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Microsurgical treatment of sacral perineural (Tarlov) cysts: case series and review of the literature

***John F. Burke, MD, PhD, Jayesh P. Thawani, MD, Ian Berger, BS, Nikhil R. Nayak, MD, James H. Stephen, MD, Tunde Farkas, MD, Hovik John Aschyan, BA, John Pierce, MS, Suhail Kanchwala, MD, Donlin M. Long, MD, PhD, and William C. Welch, MD**

University of Pennsylvania, Pennsylvania Hospital, Philadelphia, Pennsylvania

OBJECTIVE Tarlov cysts (TCs) occur most commonly on extradural components of the sacral and coccygeal nerve roots. These lesions are often found incidentally, with an estimated prevalence of 4%–9%. Given the low estimated rates of symptomatic TC and the fact that symptoms can overlap with other common causes of low-back pain, optimal management of this entity is a matter of ongoing debate. Here, the authors investigate the effects of surgical intervention on symptomatic TCs and aim to solidify the surgical criteria for this disease process.

METHODS The authors performed a retrospective review of data from consecutive patients who were surgically treated for symptomatic TCs from September 2011 to March 2013. Clinical evaluations and results from surveying pain and overall health were used. Univariate statistical analyses were performed.

RESULTS Twenty-three adults (4 males, 19 females) who had been symptomatic for a mean of 47.4 months were treated with laminectomy, microsurgical exposure and/or imbrication, and paraspinous muscle flap closure. Eighteen patients (78.3%) had undergone prior interventions without sustained improvement. Thirteen patients (56.5%) underwent lumbar drainage for an average of 8.7 days following surgery. The mean follow-up was 14.4 months. Univariate analyses demonstrated that an advanced age ($p = 0.045$), the number of noted perineural cysts on preoperative imaging ($p = 0.02$), and the duration of preoperative symptoms ($p = 0.03$) were associated with a poor postoperative outcome. Although 47.8% of the patients were able to return to normal activities, 93.8% of those surveyed reported that they would undergo the operation again if given the choice.

CONCLUSIONS This is one of the largest published studies on patients with TCs treated microsurgically. The data suggest that patients with symptomatic TCs may benefit from open microsurgical treatment. Although outcomes seem related to patient age, duration of symptoms, and extent of disease demonstrated on imaging, further study is warranted and underway.

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KEY WORDS Tarlov cyst; perineural cyst; lumbar

Tarlov cysts (TCs) are perineural cysts that were first described in 1938 by Dr. I. M. Tarlov.[11,21] These cysts are common incidental findings on MRI of the spine, with an estimated prevalence between 4.6% and 9% of the general adult population.[1] Symptomatic TCs are much more rare, however. They commonly occur in the sacral spine, arising near the dorsal root ganglion between layers of perineurium and endoneurium.[5] Given the challenges in treating this disorder and the few series describing therapy, asymptomatic TCs are justifiably not treated.

Symptomatic patients typically present with low-back pain; radicular pain; bowel, bladder, and/or sexual dysfunction; leg weakness; and sensory dysesthesias.[11] Described treatment options include antiinflammatory medications, percutaneous cyst drainage, external cerebrospinal (CSF) drainage, percutaneous fibrin glue injection, insertion of cyst-subarachnoid shunts, lumboperitoneal shunts, cyst-peritoneal shunts, as well as microsurgical options (resection of the cyst neck or wall, cyst imbrication, or cauterization).[7]

ABBREVIATIONS CSF = cerebrospinal fluid; TC = Tarlov cyst.

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* Drs. Burke and Thawani are equal contributors to this work.

TABLE 1. Literature review of studies on TCs

Authors & Year	No. of Patients	Patients Improved After Treatment/Total	Notes
Patel et al., 1997*	4	4/4	CT-guided aspiration & fibrin glue; reported aseptic meningitis as a complication w/ fibrin injection
Bartels & van Overbeeke, 1997	2	2/2	LP shunt used to divert CSF; 1 reported complication: displacement of catheter
Kunz et al., 1999	16	3/8	50% of patients randomized to surgery; in favor of surgery
Mummaneni et al., 2000	8	4/8	Patients w/ Sx that worsened w/ Valsalva &/or postural changes more likely to improve
Voyadiz et al., 2001	10	7/10	Recs: removal of symptomatic cysts >1.5 cm
Caspar et al., 2003	15	13/15	Recs: resection of all symptomatic cysts
Lee et al., 2004*	2	2/2	CT-guided aspiration of cyst
Tanaka et al., 2006	12	10/12	Used CT myelography to demonstrate delayed filling of cyst
Guo et al., 2007	11	9/11	Reported 2 surgical complications: 1 worsening of bladder function & 1 CSF leak
Zhang et al., 2007*	31	21/30	Percutaneous drainage cysts & fibrin glue; reported 2 cases of aseptic meningitis
Neulen et al., 2011	13	8/13	Found correlation btwn cyst size & clinical outcome; reported on CSF leak as a complication
Xu et al., 2012	13	11/13	Used 2 different op techniques in case series; reported a CSF leak complication
Cantore et al., 2013	19	16/19	CT myelography performed in 3 patients; no complications reported
Mezzadri et al., 2014	6	5/6	Endoscope-assisted approach to repair cyst

LP = lumboperitoneal; Recs = recommends; Sx = symptoms.
* Studies using a nonsurgical treatment approach.

With respect to microsurgical treatment, many previous studies have reported successful relief of symptoms in up to 80%–90% of patients (Table 1).[3,9,11] However, these results have been derived from relatively small case series given the relative rarity of TCs. From these studies, an anecdotal set of surgical indications have emerged to include 1) a cyst diagnosed by imaging; 2) symptoms consistent with a cyst, including radicular pain, lumbosacral pain, and/or bowel or bladder dysfunction; 3) a cyst size greater than 1–1.5 cm; and 4) no contraindications for surgery. Other suggested factors are delayed filling of the cyst on CT myelography, a single cyst, and documented unresponsiveness to conservative management. However, mostly because of the small size of previous studies, it is unclear which of these potential indications, if any, predict a response to treatment.

Here, we collected data on the largest series of patients with microsurgically treated TCs that has been reported in the literature in the last 50 years and investigated the efficacy of this treatment. We specifically performed an open sacral laminectomy to open and imbricate the cyst with the aid of autologous muscle, paraspinal muscle flap, and placement of a lumbar drain. We describe a series of 23 patients who underwent this procedure, report their surgical outcomes, and detail the clinical factors at presentation that predict whether surgery for TC resulted in an improvement of symptoms.

Methods

Patients

Patients surgically treated for symptomatic TCs over an 18-month period (September 2011 to March 2013) were retrospectively identified in our database, and data were collected from their charts in compliance with the institutional review board at our institution.

Diagnosis and Surgical Intervention

All patients underwent imaging studies demonstrating TC. Magnetic resonance imaging of the lumbar spine delineated 1 or many cystic masses consistent with a diagnosis of TC (Fig. 1). Computed tomography scanning was also performed to reveal any possible bony erosion adjacent to the TC.

Given symptoms refractory to medication and/or prior intervention as well as radiological evidence of TC, pa-

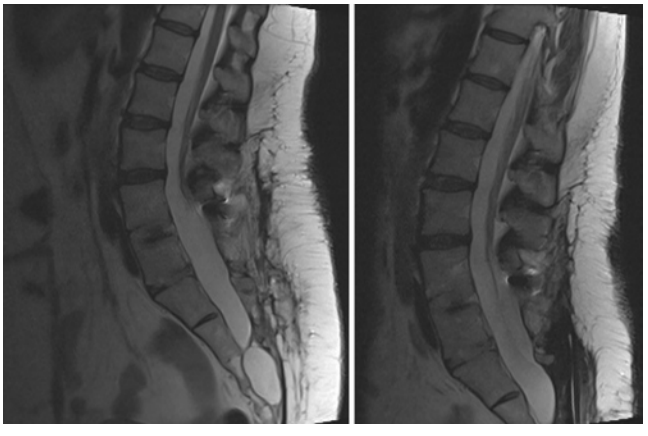

FIG. 1. Sagittal T2-weighted MR images demonstrating a sacral perineural cyst. The cyst has eroded into the dorsal vertebral bodies of S-2 and S-3, resulting in thinning of the sacral laminae.

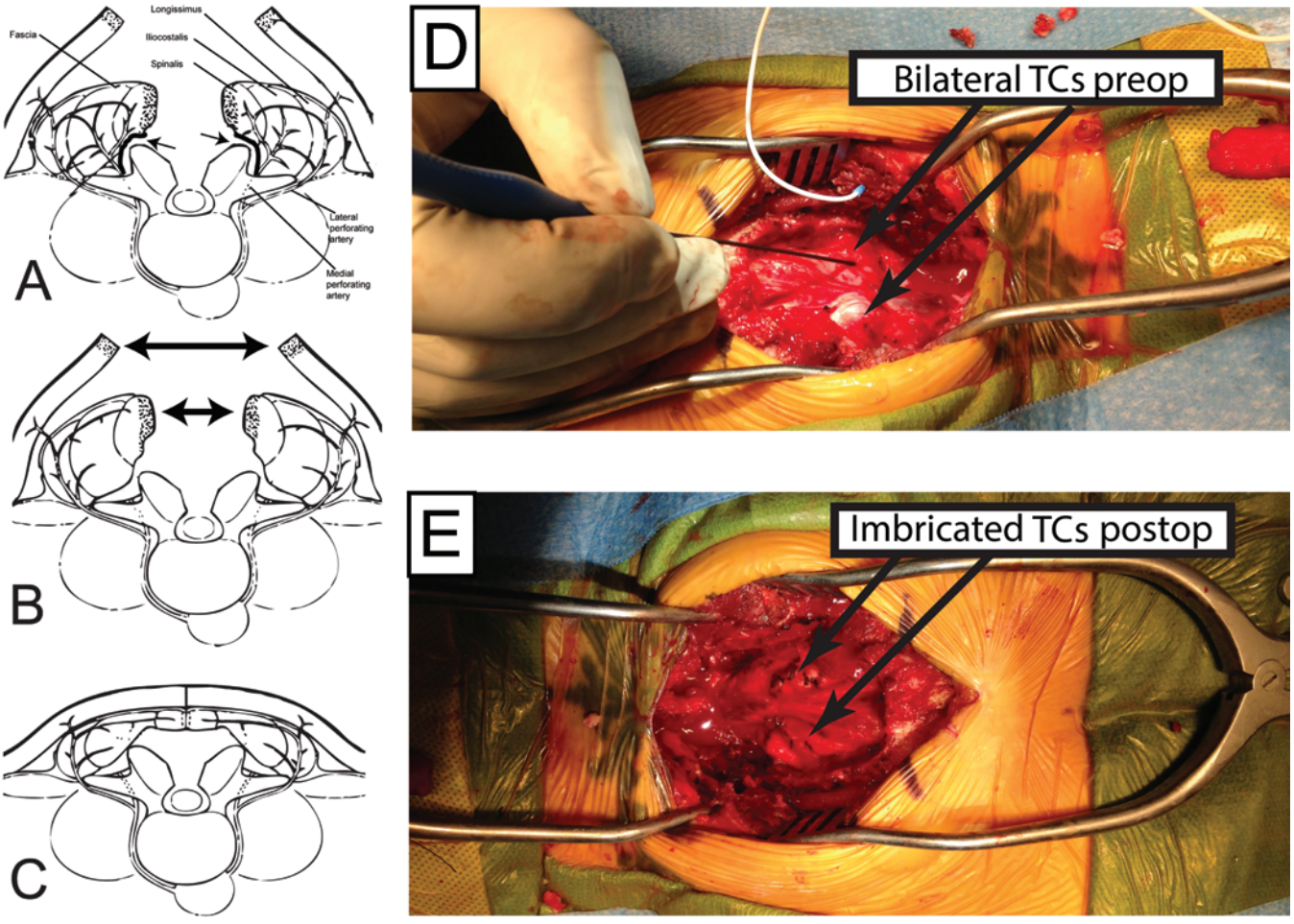

FIG. 2. Schematics of the steps of surgery: The cyst is first excised **(A)**, and then the walls of the skin and muscle are closed over the cyst remnant. **(B and C)**. In the pictured case, there were bilateral TCs (*arrows*, **D**). The TCs have been imbricated flush with the dura **(E)**. A durotomy was not needed to obliterate the TCs, and thus a lumbar drain was not used. Panels A–C copyright Jayesh P. Thawani. Published with permission. Figure is available in color online only.

tients were offered the option of surgery. Other causes of pain were ruled out before patients were presented with a surgical option. All patients elected to undergo microsurgical treatment performed by the study's senior author.

Surgery entails a lumbosacral incision, subperiosteal dissection, and an osteoplastic laminotomy that is performed over the level of the cyst. Incision and exposure are conducted using anatomical landmarks. Following incision into the cyst wall, a 4-0 Nurolon suture is placed lateral to the opening on either side to bring the dural edges inward and under the closure. Autologous muscle patches can be used to augment the dural closure and decrease the overall volume of the cyst. The resulting defect requires watertight tension-free closure. Sharp lateral dissection is used to free the paraspinous musculature. If necessary, the fascial insertion can be detached medially along the posterior iliac spine, taking care not to injure the superior cluneal nerves, the dorsal sacroiliac ligaments, or the iliolumbar ligament. The midline incision is closed in several layers, including deep and more superficial subcutaneous tissues as well the skin, by using a simple, running absorbable suture reinforced with nonabsorbable vertical mattress sutures. Patients with cysts larger than 2.5 cm in the largest dimension and/or a history of prior interventions have lumbar drains placed at the time of surgery. The lumbar drain is used in the event of large cysts, when a significant amount of dura mater is excised during excision of the cyst wall. Methods of the surgical approach are visually summarized in Fig. 2.

Our colleague in plastic and reconstructive surgery (S.K.) assisted with paraspinous muscle flap advancement and wound closure in several of our patients (11). Lumbosacral wounds may use gluteal, paraspinous, or latissimus muscle flaps to augment closure. For TC surgery, paraspinous flaps are most useful to aid in closure, which was the approach taken in this study. In patients with TCs, who have often already undergone procedures, the myofascial planes and vascular pedicles may not be well defined. Relaxing incisions can be made just above the muscular fascia to release the paraspinous muscle from the ilium. We used simple running sutures to approximate the paraspinous muscle fascia as well as pulley-type sutures to lower the flap as close to the sacral defect as possible.

Surgical specimens were obtained from each patient

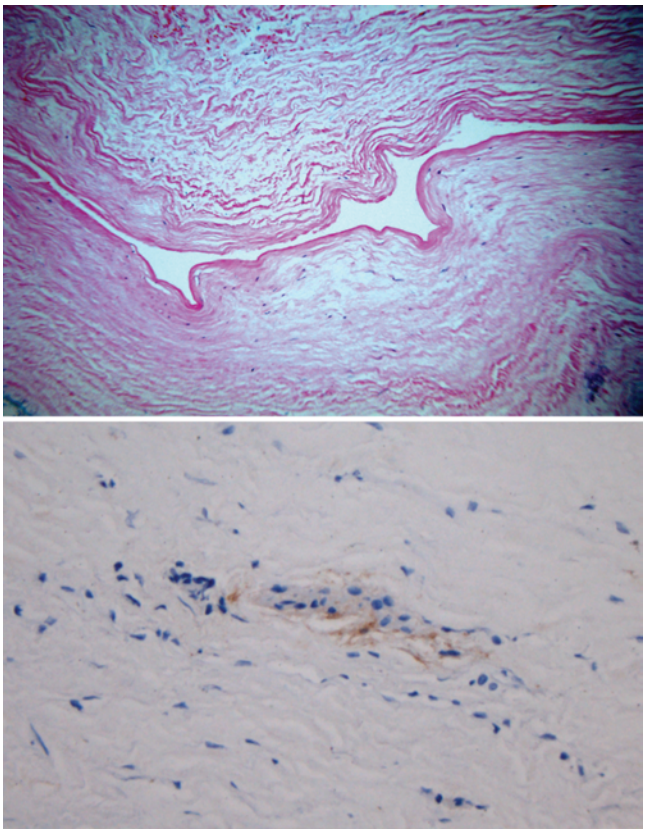

FIG. 3. Histopathological slides from surgery. **Upper:** Hyalinized paucicellular connective tissue. **Lower:** S100 staining demonstrates neural elements within the cyst wall. H & E (upper), original magnification ×100. Figure is available in color online only.

and analyzed with H & E and S100 staining, which demonstrated hyalinized paucicellular connective tissue and neural elements within the cyst wall, respectively (Fig. 3).

Postoperative Care and Follow-Up

Patients remained in the intensive care unit after surgery. If a lumbar drain was placed during the operation, it was clamped at various points, and patients were evaluated in terms of symptoms. The drain was then removed while the patient was still in the hospital. There were no complications related to lumbar drainage. Patients typically went home with suprafascial Jackson-Pratt drains placed at the time of closure. All patients were seen in clinic 4 weeks following discharge. A thorough neurological examination was performed to assess the degree of improvement. Pain levels were subjectively evaluated based on history.

Statistical Analysis

We determined whether the surgical treatment of symptomatic TCs was successful in improving patient outcomes by using a univariate approach. This approach correlated the difference in pain ratings between the pre- and postoperative periods (10-point scale) with a number of features of the patient population (for example, age, number of symptomatic months). In our univariate approach, we did not correct for multiple comparisons, as we thought that traditional methods of correction would be too stringent (Bonferroni correction). Statistical significance was determined based on a $p \leq 0.05$.

The univariate statistical analyses were split into 2 different parts. In the first, we simply described the patient population and listed significant associations to test whether certain features of the operation, such as the use of a lumbar drain, covaried with either surgical infection or the need for reoperation. In the second set of statistical analyses, we investigated outcomes from the point of view of the patients. Specifically, a detailed survey of pain was administered by phone or mail following immediate (4 weeks) and subsequent follow-up (median 14.4 months). Sixteen patients completed the survey; the remaining patients refused to take part in the survey. This survey included a quantification of patient pain on a 10-point scale, where 1 represented no pain and 10 represented the worst pain imaginable. In addition, the patients were asked to rate their overall health on a similar 10-point scale, where 1 represented extremely poor health and 10 represented perfect health. Wilcoxon rank-sum statistical tests and Spearman correlations were performed using Stata version 12.1 (StataCorp) to determine the effect of patient factors on surveyed outcomes.

Results

Twenty-three adults (19 female) were identified. Their symptoms and imaging studies were reviewed and consistent with TC (Table 2). Preoperative symptoms varied: sciatica, pelvic and/or perineal pain, positional headache, orthostasis, urinary and/or bowel dysfunction, perineal numbness, dyspareunia, and low-back pain refractory to nonsteroidal antiinflammatory medications and other medical treatments. Patients had a mean age of 49.3 years at presentation and had been symptomatic for a mean of 47.4 months (Table 3). Eighteen patients (78.3%) had undergone prior interventions without sustained improvement. Patients had a mean of 1.3 cysts on imaging, and the mean largest dimension of each cyst was 3.2 cm in diameter. All patients had cysts between the L-5 and S-4 vertebrae, with many having multiple levels affected. All patients underwent microsurgical drainage of the cyst(s) followed by repair of the cyst wall. On average, patients spent 5.96 days (SD 4.6 days) in the hospital for their surgery. In addition, lumbar drainage was used in 13 patients (56.5%) following surgery, and the drain remained in place for a mean of 8.7 days (SD 3.6 days). Other characteristics relating to TC and surgical outcomes are summarized in Fig. 4.

All patients had immediate follow-up visits (4 weeks) after surgery. The average time for the subsequent follow-up visit was 14.4 months (SD 9.5 months). Reoperation was performed in 5 patients, one for infection. This patient had previously undergone an osteoplastic laminotomy. On reoperation, the patient was found to have purulent material underlying the replaced bone. The bone was removed, and following copious irrigation, the wound was reclosed, and the patient was placed on long-term intravenous antibiotics and recovered extremely well. The other 4 patients had reoperations for persistent symptoms of CSF hypotension (1 patient) and/or leakage (3 patients). One of these

TABLE 2. Summary of patient and cyst features

Variable	No. (%)
Male	4 (17.4)
Female	19 (82.6)
Presenting sign/symptom	
Low-back pain	20 (87.0)
Sciatica	20 (87.0)
Pelvic/perineal pain	15 (65.2)
Orthostasis	14 (60.9)
Urinary dysfunction	14 (60.9)
Perineal numbness	11 (47.8)
Headache	8 (34.8)
Bowel dysfunction	8 (34.8)
Pain w/ intercourse	2 (8.7)
Sexual dysfunction	1 (4.3)
Medical history	
CVD	1 (4.3)
Root block/epidural patch	1 (4.3)
Laminectomy over cyst	2 (8.7)
ESI	7 (30.4)
Aspiration of cyst	3 (13.0)
Fibrin injection	5 (21.7)
Improvement w/ past procedures	9 (39.1)
Cyst features	
Bony erosion	14 (60.9)
Bilateral cysts	15 (65.2)
L-5 affected	1 (4.3)
S-1 affected	17 (73.9)
S-2 affected	18 (78.2)
S-3 affected	13 (56.5)
S-4 affected	5 (21.7)

CVD = collagen vascular disease; ESI = epidural steroid injection.

TABLE 3. Mean, median, and range values for patient and cyst features

Variable	Mean	Range	SD	Median
Age in yrs	49.3	26–64	11.3	53
No. of symptomatic mos	47.4	4–192	48.4	24
No. of cysts	1.3	1–4	0.765	—
Largest dimension in cm	3.2	1–6.3	1.68	—
Total no. of levels affected	2.35	1–4	1.11	2
No. of days in hospital	6.0	2–24	4.6	5
No. of days w/ lumbar drain	8.7	3–15	3.6	9

— = not applicable.

patients underwent 3 reoperations for persistent CSF leakage, and 1 year later almost all symptoms were gone. Another patient underwent reoperation to explore and close the CSF leak and slowly improved afterwards. The third patient developed a large pseudomeningocele; this patient improved but still had symptoms despite undergoing reoperation to reduce the pseudomeningocele. The fourth patient, a complicated case involving 3 operations for persistent CSF leak, pursued referral for a second opinion and shunt placement.

After surgery, 47.8% of patients reported returning to normal activities. There was no statistically significant relationship between the use of a dural sealant, the use of a lumbar drain, or the involvement of a plastic surgeon and the need for reoperation. Moreover, the rate of infection (1 case) was not significantly associated with the number of days of lumbar drainage, involvement of a plastic surgeon, use of a dural sealant, number of days in the hospital, or presence of bony erosion on imaging.

We also examined operative improvement from the patients' perspective. Among the 16 patients who agreed to participate in a detailed survey quantifying the degree of change in the subjective level of pain according to a 10-point scale, pain at the time of the follow-up was rated as an average of 2.8 points (SD 2.4 points), representing an estimated improvement of 6.3 points (SD 3.13 points) from the preoperative to the postoperative period. The patients also rated their overall health from excellent (score of 10) to very poor (score of 1), and an average score of 7.1 was reported at the follow-up (SD 3.13)

We also investigated whether there were any variables that predicted a successful surgical outcome. Of the patient variables listed in Table 2, we determined which variables, if any, predicted the degree of improvement (as reported by the patients via telephone and written survey). We found a significant difference in age distribution between patients who noted improvement following surgery and those who did not (median age 35 vs 57.7 years, respectively, $p = 0.045$), with benefit demonstrated in younger patients. In addition, the number of symptomatic months was inversely associated with an improvement of symptoms (median 23.3 vs 72 months, $p = 0.03$) and also correlated with a decrease in overall pain scores (Spearman's rho = 0.51, $p = 0.04$). In other words, the sooner a patient underwent operation after developing symptoms, the greater the likelihood of improvement. Consistent with this, patients reporting symptoms of shorter duration also experienced a decrease in pain scores following surgery ($p = 0.04$). Finally, the number of cysts noted on initial imaging correlated with a decrease in overall pain scores reported after surgery (Spearman's rho = 0.56, $p = 0.02$). Interestingly, pain scores and outcomes were not significantly associated with lumbar drainage, involvement of a plastic surgeon, use of a dural sealant, number of days spent in the intensive care unit or hospital, or infection. Cyst size and the presence of bony imaging similarly did not seem to correlate with outcome.

One question is, what factors predict a nonresponse to surgery? In other words, we showed that an older age and a greater number of symptomatic months correlate with a favorable outcome (decrease in pain scores). Ideally, however, we would also like to find factors that predict a nonresponse to surgery. In our data, we were unable to find a factor that, among patients who did not improve, predicted a nonresponse. This is probably because the majority of patients in our database displayed a positive response to

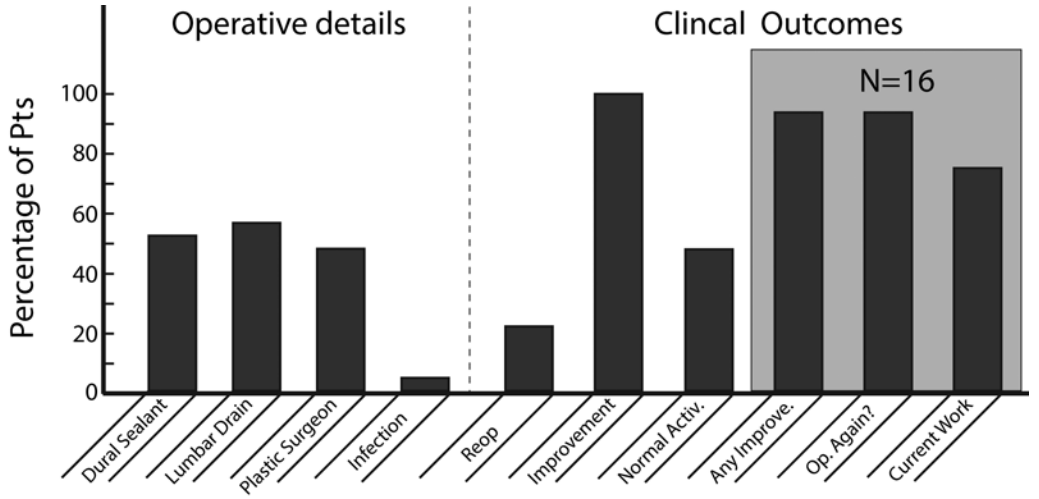

FIG. 4. Bar graph of surgical characteristics and clinical outcomes (23 patients). Categories for the latter were further assessed using a detailed questionnaire, which 16 patients agreed to complete *(gray background)*. Reop = reoperation performed; Improvement = patient's symptoms improved; Normal Activ. = patients resumed normal activities; Any Improve. = patient notes any improvement on questionnaire; Op. Again? = patient reports that he or she would undergo operation again if given the choice; Current Work = patient is currently working.

the surgery. Thus, we do not have the statistical power to find such a correlation.

Discussion

Tarlov cysts are common incidental findings on MRI of the lumbosacral spine, as are fibrolipomas and hemangiomas.[15] It is estimated that only about 1% of these cysts become symptomatic.[18] Proposed mechanisms relate to cystic dilation and nerve root irritation and/or leakage of CSF causing relative hypotension.[13]

The etiology of these cysts is largely unknown. Some groups have suggested that they may be the result of an inflammatory process caused by trauma,[22] while others have suggested that their origin is due to genetic predisposition (as may be the case in patients with collagen disorders or collagen vascular diseases).[16] Although the mechanism by which the cysts develop is disputed, a leading theory has to do with pulsatile and hydrostatic forces of CSF along with a ball-valve effect (unobstructed inflow of CSF with restricted outflow) allowing for continuous dilation of the cyst.[1,11]

Though TCs are often assessed using MRI, the diagnosis must be confirmed using histopathology. These lesions can be confused with other clinical entities, including tumors, lipomas, or arachnoid cysts.[8] By definition, a TC requires the presence of spinal nerve root fibers in the wall or within the cavity of the cyst.[14] Figure 3 demonstrates the histopathology typical of these lesions, as was seen in one of our patients.

Tarlov cysts are asymptomatic in the majority of patients.[15] In symptomatic cases, however, patients experience nonspecific symptoms similar to those seen in other lumbosacral pathologies, commonly experiencing pelvic and/or perineal pain; sensory dysesthesias; low-back pain; radicular pain; sciatic pain; and bowel, bladder, or sexual dysfunction. Patients can also experience tinnitus, orthostasis, and positional headaches—these symptoms are thought to relate to relative intracranial hypotension.[1,19] Our anecdotal experience in several cases has demonstrated notable thinning of the sacral lamina and what appeared to be "weeping" of CSF from the lamina. This was noted in regions not disturbed by cautery or retraction.

From an epidemiological standpoint, our cohort consisted of 82.6% of female patients. This finding is consistent with many previous case series reporting a female/male ratio of 1.78.[20]

Here, we found that the surgical treatment of symptomatic TCs resulted in an improvement in pain scores (net change of 6.3 points on a 10-point scale). These positive results were predicted by a number of presurgical clinical factors, including a younger patient age, fewer cysts, and a shorter symptom duration at the time of presentation. Our data suggest that a simple set of criteria can be used in the decision to operate on a TC. Namely, younger patients with simple cysts (single, unilateral) should be considered for microsurgical treatment within 6 months of sustained symptoms that are refractory to medication.

Combined with other findings in the field (Table 1) that have shown a positive correlation between cyst size and clinical outcome, the following indications for surgery in a clearly symptomatic patient (ensuring that there are no other potential causes of the symptoms) are suggested: 1) 1 or multiple cyst(s) demonstrated on MRI, 2) symptoms consistent with cyst location, 3) symptoms developed within the last 6 months, and 4) single, unilateral cysts larger than 1 cm. Our results suggest that young patients may fare better following microsurgical treatment of TCs. This finding is perhaps attributable to a relative lower capacity to heal and form scar tissue with advancing age. An open question relates to whether surgical candidates should demonstrate a cyst with delayed filling on CT myelography. However, we did not routinely use myelography in the preoperative period. Nonetheless, we report outcomes consistent with those in other studies that have examined myelography

demonstrating delayed filling.[14] Our suggested criteria represent a first step at systematizing the decision to microsurgically treat TCs; they should be verified with future prospective studies.

How do these aforementioned factors play in the context of other studies on surgery for TCs? The literature on the treatment of symptomatic TCs is rather sparse, and there does not seem to be consensus on an appropriate mode of treatment (Table 1). A study done by Voyadzis et al.[22] recommends a surgical approach if the cyst size is ≥ 1.5 cm and associated with radicular pain. Retrospective series have demonstrated a beneficial outcome with a microsurgical approach. In one study by Caspar et al.,[4] 15 patients with symptomatic TCs were treated with microsurgical removal along with duraplasty or plication of the cyst wall. Postoperatively, 13 of the 15 patients no longer had radicular pain. These authors also found that the 2 patients with motor deficits and 6 patients with bladder dysfunction had completely resolved symptoms. In another study by Mezzadri et al.,[12] 6 patients with symptomatic TCs were treated with endoscope-assisted obliteration of the communication between the cysts and the spinal subarachnoid space. During the follow-up 25 months later, 5 of the 6 cases had excellent to good outcomes, whereas 1 patient had a poor outcome.

Though the literature on the surgical management of TCs is limited, the studies discussed here demonstrate positive outcomes for symptomatic cysts managed with surgery. We augment these studies by presenting defined criteria that can be used to guide the decision to operatively treat TCs.

Limitations of our study include its small sample size and nonblinded assessments. Outcome data were limited, and not all patients could be surveyed.

We also remark the fact that there was a high reoperation rate in our study (5 patients [22%]). One reoperation was for infection, and 4 were for CSF hypotension and/or leakage. Involvement of the sacral nerve roots and cyst enlargement within the sacral cistern can be associated with urinary incontinence. One preoperative test used to diagnose this issue is the urodynamic study, which offers a useful way to measure the degree of improvement with the operation. We did not perform this test in the current series; however, we encourage all surgeons treating these patients to make use of urodynamic studies if such tests are easily available in the preoperative period.

Conclusions

Although TCs were described more than 75 years ago, there is still no consensus on their origin or treatment. Most are benign, but about 1% are symptomatic and can be managed effectively with surgery. A few studies have been conducted on the surgical management of TCs, and much of this literature shows positive outcomes (Table 1). Here, we described a cohort of patients with symptomatic TCs that was successfully treated with surgery. Age, extent of disease, and duration of symptoms were related to outcome. The overall long-term outcome for this patient group was positive.

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References

1. Acosta FL Jr, Quinones-Hinojosa A, Schmidt MH, Weinstein PR: Diagnosis and management of sacral Tarlov cysts. Case report and review of the literature. **Neurosurg Focus 15(2):**E15, 2003
2. Bartels RH, van Overbeeke JJ: Lumbar cerebrospinal fluid drainage for symptomatic sacral nerve root cysts: an adjuvant diagnostic procedure and/or alternative treatment? Technical case report. **Neurosurgery 40:**861–865, 1997
3. Cantore G, Bistazzoni S, Esposito V, Tola S, Lenzi J, Passacantilli E, et al: Sacral Tarlov cyst: surgical treatment by clipping. **World Neurosurg 79:**381–389, 2013
4. Caspar W, Papavero L, Nabhan A, Loew C, Ahlhelm F: Microsurgical excision of symptomatic sacral perineurial cysts: a study of 15 cases. **Surg Neurol 59:**101–106, 2003
5. Chaiyabud P, Suwanpratheep K: Symptomatic Tarlov cyst: report and review. **J Med Assoc Thai 89:**1047–1050, 2006
6. Guo D, Shu K, Chen R, Ke C, Zhu Y, Lei T: Microsurgical treatment of symptomatic sacral perineurial cysts. **Neurosurgery 60:**1059–1066, 2007
7. Ishii K, Yuzurihara M, Asamoto S, Doi H, Kubota M: A huge presacral Tarlov cyst. Case report. **J Neurosurg Spine 7:**259–263, 2007
8. Joshi VP, Zanwar A, Karande A, Agrawal A: Cervical perineural cyst masquerading as a cervical spinal tumor. **Asian Spine J 8:**202–205, 2014
9. Kunz U, Mauer UM, Waldbaur H: Lumbosacral extradural arachnoid cysts: diagnostic and indication for surgery. **Eur Spine J 8:**218–222, 1999
10. Lee JY, Impekoven P, Stenzel W, Löhr M, Ernestus RI, Klug N: CT-guided percutaneous aspiration of Tarlov cyst as a useful diagnostic procedure prior to operative intervention. **Acta Neurochir (Wien) 146:**667–670, 2004
11. Lucantoni C, Than KD, Wang AC, Valdivia-Valdivia JM, Maher CO, La Marca F, et al: Tarlov cysts: a controversial lesion of the sacral spine. **Neurosurg Focus 31(6):**E14, 2011
12. Mezzadri J, Abbati SG, Jalon P: Tarlov cysts: endoscope-assisted obliteration of the communication with the spinal subarachnoid space. **J Neurol Surg A Cent Eur Neurosurg 75:**462–466, 2014
13. Mummaneni PV, Pitts LH, McCormack BM, Corroo JM, Weinstein PR: Microsurgical treatment of symptomatic sacral Tarlov cysts. **Neurosurgery 47:**74–79, 2000
14. Neulen A, Kantelhardt SR, Pilgram-Pastor SM, Metz I, Rohde V, Giese A: Microsurgical fenestration of perineural cysts to the thecal sac at the level of the distal dural sleeve. **Acta Neurochir (Wien) 153:**1427–1434, 2011
15. Park HJ, Jeon YH, Rho MH, Lee EJ, Park NH, Park SI, et al: Incidental findings of the lumbar spine at MRI during herniated intervertebral disk disease evaluation. **AJR Am J Roentgenol 196:**1151–1155, 2011
16. Park HJ, Kim IS, Lee SW, Son BC: Two cases of symptomatic perineural cysts (Tarlov cysts) in one family: a case report. **J Korean Neurosurg Soc 44:**174–177, 2008
17. Patel MR, Louie W, Rachlin J: Percutaneous fibrin glue therapy of meningeal cysts of the sacral spine. **AJR Am J Roentgenol 168:**367–370, 1997
18. Paulsen RD, Call GA, Murtagh FR: Prevalence and percutaneous drainage of cysts of the sacral nerve root sheath (Tarlov cysts). **AJNR Am J Neuroradiol 15:**293–299, 1994
19. Seo DH, Yoon KW, Lee SK, Kim YJ: Microsurgical excision of symptomatic sacral perineurial cyst with sacral recapping laminectomy: a case report in technical aspects. **J Korean Neurosurg Soc 55:**110–113, 2014

20. Tanaka M, Nakahara S, Ito Y, Nakanishi K, Sugimoto Y, Ikuma H, et al: Surgical results of sacral perineural (Tarlov) cysts. **Acta Med Okayama 60:**65–70, 2006
21. Tarlov IM: Perineurial cysts of the spinal nerve roots. **Arch Neurol Psychiatry 40:**1067–1074, 1938
22. Voyadzis JM, Bhargava P, Henderson FC: Tarlov cysts: a study of 10 cases with review of the literature. **J Neurosurg 95 (1 Suppl):**25–32, 2001
23. Xu J, Sun Y, Huang X, Luan W: Management of symptomatic sacral perineural cysts. **PLoS One 7:**e39958, 2012
24. Zhang T, Li Z, Gong W, Sun B, Liu S, Zhang K, et al: Percutaneous fibrin glue therapy for meningeal cysts of the sacral spine with or without aspiration of the cerebrospinal fluid. **J Neurosurg Spine 7:**145–150, 2007

Disclosures

Dr. Welch holds stock in Transcendental Spine and is a consultant for ISTO Technologies Inc.

Author Contributions

Conception and design: Welch, Thawani, Nayak, Stephen. Acquisition of data: Welch, Thawani, Nayak, Stephen, Farkas, Aschyan, Pierce, Kanchwala. Analysis and interpretation of data: Welch, Burke, Thawani, Berger, Nayak, Stephen, Farkas, Kanchwala. Drafting the article: Welch, Burke, Thawani, Berger. Critically revising the article: Welch, Burke, Thawani, Berger, Nayak, Stephen, Farkas, Long. Reviewed submitted version of manuscript: Welch, Burke, Thawani, Berger, Nayak, Stephen, Farkas, Long. Statistical analysis: Welch, Burke, Thawani, Nayak, Stephen. Administrative/technical/material support: Welch, Thawani, Nayak, Stephen, Aschyan, Pierce, Kanchwala. Study supervision: Welch, Thawani, Pierce.

Correspondence

William C. Welch, Penn Neurosurgery, Pennsylvania Hospital, 235 S. 8th St., Philadelphia, PA 19106. email: william.welch@uphs.upenn.edu.