A systematic comparative outcome analysis of surgical versus percutaneous techniques in the management of symptomatic sacral perineural (Tarlov) cysts: a meta-analysis

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OBJECTIVE Symptomatic perineural or Tarlov cysts (TCs) are a rare cause of chronic low-back pain. Given the rarity of the disease, there is no literature consensus regarding the optimal management of these cysts.

METHODS The authors conducted a systematic comparative outcome analysis of symptomatic TCs treated with surgery (group A, 32 studies, n = 333) or percutaneous interventions (group B, 6 studies, n = 417) analyzing the demographic characteristics, baseline characteristics of the cysts, clinical presentations, types of interventions, complication rates, and the recurrence rate in both treatment groups. The literature search was performed using the PubMed, MEDLINE, Cochrane, and Ovid databases up to 2018. The MeSH search terms used were "Tarlov cyst," "sacral perineural cyst," "sacral nerve root cyst," "meningeal cyst of the sacral spine," "extra meningeal cyst with spinal nerve root fibers," "spinal extradural arachnoid pouch," and "cyst of the sacral nerve root sheath." The authors used statistical tests for two proportions using the "N-1" chi-square test with the free version of MedCalc for Windows for comparison among the groups.

RESULTS Overall symptomatic improvement was reported in 83.5% of patients in both groups; however, exacerbation of preprocedural symptoms was significantly higher in group B than group A (10.1% vs 3.3%, p = 0.0003). The overall complication rates in the surgical and nonsurgical groups were 21% and 12.47%, respectively. Transient sciatica was the most common complication in both groups (17% vs 8%, respectively; p = 0.017). The incidence of cyst recurrence was much lower in group A than group B (8% vs 20%, p = 0.0018). The mean follow-up duration for the surgical group was 38 ± 29 months (25 studies, n = 279), while that for the nonsurgical group was 15 ± 12 months (4 studies, n = 290) (p < 0.0001).

CONCLUSIONS The authors noted that although the surgical interventions were associated with higher postprocedural complication rates, long-term efficacy and success in terms of cyst resolution were superior following surgery compared to percutaneous procedures in the management of symptomatic TCs. There was no difference in symptom recurrence with either of the techniques.

https://thejns.org/doi/abs/10.3171/2018.10.SPINE18952

KEYWORDS Tarlov cyst; sacral perineural cyst; meningeal cyst of the sacral spine; extrameningeal cyst with spinal nerve root fibers; congenital

Tarlov cysts (TCs) or perineural cysts are extradural spinal meningeal cysts characterized by collections of CSF between the endoneurium and perineurium of the posterior nerve root sheath of the dorsal root ganglion.[25,48] Classically, these cysts have a variable communication with the spinal subarachnoid space (SSS), with a unidirectional influx of CSF into the cyst cavity through a ball-valve mechanism.[2,19,32] Oftentimes, inside the cyst sac and within its walls, there is impingement of spinal nerve root fibers and ganglion cells.[19,32,48] Many Tarlov cysts are small, multiple, and asymptomatic. They are most commonly located in the sacral canal, but sometimes they are

ABBREVIATIONS LP = lumboperitoneal; SSS = spinal subarachnoid space; TC = Tarlov cyst.

SUBMITTED August 6, 2018. **ACCEPTED** October 11, 2018.
INCLUDE WHEN CITING Published online February 8, 2019; DOI: 10.3171/2018.10.SPINE18952.

also found in the lumbar and thoracic regions. Their size varies from 5 mm to > 10 cm in maximum dimension. As the cyst grows in size, compression or stretching of the enclosed nerve root fibers can cause localized and radicular symptoms.

The prevalence of sacral perineural cysts has been estimated as 1.5%–4.6%. The majority of these lesions are asymptomatic, but less than 1% of these cysts may cause clinical symptoms, depending on the location of the cyst in the spinal canal and the type of nerve roots it is compressing.[30]

The most common presenting symptoms include low-back pain; sacrococcygeal pain; perineal pain; sciatica; motor deficits; sensory weakness; neurogenic claudication; bowel, bladder, and sexual dysfunction; and intrathecal hypotension. The symptoms are often intermittent at onset and are most frequently exacerbated by standing, walking, coughing, postural changes, and Valsalva maneuvers such as sneezing or straining to defecate, all of which elevate the CSF pressure. A sacral meningeal cyst is often found incidentally on neuroimaging. MRI is the investigation of choice for the initial diagnosis. These cysts are hypointense on T1-weighted images, hyperintense on T2-weighted images, and show no enhancement with gadolinium contrast administration. Lumbosacral or pelvic MRI and CT myelography are useful tools to diagnose these cysts. The presence of a communication between the cyst and thecal sac differentiates perineural cysts from other cystic lesions. Delayed contrast filling of the perineural cysts is the characteristic finding on myelographic studies.[10,14,39]

Given the rarity of the disease, there has been no consensus on the optimal management and follow-up for symptomatic Tarlov cysts since their first description by Tarlov in 1938, and only a few hundred cases have been reported in the literature.[46–48] Many surgical and nonsurgical interventions have been proposed to treat these symptomatic lesions, with wide variability in symptom resolution, cyst recurrence, and postprocedural complications. Various treatment modalities include minimally invasive techniques using CT- or fluoroscopy-guided cyst aspiration and percutaneous fibrin glue injection.[17,23,24,29,30,52] Surgical techniques described in the literature include decompressive laminectomy; cyst cauterization, fenestration, and imbrication; cyst excision; lumboperitoneal, cyst-peritoneal, or cyst-subarachnoid shunting; microsurgical cyst resection; and neck ligation together with duraplasty or plication of the cyst wall.[1,3–6,8,9,11,12,15,16,18–22,26,28,31,34,36–38,40–42,44,45,49–51,53]

In fact, every procedure is associated with multiple complications including pseudomeningocele, hemorrhage, intracranial hypotension, neurological deficit, CSF leakage, or infection, CSF fistula, aseptic meningitis, and allergic reactions to sealant, with a high risk for cyst recurrence.[6,12–46]

There are limited data available on the comparative benefit of these procedures because of limitations in the published studies, including small sample size, retrospective evaluation of data, no quantification of outcome measures, and limited follow-up. The primary objective of our study was to perform a comprehensive review of the literature and to systematically analyze the comparative outcomes of excision versus percutaneous intervention, recurrence rates, and complications in the management of symptomatic sacral TCs.

Methods

Meta-Analysis

The present review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement criteria (Fig. 1). The literature search was updated to include articles published up to April 15, 2018, for all clinical human studies, without other temporal limits. The search was performed using the PubMed, MEDLINE, Cochrane, and Ovid databases for the years 1952 to 2018, ensuring that up-to-date data were included in the analysis. The bibliography section of the selected articles was scanned for additional reference articles pertaining to the topic. The MeSH search terms used were "Tarlov cyst," "sacral perineural cyst," "sacral nerve root cyst," "meningeal cyst of the sacral spine," "extra meningeal cyst with spinal nerve root fibers," "spinal extradural arachnoid pouch," and "cyst of the sacral nerve root sheath."

Research Design

All studies with lumbosacral perineural cysts and their management were carefully analyzed and included in our study if details of treatment and outcome were reported. Following best practice, published systematic reviews were hand-searched to ensure that all relevant papers were captured in the literature search. Symptomatology, pathophysiological mechanisms, neuroimaging, treatment options, and surgical indications were reviewed. Reviews, perspectives, letters to the editor, reports describing a single case, commentaries, and papers focusing on only diagnostic methods or interventional management were excluded during the search. In addition, papers in languages other than English and abstracts without full text were also excluded. Eligibility assessment was performed independently in a standardized manner by two reviewers (M.S. and P.S.). Disagreements between reviewers were resolved by consensus and discussions with senior authors (M.B. and B.U.) when necessary. The following clinical data were extracted from each paper: author(s), year of publication, total number of patients in the study, patient characteristics, including age and sex, location of the cyst, size of cyst, number of cysts, presenting symptoms, treatment modalities (CT- or fluoroscopy-guided cyst aspiration with percutaneous fibrin glue injection, and surgical techniques, including decompressive laminectomy; cyst cauterization, fenestration and imbrication; cyst excision; lumboperitoneal [LP], cyst-peritoneal, or cyst-subarachnoid shunting; microsurgical cyst resection; and neck ligation together with duraplasty or plication of the cyst wall), postprocedural improvements (symptomatic improvement, recurrence of symptoms, recurrence of cyst on neuroradiological follow-up), complication rates, follow-up, and recurrence rates. These outcomes were compiled and organized using Microsoft Excel. We summarized the data from these studies focusing on the comparative outcome analyses of surgical and nonsurgical treatment groups, procedure-related complication rates, and recurrence rates.

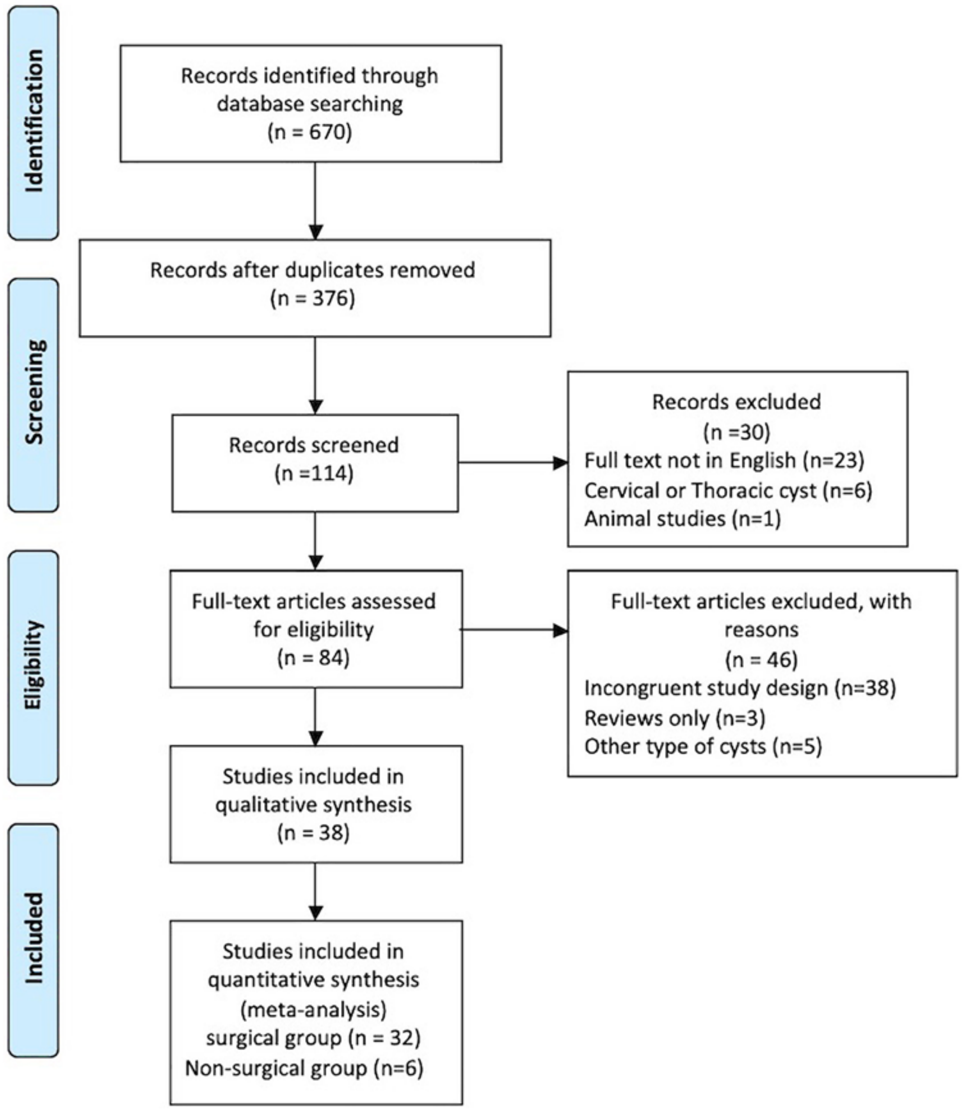

FIG. 1. PRISMA flowchart showing inclusion and exclusion criteria used in the meta-analysis. Figure is available in color online only.

Meta-Analysis Estimates and Statistical Analysis

Patient characteristics, presenting symptoms, postprocedural improvement, and follow-up duration are presented in pooled values within each of the two groups (surgery and nonsurgery). The age and follow-up duration (months) were summarized using the weighted means calculated as

$$\bar{x} = \frac{\sum n_i x_i}{\sum n_i}.$$

All the other variables were binary and were summarized by calculating the overall rates as

$$\bar{x} = \frac{\sum n_i}{n}.$$

We used a meta-analysis to summarize the outcomes for each group. All outcomes (complications and recurrence) were binary, and for each study the rates $p = n_i/n$ were calculated and used as the effect size in the meta-analysis. The standard error of the effect size was calculated as

$$SE = \sqrt{\frac{p\,(1-p)}{n}}.$$

Each outcome had its meta-analysis to estimate the effect. We used Meta-Essentials software for the meta-analyses.[43] The resulting forest plots, funnel plots, and I^2 were analyzed for the quality of the estimate. Outcomes that had an $I^2 < 25\%$ were deemed to be from a homogeneous population. Their estimated effect size and confidence intervals were recorded. Outcomes that were from only one study were also included, and the estimates were noted. To compare the two groups, we used statistical tests for two proportions using the "N-1" chi-square test[7,33] with the free version of MedCalc for Windows (MedCalc Software). Statistical tests were two-sided with a 95% confidence level and significance at p < 0.05.

Results

Meta-Analysis

The database search was performed using the PubMed, MEDLINE, Cochrane, and Ovid databases and yielded 114 items. Among the collected studies, 76 were discarded per the exclusion criteria (Fig. 1): incongruent study design (n = 38), reviews (n = 3), cysts other than TCs (n = 5), cervical/thoracic location of the cyst (n = 6), TCs in animal studies (n = 1), and studies in languages other than English (n = 23). We identified 38 full-text articles with a total of 750 patients in the mainstream analysis. The study design was constructed based on a differential approach for symptomatic cyst management. Group A (32 studies, n = 333) included all the patients treated surgically, whereas group B (6 studies, n = 417) included all the patients treated with percutaneous intervention (Tables 1 and 2).

Demographics

In the surgically treated group, 71.4% of the patients were female (information available in 31 studies, n = 325; group A) compared to 74% (information available in 5 studies, n = 204) in the nonsurgical group (group B) (p = 0.515). The mean age for group A was 45 ± 13 years (range 21–83 years), whereas that for group B was 38 ± 10 years (range 20–73 years). The mean follow-up duration for group A was 38 ± 29 months (n = 279), whereas that for group B was 15 ± 12 months (n = 290) (p < 0.0001, Table 3).

Baseline Characteristics of the Cyst

In group A, the cyst size ranged from 0.8 cm to 10 cm (n = 220), whereas in group B, only one study reported the cyst size (n = 5), with the TCs ranging from 1.6 cm to 3.2 cm. In group A, 52 patients had solitary cysts (n = 122), whereas in group B, 70 patients had multiple cysts (n = 122). In group B, 61 patients had solitary cysts (n = 82), whereas in group A, 21 patients had multiple TCs (n = 82). The most common location of TCs in group A was S1–3 (n = 232), whereas that in group B was S2–3 (n = 264).

Clinical Presentation

A summary of the comprehensive analysis and the statistical significance of clinical presentation of symptomatic TCs is shown in Table 3. The most common presenting symptoms in group A (n = 325) were back pain (82.8%), sciatica (51.4%), urinary incontinence (37.8%), sensory deficits (35.7%), and perineal pain (26.5%), whereas the predominant symptoms in group B (n = 295) were back pain (94.2%), perineal pain (77.6%), coccygodynia (65.8%), sciatica (62.7%), and sensory deficits (62.7%). Patients in the surgical group had a higher incidence of bladder incontinence than the nonsurgical group (37.8% vs 27.6%, p = 0.0070), with no difference in the incidence of bowel incontinence between the groups (20.3% group A, 18.5% group B, p = 0.57). The incidence of the remaining clinical symptoms was higher in group B than group A (Table 3).

Baseline Interventions: Surgical Versus Nonsurgical Group

Multiple innovative surgical and nonsurgical interventions were implemented in the management of symptomatic TCs, with variable success, as shown in Tables 1 and 2. Various treatment modalities included minimally invasive techniques with CT- or fluoroscopy-guided cyst aspiration and percutaneous fibrin glue injection and surgical techniques, including decompressive laminectomy; cyst cauterization, fenestration, and imbrication; cyst excision; LP, cyst-peritoneal, or cyst-subarachnoid shunting; microsurgical cyst resection; and neck ligation, together with duraplasty or plication of the cyst wall. It was not feasible to perform a head-on comparison among different surgical techniques due to high variability in the application of these techniques in different series. Also, the use of different combinations of these techniques in the management of TCs made it difficult to compare them upfront.

Procedural Complications and Technical Failure

The overall complication rates in the surgical and nonsurgical groups were 21% and 12.47%, respectively. Transient sciatica was the most common complication in both groups (17% vs 8%, respectively; p = 0.017), and the time for resolution of sciatica ranged from 2 weeks to 6 months. The rates of CSF-related complications, including CSF leak, fistula, and pseudomeningocele, were 9% in group A (95% CI 6–13) and 3% in group B (95% CI 1–5; p = 0.171). The rates of sexual and bladder/bowel complications were higher in group A than group B (11% vs 0% and 12% vs 1%, respectively; p = 0.0007). In group A, 5% of patients (4 studies, total n = 95) had moderate to severe wound infection requiring debridement surgery and extended hospitalization with external CSF drainage, whereas none of the patients in group B had reported wound infection. Two patients treated with CT-guided cyst aspiration and fibrin glue placement suffered from aseptic meningitis and were managed conservatively. Allergic reactions to sealant were seen in 15 cases (of 408 patients in 4 studies that reported this complication) and ranged from mild urticaria to severe anaphylaxis.

Comparative Outcome Analysis and Cyst Recurrence

Overall, symptomatic improvement was reported in 83.5% of patients in both groups, but transient exacerbation of preprocedural symptoms was significantly higher in group B than group A (10.1% vs 3.3%, p = 0.0003). Patient-reported outcomes were measured in terms of recurrence of symptoms at last follow-up and were similar in both groups: a rate of 21% in group A (95% CI 12%–54%) and a rate of 20% in group B (95% CI 10%–50%; p = 0.84). However, the incidence of cyst recurrence was much lower in group A than group B (8% vs 20%, p = 0.0018).

TABLE 1. Literature review of surgically treated TC series

Authors & Year (no. of pts)	Age in yrs/Sex (no. of that sex)	Presenting Sxs	Management & Surgical Techniques	Surgical Complications	Cyst Recur, no.	FU, mos
Abbott, 1956 (n = 6)*	50.33 ± 16.59/F (3)	LBP (n = 5), UI (n = 2), BI (n = 1), LL weakn (n = 2), LL paresth (n = 2), SR (n = 4), perin pain (n = 1)	Cyst incision & imbric (n = 2), STR & imbric (n = 2), decompressive laminect & CR (n = 2)	S1–2 dermatome sensory deficit & sphincter weakn (n = 1), S2–4 sensory loss, ED, bilat sciatic pain (n = 1)	0	NR
Strully, 1956 (n = 4)	47.75 ± 8.09/F (4)	LBP (n = 4), coccyg (n = 1), SR (n = 2), perin pain (n = 1), VM aggravation of pain (n = 1)	PR & cyst marsupialization (n = 1), SL w/ cyst & nerve root resect (n = 3)	Genital area sensory loss (n = 2)	0	NR
Bartels & van Overbeeke, 1997 (n = 3)	53.6 ± 8.14/M (3)	LBP (n = 3), SR (n = 3), paresth (n = 2), UI (n = 1), VM aggravation of pain (n = 1)	External CSF drainage (n = 3), LP shunt (n = 2)	None	0	10 ± 1
Kunz et al., 1999 (n = 8)	45 ± 7.75/NR	NR	SL w/ CR (n = 3), PR (n = 5)	Neurological deficits (n = 4), hypesthesia (n = 3), bladder incontinence (n = 1), SD (n = 1), coccyg (n = 1), residual pain (n = 4)	2	NR
Mummaneni et al., 2000 (n = 8)	NR/F (6)	SR (n = 8), UI (n = 3), VM aggravation of pain (n = 2)	SL, microsurgical cyst fenestration & imbric (n = 8), f/b lumbar drain (n = 5)	None	1	19 ± 17.5
Voyadzis et al., 2001 (n = 10)	48.1 ± 8.99/F (8)	Leg/sacral/coccygeal pain (n = 9), coccyg (n = 2), paresth (n = 3), UI (n = 3), BI (n = 2), dyspareunia (n = 2)	SL w/ CR of sacral cyst(s) w/ neck ligation using clip f/b Gelfoam & FG placement over cut neck (n = 10)	UI & lt inner buttock numbness (n = 1), overflow incontinence (n = 1)	0	31.7 ± 38.34
Caspar et al., 2003 (n = 15)	45 ± 11/F (10)	LBP or SR exacerbated by standing, walking, & coughing (n = NR)	Microsurgical cyst excision w/ duraplasty or plication of cyst wall f/b lumbar drainage for 10 days (n = 15)	None	0	60 ± 25.5
Lee et al., 2004 (n = 2)	35 ± 11/F (3)	LBP (n = 3), SR (n = 2), UI (n = 1)	CT-guided aspir f/b complete cyst resect, neck ligation, & cyst wall wrapping around nerve root (n = 2)	None	0	6 ± 0
Guest et al., 2005 (n = 2)	NR/M (2)	Progressive leg weakn (n = 1), sensory loss (n = 1), LBP (n = 1)	Intracystic lumbar drain w/ percutaneous endoscopy (n = 1), cyst-peritoneal shunt (n = 1)	None	0	24 ± 0
Langdown et al., 2005 (n = 3)	NR/F (3)	LBP, SR, & intermittent UI (n = 1), rt SR (n = 1), intermittent cauda equina syndrome (n = 1), paresth (n = 1)	SL, cyst fenestration w/ aspir & muscle patch (n = 3)	CSF leak (n = 1), cauda equina due to muscle patch dislodgement (n = 1)	0	NR
Tanaka et al., 2006 (n = 12)	50.6 ± 16.47/M (7)	LBP (n = 8), coccyg (n = 4), sciatica (n = 3), UI (n = 8), perianal pain (n = 5), leg pain (n = 2), sensory disturbance (n = 8), leg weakn (n = 1)	Sacral recapping laminect w/ cyst imbric (n = 4), SL w/ cyst & nerve root resect & imbric (n = 8)	Cerebellar ICH (n = 1), prostatitis (n = 1)	0	31.7 ± 16.11
Guo et al., 2007 (n = 11)	36.7 ± 4.85/M (6)	LBP (n = 7), sacrococcyg (n = 9), paresth (n = 6), SR (n = 4), bilat LL sensory or motor disturbance (n = 7), UI/BI (n = 4), claudication (n = 4)	SL, cyst fenestration, cyst resect/imbric (n = 11)	CSF leak (n = 1), worsening bladder function (n = 1)	2	39.6 ± 47.22

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TABLE 1. Literature review of surgically treated TC series

Authors & Year (no. of pts)	Age in yrs/Sex (no. of that sex)	Presenting Sxs	Management & Surgical Techniques	Surgical Complications	Cyst Recur, no.	FU, mos
Park et al., 2008 (n = 2)	45 ± 2.82/F (2)	LBP (n = 1), SR (n = 1), paresth (n = 2), perianal pain (n = 2)	SL, cyst resect, FG & Gelfoam (n = 2)	None	0	NR
Sajko et al., 2009 (n = 3)	58.33 ± 10.01/F (3)	LBP (n = 3), SR (n = 2), paresth (n = 2), leg weakn (n = 2), UI (n = 1), claudication (n = 1)	SL, cyst fenestration, resect, FG placement (n = 3)	None	0	NR
Smith et al., 2011 (n = 18)	49.43 ± 13.75/F (17)	Coccyg (n = 16), UI (n = 5), SR (n = 15), paresth (n = 11), LL weakn (n = 3)	SL, cyst fenestration & resect, reconstructive laminoplasty (n = 18)	CSF leak (n = 1)	0	15.83 ± 8.41
Neulen et al., 2011 (n = 13)	60 ± 9.8/F (10)	LBP (n = 10), radiating pain to buttocks (n = 8), radiating pain to legs (n = 7), radiating pain to groin & abdomen (n = 4), genital pain (n = 3), UI/BI (n = 3)	SL, cyst fenestration, resect, imbric/plication (n = 13)	CSF leak (n = 1)	1	10.7 ± 6.6
Xu et al., 2012 (n = 13)	38.61 ± 12.25/M (9)	LBP (n = 12), SR (n = 7), paresth (n = 6), perin pain (n = 9), claudication (n = 4), UI/BI (n = 6)	SL, PR, & imbric (n = 6), partial cyst wall resect & aperture repair (n = 7)	CSF leak (n = 1)	1	37.61 ± 31.55
Sen et al., 2012 (n = 2)	31 ± 4.24/F (1)	LBP (n = 2), paresth (n = 1), SR (n = 2), UI/BI (n = 1), claudication (n = 1)	SL, cyst excision, neck ligation (n = 2)	None	0	42 ± 25.45
Sun et al., 2013 (n = 38)	41.4 ± 15.57/M (24)	LBP (n = 28), SR (n = 10), UI/BI (n = 10), LL weakn (n = 11), paresth (n = 16)	SL, PR, neck ligation, over-sewing, cyst cauterization, local muscle flap (n = 38)	Delayed wound healing (n = 2), wound infection requiring debridement & suturing (n = 5)	0	21 ± 12.54
Arnold & Teuber, 2013 (n = 2)	40.5 ± 9.19/M (2)	LBP (n = 2), LL weakn (n = 1), ED (n = 1), urinary retention (n = 1), perin pain (n = 2), paresth (n = 1)	SL w/ exploration & decompression of large sacral cyst & duraplasty (n = 2)	Large posterior soft tissue pseudomeningocele (n = 1)	0	27 ± 4.24
Asamoto et al., 2013 (n = 9)	42.1 ± 13.18/M (6)	Sciatica (n = 9), bowel sphincter dysfunction (n = 2), LL weakn (n = 1), coccyg (n = 3), paresth (n = 9)	SL w/ suturing of cyst wall after collapse of cyst (n = 7), duraplasty & suture after collapse of cyst wall (n = 1), primary nerve root sacrificed (n = 1)	CSF leak (n = 1)	1	120 ± 44.09
Takemori et al., 2014 (n = 2)	48.5 ± 19.09/F (2)	LBP (n = 2), radiculopathy (n = 1), bladder dysfunction (n = 2)	Cyst-subarachnoid shunt (n = 2)	None	0	54 ± 42.42
Cantore et al., 2013 (n = 19)	45.4 ± 13.01/F (14)	Perianal & perin pain (n = 10), leg pain (n = 5), complete UI (n = 4), incomplete UI (n = 11), VM aggravation of pain (n = 8)	SL, CSF aspir, titanium clips at neck & cyst wall (n = 19)	None	0	122.6 ± 72.75
Mezzadri et al., 2014 (n = 6)	45 ± 5/M (4)	LBP (n = 6), SR (n = 2), perin pain (n = 5), UI (n = 1), BI (n = 1)	Endoscopic cyst aspir, SSS communication plugged w/ muscle, fat tissue, Gelfoam, & FG f/b external lumbar drainage (n = 6)	None	1	25.8 ± 10.75
Seo et al., 2014 (n = 3)	47.33 ± 22.81/M (2)	LBP (n = 3), SR (n = 3), hypesthesia (n = 2), UI (n = 1), motor weakn (n = 1), VM aggravation of pain (n = 1)	Sacral recapping laminect w/ complete cyst resect, ligation of cyst neck f/b lumbar drain (n = 3)	None	0	12 ± 0

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TABLE 1. Literature review of surgically treated TC series

Authors & Year (no. of pts)	Age in yrs/Sex (no. of that sex)	Presenting Sxs	Management & Surgical Techniques	Surgical Complications	Cyst Recur, no.	FU, mos
Sharma et al., 2015 (n = 3)	39.33 ± 10.26/F (2)	SR (n = 3), LL weakn (n = 1), dysesthesia (n = 3), UI (n = 1)	Hemilaminect, medial facetectomy, CR (n = 2), laminect, marsupialization, FG (n = 1)	CSF leak (n = 1)	0	NR
Feigenbaum et al., 2015 (n = 8)	51 ± 11.07/F (8)	Sacral Sxs (n = 8), buttock Sxs (n = 6), perin Sxs (n = 7), persistent genital arousal disorder (n = 8), UI (n = 7), BI (n = 7), dyspareunia (n = 7)	NR	None	0	19.37 ± 18.73
Zheng et al., 2016 (n = 22)	42.6 ± 11.75/F (20)	Leg pain (n = 8), perianal & perin pain (n = 18), UI (n = 3), BI (n = 7), orthostatic headache (n = 1)	SL, balloon-assisted fistula sealing op for high-flow cyst, muscle closure of fistula & FG (n = 18), cyst imbric for low-flow cyst (n = 4)	Trans intracranial hypotension (n = 5), delayed wound healing (n = 1)	1	20.5 ± 5.25
Potts et al., 2016 (n = 35)	52 ± NR/F (29)	LBP (n = 18), SR (n = 7), leg pain (n = 5), perin pain (n = 5), motor deficit (n = 4), sensory deficit (n = 17), UI (n = 16), BI (n = 7), postural changes (n = 32), VM aggravation of pain (n = 20)	SL, microsurgical cyst fenestration, vascularized muscle pedicle flap insertion for complete closure of cyst wall (n = 7), incomplete closure of cyst wall w/ nonwatertight seal (n = 5), no attempt at closure of cyst wall (n = 22), cyst not fenestrated (n = 1)	Incisional erythema (n = 1), superficial seroma (n = 1), pulmonary embolism (n = 1), pseudomeningoceles (n = 5)	19	8 ± 21.25
Burke et al., 2016 (n = 23)	49.3 ± 11.3/F (19)	LBP (n = 20), SR (n = 20), pelvic/perin pain (n = 15), orthostasis (n = 14), UI (n = 14), perin numbness (n = 11), headache (n = 8), BI (n = 8), dyspareunia (n = 2), SD (n = 1)	SL, cyst incision, autologous muscle patching to augment dural closure & decrease cyst volume & watertight tension-free closure (n = 23)	Wound infection (n = 1), CSF leak (n = 3)	1	14.4 ± 9.5
Elsawaf et al., 2016 (n = 15)	31 ± 14.4/F (10)	LBP (n = 7), coccyg (n = 3), SR (n = 3), LL pain w/ dysesthesia (n = 8), perin pain (n = 1), buttock pain (n = 3), nocturnal enuresis (n = 2)	SL, cyst excision, local fat grafting, & gelatin sponge for neck closure, FG placement f/b lumbar subarachnoid drain for 7 days to prevent CSF leak (n = 15)	Superficial wound infection (n = 1), CSF leak after 5 days due to malfunction of lumbar drain (n = 1)	0	56.2 ± 43.54
Weigel et al., 2016 (n = 13)	51.8 ± 13.98/F (9)	LBP (n = 13), SR (n = 13), perin pain (n = 2), UI/BI (n = 7), SD (n = 2), paresth (n = 3), weakn (n = 2)	Microsurgical CSF drainage, cyst wall plication, nerve root decompression, & sacroplasty (n = 13)	Marked venous bleeding from venous intrasacral epidural plexus after cyst decompression (n = 2), delayed CSF leak (n = 1)	2	63 ± 44.73

aspir = aspiration; BI = bowel incontinence; coccyg = coccygodynia; CR = complete resection; ED = erectile dysfunction; f/b = followed by; FG = fibrin glue; FU = follow-up; ICH = intracerebral hemorrhage; imbric = imbrication; laminect = laminectomy; LBP = low-back pain; LL = lower limb; NR = not reported; paresth = paresthesia; perin = perineal; PR = partial resection; recur = recurrence; resect = resection; SD = sexual dysfunction; SL = sacral laminectomy; SR = sacral radiculopathy; STR = subtotal resection; Sxs = symptoms; trans = transient; UI = urinary incontinence; VM = Valsalva maneuver; weakn = weakness.

All included studies were retrospective in nature (Oxford level of evidence 4). Values presented as mean ± standard deviation except where indicated.

* Of the 8 cases described in this manuscript, one had no surgical intervention and another one was diagnosed to have metastatic malignancy.

TABLE 2. Literature review of TCs treated w/ percutaneous intervention

Authors & Year (no. of pts)	Age in yrs/Sex (no. of that sex)	Presenting Sxs	Management & Percutaneous Technique	Postprocedural Complications	Cyst Recur, no.	FU, mos
Paulsen et al., 1994 (n = 5)	52.8 ± 14/F (n = 5)	LBP (n = 5), SR (n = 5)	Percutaneous drainage (n = 5)	None	3	NR
Patel et al., 1997 (n = 4)	51.5 ± 14.93/F (n = 3)	LBP (n = 4), SR (n = 3), bilat leg weakn (n = 1), pelvic pain (n = 1), UI (n = 1), severe perin pain w/ difficulty urinating (n = 1)	Cyst aspir w/ FG placement (n = 4)	Aseptic meningitis (n = 2)	0	13.5 ± 7.85
Zhang et al., 2007 (n = 31)	38.5 ± 11.5/F (n = 19)	LBP + SR + intermittent claudication (n = 25), SR (N = 21), sensory disturbance w/ leg weakn (n = 15), perin pain (n = 15), UI (n = 9), BI (n = 2), 1 LL muscle atrophy w/o pain/neurological abnormality (n = 3)	Cyst aspir f/b glue placement (n = 15), only glue placement w/o aspir (n = 16)	ARx to sealant (n = 3)	0	23 ± 4.5
Murphy et al., 2011 (n = 122)	54 ± NR/F (n = 102)	LBP (n = NK), SR (n = NK), buttock pain (n = NK), perin pain & burning sensation in buttocks, perineum & LL (n = NK), UI/BI (n = 9)	119 CT-guided cyst aspirs in 100 pts; 28 underwent op	Trans postop sciatica (n = 6), trans postop rectal fullness (n = 1), urticaria (n = 1)	17	NR
Jiang et al., 2015 (n = 42)	34.3 ± 8.5/F (n = 22)	LBP & paresth (n = 33), leg pain w/ or w/o muscle atrophy (n = 5), cauda equina syndrome (n = 4), postural changes in pain & numbness (n = 20)	C-arm fluoroscopy–guided percutaneous cyst aspir f/b fibrin gel injection therapy (n = 42)	ARx to sealant (n = 7)	0	24 ± 6.5
Murphy et al., 2016 (n = 213)	NR/NR	LBP (n = 210), L4–5 radiculopathy (n = 2), SR (n = 151), S1–2 neuropathy (n = 137), LBP (n = 189), pelvic/perin pain (n = 209), UI (n = 92), BI (n = 62), SD (n = 92), weakn (n = 91), absent Achilles reflex (n = 130)	CT fluoroscopy–guided cyst aspir f/b FG placement (n = 168); 34 pts underwent op	CSF leak (n = 7), trans sciatica (n = 21), ARx to sealant (n = 4)	47	

ARx = allergic reaction; NK = not known; pts = patients.
All included studies were retrospective in nature (Oxford level of evidence 4). Values presented as mean ± standard deviation except where indicated.

These findings suggest that although surgery was associated with a higher postprocedural complication rate, for TCs the long-term efficacy and success in terms of cyst resolution were superior following surgery rather than following percutaneous techniques (Table 4 and Fig. 2).

Discussion

Perineural cysts are a rare cause of chronic low-back pain and the clinical course varies widely depending on the size and location of the cysts. These lesions can be confused with other clinical entities, including tumors, meningeal diverticula, or arachnoid cysts. There is a paucity of data in the literature regarding the etiology, natural history, and pathogenesis of TCs. Their minuscule size and remote anatomical locations pose diagnostic and therapeutic challenges regarding the optimal management of symptomatic TCs.

Pathophysiology

Various theories have been postulated for the probable mechanism of cyst formation. Tarlov proposed that traumatic hemorrhage into the SSS caused hemosiderin deposition, which impeded venous drainage in the perineurium and epineurium, leading to rupture and subsequent cyst formation. Four of the 7 patients in his seminal series had a history of trauma.[46–48] Nishiura et al.[27] described a history of trauma in 40% of their patients with Tarlov cysts. Schreiber and Haddad[35] and Strully[41] noted that cysts can form as a result of dural lacerations during spinal surgery, leading to pseudomeningocele formation. Fortuna et al.[13] favored a congenital origin of perineural cysts that can arise from a congenital dural diverticulum or weakness or from persistent embryonic fissures. The cyst can enlarge via a net inflow of CSF, eventually causing symptoms by distorting, compressing, or stretching adjacent nerve roots. Tarlov cysts have been associated with other congenital abnormalities, connective tissue disorders, and nerve root sheath duplication. Rexed argued that the cysts occur as a result of proliferation of arachnoid mater, followed by a closure of the communication between the arachnoid proliferations and the SSS.[32] The cysts often are multiple, extending around the circumference of the nerve, and can enlarge to compress neighboring nerve roots and cause significant bone erosion. The most accepted theory, confirmed by intraoperative findings from numerous studies, is that the enlargement of the cysts is caused by pulsatile and hydrodynamic forces of CSF because of a ball-valve

TABLE 3. Demographics, presentation, and symptoms

Variable	Type of Procedure (no. of studies, pts)		p Value
	Surgery (studies n = 32, pts n = 333)	Nonsurgery (studies n = 6, pts n = 417)	
Demographics			
Age	45 + 13 (28 studies, n = 285)	38 + 10 (4 studies, n = 82)	**<0.0001**
Sex: female	71.4% (31 studies, n = 325)	74.0% (5 studies, n = 204)	0.5153
Presentation			
Back pain	82.8% (31 studies, n = 325)	94.2% (5 studies, n = 295)	**<0.0001**
Sacral radiculopathy	51.4% (31 studies, n = 325)	62.7% (5 studies, n = 295)	**0.0046**
Coccygodynia	25.5% (31 studies, n = 325)	65.8% (5 studies, n = 295)	**<0.0001**
Perineal pain	26.5% (31 studies, n = 325)	77.6% (5 studies, n = 295)	**<0.0001**
LL weakness	11.7% (31 studies, n = 325)	36.3% (5 studies, n = 295)	**<0.0001**
Sensory disturbances	35.7% (31 studies, n = 325)	62.7% (5 studies, n = 295)	**<0.0001**
Bowel incontinence	20.3% (31 studies, n = 325)	18.5% (6 studies, n = 417)	0.5720
Bladder incontinence	37.8% (31 studies, n = 325)	27.6% (5 studies, n = 417)	**0.0070**
Orthostasis	15.1% (31 studies, n = 325)	5.33% (5 studies, n = 375)	**<0.0001**
Sexual dysfunction	4.62% (31 studies, n = 325)	31.2% (5 studies, n = 295)	**<0.0001**
VM aggravation of Sxs	12.6% (31 studies, n = 325)	0.00% (5 studies, n = 295)	—
Other	10.2% (31 studies, n = 325)	46.4% (5 studies, n = 295)	**<0.0001**
Sxs			
Symptomatic improvement	83.5% (32 studies, n = 333)	83.5% (6 studies, n = 417)	1.0000
Worsening of preop Sxs	3.30% (32 studies, n = 333)	10.1% (6 studies, n = 417)	**0.0003**
FU in mos	38 ± 29 (25 studies, n = 279)	15 ± 12 (4 studies, n = 290)	**<0.0001**

Values presented as pooled mean ± standard deviation or pooled rate in percentage. Boldface type indicates statistical significance.

effect, whereby CSF enters the cyst with systolic pulsation but is unable to exit through the same portal during diastole. Postural changes and Valsalva maneuvers force CSF into the cysts with increased spinal subarachnoid pressure via the ball-valve mechanism.[30,40,49] This temporarily increased pressure within the cyst may stretch any overlying nerve fibers within the cyst wall or may compress the ventrally displaced main portion of the nerve root, which may in turn lead to exacerbated radiculopathy or sensory loss, compression of the adjacent sacral thecal sac, and associated urinary and bowel incontinence. Although TCs are small in size, they can cause a significant mass effect, given their higher internal pressure, compressing the surrounding neural tissue and bony structures.

TABLE 4. Summary of outcomes

Outcome	Type of Procedure (no. of studies, pts)		p Value
	Surgery (studies n = 32, pts n = 333)	Nonsurgery (studies n = 6, pts n = 417)	
Complications			
CSF leak	9% (6% to 13%) (11 studies, n = 123)	3% (1% to 5%) (1 study, n = 213)	**0.0171**
Transient sciatica	17% (4% to 30%) (4 studies, n = 74)	8% (−24% to 39%) (2 studies, n = 335)	**0.0177**
Sexual dysfunctions*	11% (0% to 21%) (3 studies, n = 27)		
Bowel/bladder†	12% (8% to 15%) (7 studies, n = 78)	1% (−1% to 3%) (1 studies, n = 122)	**0.0007**
Wound infections	5% (4% to 7%) (4 studies, n = 95)		
Other complications‡	18% (9% to 26%) (6 studies, n = 113)	3% (−5% to 12%) (4 studies, n = 408)	**<0.0001**
Recurrence			
Recurrence of Sxs	21% (−12% to 54%) (7 studies, n = 77)	20% (−10% to 50%) (3 studies, n = 340)	0.8437
Recurrence of cyst	8% (5% to 10%) (10 studies, n = 130)	20% (−10% to 50%) (3 studies, n = 340)	**0.0018**

Values presented as meta-analytic rates and associated 95% CIs. Boldface type indicates statistical significance.
* Sexual dysfunctions such as erectile dysfunction and loss of genital sensations.
† Bowel/bladder complications such as sphincter weakness, urinary incontinence, and overflow incontinence.
‡ Other complications include allergic reactions to sealants in the nonsurgery group, whereas in the surgery group they include marked venous bleeding, transient intracranial hypotension, superficial seroma, incisional erythema, cerebellar intracerebral hemorrhage, and prostatitis, as described in Table 1.

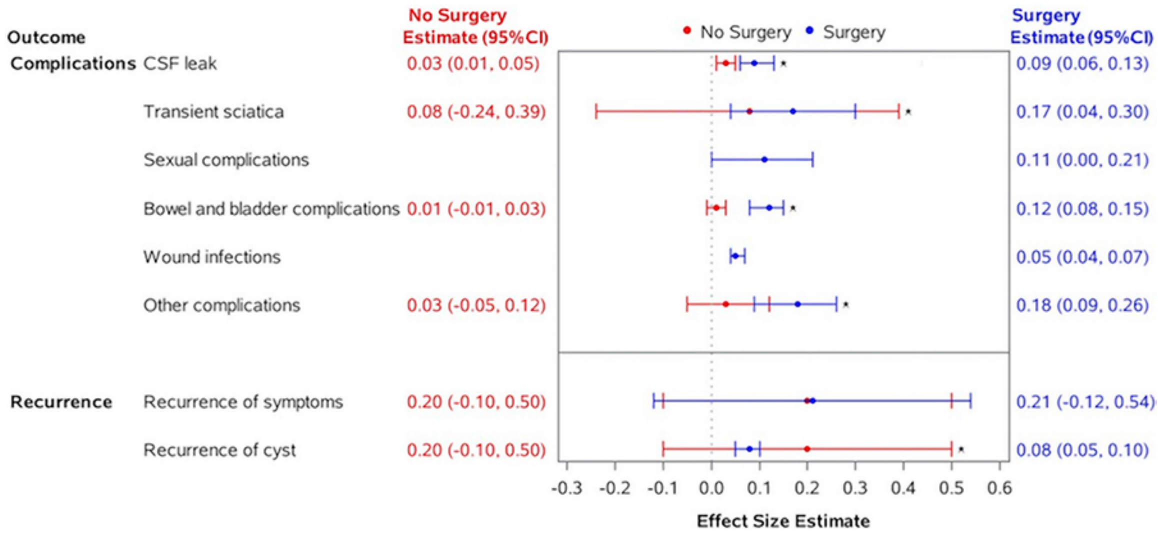

FIG. 2. Forest plots showing the estimates of cyst recurrence and complications following surgery (*blue*) compared with percutaneous techniques (*red*). *Statistically significant. Figure is available in color online only.

Management of TCs

Numerous techniques for the management of TCs have been described in the literature, with variable results. Tarlov, in his seminal series, removed the domes of the cysts or completely excised the lesions along with the dorsal root ganglion. Paulsen et al.[30] reported that patients who underwent sacral meningeal cyst aspiration tended to accumulate CSF and become symptomatic in 3 weeks to 6 months. Patel et al.[29] proposed that the injection of a sealant into the cyst would thicken the wall of the cyst via fibrosis and block the one-way valve at the neck of the cyst, reducing the entry of CSF and thereby preventing the cyst from distending and compressing local nerves. It has been proven that fibrin glue injection into a sacral meningeal cyst may be a definitive therapy. Murphy et al.[23] reported the largest series of patients (n = 213) treated with CT-guided cyst aspiration and fibrin glue using single- and double-needle techniques, whereas Jiang et al.[17] utilized C-arm fluoroscopy–guided cyst aspiration. Bartels and van Overbeeke[5] described external CSF drainage with LP shunt placement. Voyadzis et al.,[49] Guo et al.,[16] Tanaka et al.,[45] and Neulen et al.[26] suggested that surgical treatment is indicated for cysts larger than 1–1.5 cm in size presenting with radicular symptoms, and is strongly correlated with excellent clinical outcome. Langdown et al.[19] found that it is not the size of the cyst per se but its proximity to the nerve root and the presence of a valve mechanism within the cyst that predict the development and progression of symptoms. Acosta et al.[2] and Mummaneni et al.[22] observed that patients who present with pain (exacerbated by both postural changes and Valsalva maneuvers) but not with urinary dysfunction are likely to benefit most from surgery. Burke et al.[6] performed a meta-analysis of microsurgically treated TCs and showed that advanced age, a large number of cysts, and duration of preoperative symptoms were associated with poor postoperative outcomes. These authors also defined the criteria that can be used to guide the surgical decision-making process in treating these patients.[6]

Our extensive literature review and meta-analysis of all the available cases of symptomatic TCs suggests that surgical procedures are superior to percutaneous interventions in terms of symptom resolution and long-term patient-reported outcomes.

Variability in Open Surgical Techniques for TCs

A variety of surgical techniques have been described in managing patients with TCs in various series by different authors and even within series by the same authors (Table 1). In the largest series to date (n = 38), Sun et al.[42] reported no cyst recurrence at a mean follow-up of 21 months in their series after performing a partial resection of the cyst, ligation of the cyst neck, over-sewing, cyst cauterization, and using a local muscle flap for obliterating the cyst. Delayed wound healing (n = 2) and wound infection requiring debridement and suturing (n = 5) were the reported complications in their series. In contrast, the authors of another series using a similar surgical technique (microsurgical cyst fenestration and vascularized muscle pedicle flap insertion for complete closure of cyst wall [n = 7], incomplete closure of the cyst wall without a watertight seal [n = 5], no attempt at closure of cyst wall [n = 22], and no fenestration of the cyst [n = 1]) reported cyst recurrence in 19 of 35 patients at a mean follow-up of 8 months.[31] Similarly, Burke et al.[6] (n = 23) have described a technique of cyst incision followed by autologous muscle patching to augment dural closure, and cyst recurrence was noted in only one patient. Zheng et al.[53] described the use of a balloon-assisted fistula-sealing procedure for high-flow cysts (n = 18) and cyst imbrication for low-flow cysts (n = 4). Fibrin glue for sealing the cyst has been consistently described in a variety of studies with variable success.[11,21,28,34,38,49] In 2014, Takemori et al.[44] described using a cyst-subarachnoid shunt in 2 patients with TCs; they found no complications or recurrence at 54 months' follow-up. Also, the use of lumbar drain or LP shunt has been inconsistently described in the literature.

Mummaneni et al.[22] (n = 8) and Caspar et al.[9] (n = 15) used a postprocedural lumbar drain in patients with TCs and observed no complications (Table 1). Overall, there is wide inter- and intra-variability among the surgical procedures performed in these studies. Therefore, it was not possible to compare and establish the superiority of one surgical procedure over another.

Clinical Decision-Making in Patients With TCs

Based on our analyses, surgical procedures can be chosen for younger, healthy patients with better long-term cyst resolution but with increased risk of postprocedural complications. Percutaneous techniques can be considered in elderly patients with multiple medical morbidities who are otherwise not fit to undergo surgical procedures involving general anesthesia and who cannot withstand postprocedural complications. The choices regarding different surgical procedures cannot be concluded based on our analyses, given the heterogeneity of reported retrospective surgical series and the low number of patients. This decision-making must involve patients' perspectives and choices in an informed manner.

Limitations

Our meta-analysis was limited by the variability in the available articles due to the reporting bias of included retrospective studies and institutional/operational protocols. Also, the size of cysts was inconsistently reported across the studies (group A, 17 studies [n = 220]; group B, 1 study [n = 5]), which limited our ability to assess the impact of cyst size on clinical presentation and outcomes. No clear-cut imaging protocols were mentioned across the different studies to determine cyst recurrence. Each study had patient-reported outcomes per the study site protocols and could not be unified using a validated pain scale disability rating. However, to the best of our ability, the studied parameters were standardized, and variables that were not explicitly reported were excluded from the analysis. Also, the low incidence of TCs limits the statistical analysis and firm conclusions that can be drawn from this study. Therefore, given the heterogeneous nature of the patient populations and the variable cyst sizes, the multitude of procedures, and the variable clinical follow-up, it is critical to interpret these results with caution. This is by far the largest seminal study comparing outcomes in symptomatic TCs managed using surgical and percutaneous techniques.

Conclusions

Our comparative outcome analysis of symptomatic TCs treated with surgical or percutaneous interventions suggests that, although the surgical interventions were associated with higher postprocedural complication rates, the long-term efficacy and success in terms of cyst resolution (no difference in recurrence of symptoms) were superior following surgery rather than following percutaneous techniques in patients with symptomatic TCs. These results can guide clinicians in decision-making while managing these patients with this complicated clinical condition.

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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: Sharma, Dietz. Acquisition of data: Sharma, SirDeshpande. Analysis and interpretation of data: Boakye, SirDeshpande, Ugiliweneza. Drafting the article: Boakye, Sharma, SirDeshpande, Dietz. Critically revising the article: SirDeshpande, Ugiliweneza, Dietz. Statistical analysis: Sharma. Study supervision: Boakye.

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