patient's pseudomeningocele. Each surgeon was free to choose the type and timing of intervention (i.e., no specific management protocol was followed).

Demographic, clinical, and surgical details regarding the index hospitalization and any readmission were collected. Several historical variables pertinent to the index admission were noted, including history of prior craniot-

omy and the location of the previous surgical site relative to the index procedure (i.e., same site or different), hydrocephalus history (existing shunt or prior endoscopic third ventriculostomy [ETV]), and prior exposure to cranial irradiation. Index procedural variables included whether the operation was a craniotomy or craniectomy, type of procedure, location of procedure (supratentorial vs infratentorial), and whether a dural patch graft was used. Dural grafts are routinely applied to the native dura by suture rather than onlay, especially for posterior fossa surgery. Procedure types included tumor resection (supratentorial or infratentorial), craniostomy, seizure surgery (subdural grid placement or resection of seizure focus), Chiari decompression, and vascular surgery of any kind, as well as the category of “other.” Tumors were further categorized into specific tumor types. Finally, several postoperative complications relevant to pseudomeningoceles were recorded, such as bacterial meningitis, CSF leak, hydrocephalus, and wound infection, the latter being defined as having positive representative cultures obtained from the wound. Any and all interventions that were needed to definitively address the pseudomeningocele were noted.

Study Questions

With this retrospective observational study, we sought to answer the following two questions: 1) What are the characteristics of the cohort who developed a clinically significant pseudomeningocele following an elective craniotomy or craniectomy? 2) What variables are associated with the need for pseudomeningocele treatment?

Statistical Analysis

Demographic, clinical, and surgical variables were summarized using frequency and percentages for categorical variables and mean and range for continuous variables. Odds ratio (OR) estimates and 95% confidence intervals (CIs) were generated using generalized estimating equations with an independent correlation structure to examine associations between each variable and the outcome of treatment versus no treatment of pseudomeningocele. Due to the small ratio of the number of observations in each outcome category to the number of variables, only bivariate analyses were conducted, in accordance with the proposed rules for events per variable set forth by Peduzzi et al.¹⁷ and Wynants et al.²⁴ Statistical significance was defined as $p < 0.05$. All analyses were performed using SAS software version 9.3 (SAS Institute Inc.).

Results

Of the 1648 elective craniotomies or craniectomies performed from January 1, 2010, to December 31, 2017, 84 (5.1%) resulted in a postoperative pseudomeningocele, with 58 (69%) diagnosed during the index admission and 26 (31%) during the readmission. Eight patients developed pseudomeningoceles during the index admission that persisted to readmission. All readmissions occurred within 30 days of discharge following the index surgery. Thirty-four index surgeries (40.5%) were followed by at least 1 readmission, of which 2 (2.4%) required a second readmission and 2 (2.4%) required a third readmission to

TABLE 1. Demographics and prior treatment information

Patient Variable	All Pseudomeningoceles (n = 84)	No Intervention (n = 34)	Intervention Required (n = 50)
Age in yrs, mean (range)	6.62 (0.13–24.81)	6.24 (0.24–18.56)	6.89 (0.13–24.81)
Age in yrs			
<5	40 (47.6%)	17 (50%)	23 (46%)
5–10	27 (32.1%)	10 (29.4%)	17 (34%)
>10	17 (20.2%)	7 (20.6%)	10 (20%)
Sex			
Male	57 (67.9%)	22 (64.7%)	35 (70%)
Female	27 (32.1%)	12 (35.3%)	15 (30%)
Race			
Caucasian	48 (57.1%)	17 (50%)	31 (62%)
African American	17 (20.2%)	3 (8.8%)	14 (28%)
Hispanic	6 (7.1%)	4 (11.8%)	2 (4%)
Other/unspecified	13 (15.5%)	10 (29.4%)	3 (6%)
Insurance			
None	1 (1.2%)	1 (2.9%)	0 (0%)
Private	50 (59.5%)	20 (58.8%)	30 (60%)
Government	33 (39.3%)	13 (38.2%)	20 (40%)
Existing shunt			
No	76 (90.5%)	31 (91.2%)	45 (90%)
Yes	8 (9.5%)	3 (8.8%)	5 (10%)
Prior ETV			
No	77 (91.7%)	31 (91.2%)	46 (92%)
Yes	7 (8.3%)	3 (8.8%)	4 (8%)
Prior radiation			
No	76 (90.5%)	29 (85.3%)	47 (94%)
Yes	8 (9.5%)	5 (14.7%)	3 (6%)

Values are presented as number of pseudomeningoceles (%) unless otherwise indicated.

resolve the pseudomeningocele. Demographics are summarized in Table 1. At the time of the index procedure, the mean patient age was 6.6 years (range 0.1–24.8 years), and 57 (65.9%) patients were male. The majority of children were Caucasian (57.1%) with private insurance (59.5%). A minority of patients had an existing shunt (9.5%), had undergone prior ETV (8.3%), or had previously received cranial irradiation (9.5%).

Index Surgery Characteristics

Details of the index surgeries are summarized in Table 2. In 77 cases, the index procedure consisted of a craniotomy, while in 7 cases, the procedure was a craniectomy. In 35 (41.7%) cases there was a prior craniotomy, and of these, the index surgery was performed at the same surgical site in 30 (35.7%) cases. Duraplasty was performed in 32 cases (38.1%, 14 supratentorial and 18 infratentorial).

Index procedures were largely tumor resections (64 cases, 76.2% of the total sample), with 38 tumors (59.4% of tumor resections) being supratentorial and 26 (40.6% of tumor resections) infratentorial. Table 3 lists the various tumor types, with the 3 most common being pilocytic as-

trocytoma or ganglioglioma (n = 12; 18.8%), medulloblastoma (n = 11; 17.2%), and “other” high-grade tumors (n = 10; 15.6%). Additional index surgeries were craniotomies for epilepsy (n = 13; 15.5%), Chiari decompressions (n = 3; 3.6%), and vascular procedures (n = 1; 1.2%). Six operations were categorized as “other” (7.1%).

Pseudomeningocele and Associated Complications

Isolated pseudomeningoceles, those without accompanying adverse events such as wound complications or meningitis, occurred after 61 operations—41 were diagnosed during the initial hospitalization and 20 upon readmission. The remaining 23 pseudomeningoceles were diagnosed with one or more surgical postoperative events, as listed in Table 4. The most common comorbidities were previously untreated hydrocephalus (8 instances during initial admission and 10 on readmission) and CSF-cutaneous fistulas (9 during initial admission and 9 on readmission).

Intervention(s)

On average, 1.29 procedures were performed at the index visit, while 2.27 were performed during readmission.

TABLE 2. Index surgery details grouped by surgery location (supra- vs infratentorial)

Variable	All Pseudomeningoceles (n = 84)	No Intervention (n = 34)	Intervention Required (n = 50)
Supratentorial	54 (64.3%)	26 (76.5%)	28 (56%)
Prior craniotomy			
No	28 (51.9%)	12 (46.2%)	16 (57.1%)
Yes, same location	21 (38.9%)	10 (38.5%)	11 (39.3%)
Yes, different location	5 (9.3%)	4 (15.4%)	1 (3.6%)
Procedure type			
Craniotomy	52 (96.3%)	25 (96.2%)	27 (96.4%)
Craniectomy	2 (3.7%)	1 (3.8%)	1 (3.6%)
Duraplasty			
No	40 (74.1%)	22 (84.6%)	18 (64.3%)
Yes	14 (25.9%)	4 (15.4%)	10 (35.7%)
Indication			
Tumor resection	38 (70.4%)	18 (69.2%)	20 (71.4%)
Seizure surgery	13 (24.1%)	5 (19.2%)	8 (28.6%)
Other	6 (11.1%)	3 (11.5%)	3 (10.7%)
Infratentorial	30 (35.7%)	8 (23.5%)	22 (44%)
Prior craniotomy			
No	21 (70%)	5 (62.5%)	16 (72.7%)
Yes, same location	9 (30%)	3 (37.5%)	6 (27.3%)
Yes, different location	0 (0%)	0 (0%)	0 (0%)
Procedure type			
Craniotomy	25 (83.3%)	7 (87.5%)	18 (81.8%)
Craniectomy	5 (16.7%)	1 (12.5%)	4 (18.2%)
Duraplasty			
No	12 (40%)	4 (50%)	8 (36.4%)
Yes	18 (60%)	4 (50%)	14 (63.6%)
Indication			
Tumor resection	26 (86.7%)	7 (87.5%)	19 (86.4%)
Chiari decompression	3 (10%)	0 (0%)	3 (13.6%)
Vascular	1 (3.3%)	1 (12.5%)	0 (0%)

Of the 58 pseudomeningoceles that developed during the initial hospitalization, 21 (36.2%) required one or more of the following interventions: lumbar puncture(s) (n = 10), shunt placement or revision (n = 7), wound exploration (n = 6), percutaneous aspiration (n = 2), and lumbar drain placement (n = 2). Of the 34 patients who were readmitted, 30 (88.2%) required one or more of the following interventions for their pseudomeningoceles: wound exploration (n = 24), lumbar puncture(s) (n = 16), lumbar drain placement (n = 11), shunt placement or revision (n = 10), and percutaneous aspiration (n = 2).

In total, 30 (35.7%) cases of pseudomeningocele required surgical wound exploration. Of these, complete resolution of the pseudomeningocele (i.e., definitive treatment) occurred in 16 (53.3%) cases. In 14 cases, however, the patients required further treatment, primarily with shunting (9 cases) or lumbar drain placement (4 cases), and with 1 additional case requiring more extensive management with multiple interventions to achieve resolution. Of note, the latter case was the only case of the 14 that was

managed at the index visit. All others required readmission to successfully treat the pseudomeningocele.

Associations With Intervention

The results of the bivariate analyses are shown in Table 5, which models the probability that intervention of any kind was required. Of all the variables tested, only race ($p = 0.007$) and duraplasty at index operation ($p = 0.03$) were statistically significant. Caucasian children had 3.7 ($p = 0.16$) and 6.25 ($p = 0.008$) greater odds of requiring treatment than Hispanic patients and other/unspecified race patients, respectively. African American patients had 2.56 greater odds of requiring treatment than Caucasian patients, but this difference did not reach statistical significance ($p = 0.18$). Twenty-four of 50 pseudomeningoceles (48%) that required intervention occurred following index procedures during which a duraplasty had been performed, compared with 8 of 34 pseudomeningoceles (23.5%) that did not require intervention. Surgeries

TABLE 3. Tumor details

Variable	All Pseudomeningoceles (n = 84)	No Intervention (n = 34)	Intervention Required (n = 50)
Tumor present			
No	20 (23.8%)	9 (26.5%)	11 (22%)
Yes	64 (76.2%)	25 (73.5%)	39 (78%)
Tumor type			
Medulloblastoma	11 (17.2%)	4 (16%)	7 (18%)
Ependymoma	9 (14.1%)	3 (12%)	6 (15.4%)
Pilocytic astrocytoma or ganglioglioma	12 (18.8%)	4 (16%)	8 (20.5%)
Craniopharyngioma	5 (7.8%)	4 (16%)	1 (2.6%)
High-grade glioma	6 (9.4%)	2 (8%)	4 (10.3%)
ATRT	4 (6.3%)	1 (4%)	3 (7.7%)
Choroid plexus tumor	1 (1.6%)	1 (4%)	0 (0%)
Other: high grade	10 (15.6%)	3 (12%)	7 (18%)
Other: low grade	6 (9.4%)	3 (12%)	3 (7.7%)

ATRT = atypical teratoid rhabdoid tumor.

involving a duraplasty carried 3-fold odds ($p = 0.03$) of resulting in a pseudomeningocele that needed intervention, compared with surgeries in which no duraplasty was performed. The surgical site demonstrated a nearly significant association, with supratentorial surgery having a decreased risk (OR 0.39; $p = 0.06$) of leading to pseudomeningocele formation.

Discussion

CSF complications after elective cranial or spinal surgery in children—such as hydrocephalus, meningitis, and CSF leak—can cause significant morbidity, necessitating one or more interventions, prolonging hospitalization, prompting readmission, and adding to healthcare costs.^{1,20} While there is substantial literature that evaluates the risk of pseudomeningocele *development*, there is surprisingly little that deals with the risk of needing pseudomeningocele *treatment*. One cannot assume that variables associated with *development* would be the same for *treatment*. For neurosurgeons, we felt that the latter was the more clinically relevant question since most pseudomeningoceles will resolve on their own.

Study Results

The overall rate of developing a clinically relevant pseudomeningocele (i.e., one that was evident on physical examination) after an elective craniotomy or craniectomy was 5.1%. Of these cases, 64% followed supratentorial surgery and 36% followed infratentorial surgery. Tumor resection was the predominant reason for surgery (64/84; 76%) and the majority of these patients had high-grade pathology (40/64; 63%). Almost all index surgeries were craniotomies as opposed to craniectomies (77/84; 92%), and a duraplasty was performed in 38% (32/84) of cases.

One of the most serious consequences of a pseudomeningocele is a CSF-cutaneous fistula, which demands urgent intervention to mitigate the risk of bacterial contamination. Those pseudomeningoceles that developed a leak ($n = 18$) were more likely to be treated with a major operative intervention (i.e., shunt or wound exploration) than were those without a leak, for which “bedside” procedures (i.e., lumbar puncture, lumbar drain, or percutaneous aspiration) were favored. In our series, bacterial meningitis and wound infection developed after 6 and 5 index operations, respectively. These patients often under-

TABLE 4. Surgical postoperative events

Variable	Index Surgery (n = 58)	Readmission (n = 34)	Total (n = 84)*
Pseudomeningocele only	41 (70.7%)	20 (58.8%)	NA
Pseudomeningocele with:			
Bacterial meningitis	4 (6.9%)	2 (5.9%)	6 (7.1%)
Wound infection	0 (0%)	5 (14.7%)	5 (6%)
CSF leak	9 (15.5%)	9 (26.5%)	18 (21.4%)
Hydrocephalus	8 (13.8%)	10 (29.4%)	18 (21.4%)

NA = not applicable.

* Total postoperative events. Eight patients developed pseudomeningoceles during their index admission that persisted to readmission.

TABLE 5. Bivariate analyses (n = 84 pseudomeningoceles)

Variable	OR Estimate (95% CI)	p Value
Age in yrs (continuous)	1.02 (0.94–1.11)	0.56
Age in yrs (categorical)		0.90
<5	1.26 (0.47–3.39)	0.65
5–10	1.06 (0.34–3.31)	0.93
>10	Reference	—
Sex		
Female	0.79 (0.32–1.95)	0.60
Male	Reference	—
Race		0.007
African American	2.56 (0.64–10.2)	0.18
Hispanic	0.27 (0.05–1.66)	0.16
Other/unspecified	0.16 (0.04–0.62)	0.008
Caucasian	Reference	—
Insurance		
Government/none	0.95 (0.39–2.32)	0.91
Private	Reference	—
Existing shunt prior to index		
Yes	1.15 (0.26–5.16)	0.86
No	Reference	—
ETV prior to index		
Yes	1.02 (0.33–3.2)	0.97
No	Reference	—
Radiation prior to index		
Yes	0.37 (0.08–1.63)	0.19
No	Reference	—
Prior craniotomy		
Yes at same site	0.83 (0.34–2.05)	0.69
No or yes but at different site	Reference	—
Index: tumor resected		
Yes	1.28 (0.46–3.51)	0.64
No	Reference	—
Index: craniectomy		
Yes	1.78 (0.32–9.74)	0.51
No	Reference	—
Index: surgical site		
Supratentorial	0.39 (0.15–1.03)	0.06
Infratentorial	Reference	—
Index: duraplasty		
Yes	3 (1.14–7.89)	0.03
No	Reference	—

went reoperations for one or more indications in addition to several weeks of intravenous antibiotics, all resulting in extended lengths of stay and increased cost.

Of our 84 pseudomeningocele events, 50 (60%) required one or more interventions, either during the initial admission or upon readmission. The odds of receiving treatment were 13 times greater upon readmission than during the initial admission (88% vs 36%; $p < 0.0001$), a reflection of the reluctance by the treating surgeon to im-

mediately intervene in a case of an early postoperative pseudomeningocele or seroma with the hope that it will regress with time. Patients often underwent more than one intervention, with the overall rate being 1.76 procedures per pseudomeningocele. Most of the readmitted patients ($n = 30$; 88.2%) underwent some form of intervention during their initial hospital stay; 2 patients (2.4% of full sample) were readmitted for a third time, and both received further intervention for their pseudomeningoceles during their third admission.

There is no standardized approach to patients with a postoperative pseudomeningocele within our group of surgeons, but several generalizations can be made. While management is generally dictated by the physical examination and imaging findings, a conservative attitude is often initially taken with the hope that the pseudomeningocele will improve sufficiently or completely resolve within a reasonable time period. Minor procedures (i.e., lumbar punctures, lumbar drains, and aspirations) can be of some use, but major procedures (i.e., shunt placement or revision and wound exploration) are more commonly performed when the pseudomeningocele is large or tense, is associated with a leak or hydrocephalus, or is the primary reason for readmission. It should be noted that some lumbar punctures were done in conjunction with other procedures, such as wound explorations, as a means not only to assess intracranial pressure, but also to fenestrate the dura of the lumbar cistern.

Patient characteristics in the group requiring intervention for their pseudomeningoceles were largely similar to those who underwent observation. Both patient groups exhibited a moderate male predominance, and those undergoing intervention were slightly older on average (6.9 years vs 6.2 years). The variable “race” was statistically significant in the bivariate analysis for association with pseudomeningocele treatment ($p = 0.007$). While the only statistically significant comparison within this category was “other/unspecified” versus “Caucasian” (OR 0.16; $p < 0.01$), there was a notable trend of African American patients having a greater risk than Caucasian patients of undergoing treatment (OR 2.56; $p = 0.18$). An explanation for this finding is not readily available, but it is possible that a family’s preference could influence a surgeon’s decision whether to treat a pseudomeningocele.

Duraplasty was the only other variable found to be associated with treatment (OR 3; $p = 0.03$). Surgical site was almost statistically significant ($p = 0.06$), with an infratentorial pseudomeningocele having 2.56 greater odds of undergoing treatment. This finding makes clinical sense, and there is an interaction between surgical site and duraplasty, as the rate of duraplasty with infratentorial surgery was greater than that with supratentorial surgery (60% vs 26%). The importance of duraplasty emphasizes the need for meticulous technique in order to achieve as watertight of a closure as possible, especially with posterior fossa surgery. Various adjuncts have been investigated, from the type of dural graft or sealant used to whether the bone flap was replaced or the type of wound closure used (e.g., myofascial cuff technique), but in our opinion, there is *no substitute* for careful closure of the dura, done in conjunction with the various soft-tissue layers (muscle, fascia, ga-

lea, and skin).³ The same degree of attention given to the reason for the operation itself should be paid to wound closure; it should not be automatically relegated to a trainee without proper instructions or supervision.

Literature

There are no studies, to our knowledge, that are directly comparable to ours. A series of 105 posterior fossa tumor resections from 1982 to 1992 resulted in 5 patients (4.8%) developing a pseudomeningocele “requiring additional treatment.”⁷² Previous studies have examined the development of pseudomeningoceles in Chiari patients, but neither explored predictors of intervention.^{13,16} There were only 3 patients with Chiari malformation in our series and all underwent intervention. Previous studies have reported a significant association between craniectomies and pseudomeningocele development, but like the Chiari studies, these did not examine variables associated with intervention.^{4,5} In our series, 5 of 7 craniectomy patients underwent intervention for their pseudomeningoceles, but no significant difference was found between groups. The small number of craniectomies in our sample makes this factor difficult to evaluate.

A recent study by Roth et al.¹⁹ included patients with features similar to those of our cohort. Among 163 craniotomies, 74% were supratentorial, 74% were for tumor resections, 96% had a dural substitute, and 89% were considered to have a nonwatertight dural closure. The authors found that the only variable significantly associated with pseudomeningocele development or the need for CSF diversion was an infratentorial location.¹⁹

If we assume that the development of a postoperative CSF leak is always an indication for some form of intervention, then there is some comparable literature. In a consecutive series of 211 children who underwent 273 craniotomies for tumors, Lassen et al. reported a CSF leak rate of 7.3%; 1.8% of their cases developed an isolated pseudomeningocele requiring treatment.¹² Variables associated with a CSF-cutaneous fistula were age < 3 years ($p < 0.01$), female sex (OR 0.36; $p < 0.05$), infratentorial surgery (OR 2.67; $p < 0.05$), and untreated *preoperative* hydrocephalus (OR 5.16; $p < 0.001$). Repeat craniotomy, as in our study, was not predictive. The same group published another analysis several years later, now with 381 craniotomies for tumor and a multivariable analysis that identified younger age (OR 1.2; $p < 0.01$), infratentorial tumor location (OR 3; $p < 0.05$), and new-onset *postoperative* hydrocephalus (OR 5.6; $p < 0.01$) as being significantly associated with postoperative CSF leaks.⁸

Study Limitations

Our study had a number of notable limitations. First and foremost, our study was limited to patients who underwent inpatient treatment of their pseudomeningocele. This was a limitation because all postoperative visits in our practice are conducted at facilities apart from where the elective craniotomy took place, each with its own electronic medical records system. Consequently, any patient with a postoperatively detected pseudomeningocele that did *not* require readmission would not have been captured in this study. We estimate this group of patients with small

and self-limiting pseudomeningoceles to be few in number. The effect of not having an “outpatient surveillance system” as part of this study is a lower overall incidence (5.1%, 84/1648) but a higher intervention (60%, 50/84) rate compared with the true values.

The low incidence (5%) of our outcome of interest—clinically significant pseudomeningocele—limited us to bivariate analysis. Results for this retrospective observational study should be considered exploratory and used in a larger study for validation purposes and in order to construct multivariable models to adjust for confounding. Some variables were not explicitly captured in our review, such as the presence of preoperative or postoperative hydrocephalus. However, we did record whether the patient had an existing shunt or had undergone an ETV prior to their elective craniotomy as well as the need for a new shunt or revision of an existing one, which serves as a surrogate for persistent or new-onset altered CSF dynamics postcraniotomy. Raised intracranial pressure, most commonly due to new, persistent, or unrecognized preoperative hydrocephalus, would undoubtedly be a risk factor for pseudomeningocele development and treatment. Other variables that were lacking were the type of dural graft and whether a dural sealant was used. We did not feel that graft type would have an impact on pseudomeningocele development and sealants are used infrequently. Likewise, the presence of temporary CSF diverting devices, such as external ventricular or lumbar drains, was also not recorded, but these too are very rarely used in our elective practice.

As stated previously, there was no standardization for how or when to intervene, and our reasons for intervention may differ from those of other centers, although common indications were CSF leak, overt or suspected postoperative hydrocephalus, and impending wound breakdown. For example, as many of our patients had tumors, having a sizable pseudomeningocele typically prohibits the start of radiation or chemotherapy. Furthermore, we would prefer to repair a pseudomeningocele prior to the onset of any adjuvant therapy. For these two reasons, some of our patients received treatment for pseudomeningoceles that could possibly have resolved with enough time. Additionally, a seroma can masquerade as a pseudomeningocele and would be difficult to distinguish without fluid analysis (i.e., beta-2 transferrin). This is another reason why interventions for early postoperative fluid collections were less common than those for fluid collections that persisted on readmission. Nonetheless, our assumption that a “clinically significant” fluid collection solely represented a pseudomeningocele is an additional study limitation.

Conclusions

While the literature on cranial pseudomeningoceles is robust, to our knowledge, no previous pediatric study to date has examined factors associated with intervention. Of the variables analyzed in our study, race and use of a dural patch graft were found to have a statistically significant association with intervention for a pseudomeningocele.

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Disclosures

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

Author Contributions

Conception and design: Klimo. Acquisition of data: Norrdahl, Dave, Vaughn. Analysis and interpretation of data: Norrdahl, Jones. Drafting the article: Klimo, Norrdahl. Critically revising the article: Klimo, Norrdahl, Jones, Hersh. Reviewed submitted version of manuscript: Klimo, Hersh. Approved the final version of the manuscript on behalf of all authors: Klimo. Statistical analysis: Jones.

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