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One-year results of minimally invasive sutured fixation of the slipped ribs in the pediatric population

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Abstract

Purpose: Costal cartilage resection with or without rib resection is the gold standard surgery for slipping rib syndrome. Minimally invasive restoration of normal anatomy via nonabsorbable sutures has been described in the adult population with encouraging results. We sought to assess the efficacy of minimally invasive sutured fixation of the hypermobile rib in the pediatric population.

Methods: A retrospective review was performed at Mayo Clinic involving 31 pediatric patients diagnosed with slipped rib syndrome. Minimally invasive sutured open reduction internal fixation was performed between 2020 and 2022. The standardized Örebro Musculoskeletal Pain Screening Questionnaire was given at dedicated time points pre- and post-operatively to assess efficacy. Significance was determined via the Wilcoxon rank sum test.

Results: SRS was diagnosed clinically in 31 patients (24 females, 7 males, 12-20 years-old). Symptoms were present for an average of 18.9 months and patients had seen an average of 4.7 specialists. Traumatic causes were identified in three patients and eight patients had hypermobility. At one month follow up, there were no surgical complications and patients reported significantly less pain ($p<0.001$). Preoperative analgesics reduced by 80%. Ultimately, seven patients underwent a second operation; three patients underwent a third operation; one patient underwent five total operations. Recurrent pain was reported in six patients. Only nine patients followed-up at 1-year post-operation.

Conclusion: Pediatric patients with SRS demonstrated an early positive response to suture fixation without costal cartilage excision. Reoperation and recurrent pain, however, remain significant in this population.

Keywords: Sslipping rib syndrome; Slipped rib syndrome; SRS; Suture fixation; Intercostal neuralgia; Minimally invasive

Level of Evidence: Case series with no comparison group – Level IV

Abbreviations: SRS – slipped rib syndrome; NSAID – non-steroid anti-inflammatory drug; BMI – body-mass index; CT – computed tomography; MRI – magnetic resonance imaging; GI – gastrointestinal; COVID-19 – coronavirus disease 2019

Background

Slipped rib syndrome (SRS) occurs with laxity in intercostal cartilage, allowing for the affected rib to impinge on the intercostal nerve of the above rib. It is underdiagnosed, commonly resulting in unnecessary medical testing and procedures before identification. The typical demographic is young athletic females, and authors have suggested hormonal shifts as potentially influential [1-2]. The pain involved can be somatic or visceral, leading to vague lower thoracic or upper abdominal symptoms, and often an extensive diagnostic workup prior to elucidation. The diagnosis is made via history and physical examination, noting a positive hooking maneuver in these patients (curling the fingers underneath the affected rib and gently pulling it forward) [3]. Imaging is not necessary to confirm SRS, but helps to exclude conditions in the differential diagnosis. Recently, dynamic ultrasound while performing a crunch or the hook maneuver was found to be an effective and reproducible tool for diagnosing SRS [4]. Current treatment regimens include the conservative (NSAIDs, anesthetics, steroids, and physical therapy) and surgical (cartilage and/or rib resection) approaches with varying efficacy [5].

Hansen *et al*. found success in 29 adult patients via minimally invasive nonabsorbable suture fixation with encouraging results at six months, but long-term durability is pending [6]. We aimed to assess this surgical approach to slipping rib syndrome in the pediatric population, with an emphasis on alleviating accompanying intercostal neuralgia.

Materials & Methods

Study design

This retrospective review was approved by the institutional review board at Mayo Clinic and in compliance with Health Insurance Portability and Accountability Act regulations. The study was considered exempt from review by the institutional review board of Mayo Clinic as it was considered not human participant research. Any identifiable patient information was subsequently deidentified and maintained in an encrypted folder on the Mayo Clinic intranet. The study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

Patients who underwent surgical fixation between 2020-2022 were included, and the study size was derived from interested patients that fit the inclusion criteria of patients aged 10-21 with the diagnosis of SRS seeking surgical treatment. Exclusion criteria were patients under the age of 10 or over the age of 21, or previously attempted surgical correction. The specific parameters obtained from the medical record were demographic information (age, sex), BMI, laterality, duration of symptoms, traumatic cause, number of specialists seen leading up to diagnosis, imaging studies performed, preoperative and post-operative medication use, intraoperative details, surgical outcomes, and responses to the standardized Örebro Musculoskeletal Pain Screening Questionnaire [7]. The survey was administered at the predetermined time points of preoperation, 1-month post-operation, 6-months post-operation, and 12-months post-operation. Follow-up visits occurred in person or via telephone call (only in cases of connection issues) or video. There was no attempt to contact patients if they missed follow-up appointments. There was no blinding and we included data from all time points patients followed-up. Numeric values were reported as number (percent) for categorical variables and quantity, means, and ranges for continuous variables. Questionnaire outcomes were compared using the Wilcoxon signed rank sum test for continuous variables and chi-square test for categorical variables. P-values less than 0.05 were considered statistically significant. Analysis was performed using SAS (Version 9.4, SAS Institute, Cary, NC).

Procedure

Patients were seen in clinic for physical examination, and the point(s) of maximal pain was marked in the preoperative area, with patient and parental confirmation. The procedure was performed as described by

Hansen *et al* [5]. Intraoperative photography and videography were obtained, demonstrating the mobility and the post procedure fixation with Flexi-Tape and Ethibond sutures. Our procedure began with a rib block using 1:2 mixture of 0.5% bupivacaine and liposomal bupivacaine. We initially made a 4 cm incision overlying the common costal cartilage and performing muscle-sparing separation taking care to avoid the overlying abdominal external oblique muscle fibers. A heavy, permanent suture (Flexi-Tape laterally and 2-0 Ethibond at the tips) was placed at 2-4 points above and through the key rib to reapproximate normal anatomy and maintain stability. Sutures were placed over the top of the superior rib and through the rib below to avoid entering the pleural space and potentially causing a pneumothorax. Careful attention was paid to the intercostal nerves to avoid confounding pain that could unnecessarily skew the results. Complications were assessed intra- and post-operatively throughout the patients' hospitalization and subsequent follow-up examinations.

Figure 1. Depiction of our minimally invasive repair (A) suturing the affected and adjacent rib(s) together as compared with our intraoperative repair (B).

Results

Demographics

Between 2020 and 2022, 31 pediatric patients with clinically diagnosed SRS sought surgical counsel. Table 1 summarizes notable characteristics regarding the demographic, disease burden, and extent of workup. The ages ranged between 12 and 20 years old, with an average age of 17 years old. Most patients were female (77.4%) and 51.6% were within a normal BMI (between 20-25, 19.4% were under 20 and 35% were over 25). Nearly half of all patients had bilateral slipped ribs (48%), 36% occurred unilaterally on the left, and 16% occurred unilaterally on the right. The average number of ribs involved was 2.35, ranging between 1 and 5 ribs. Rib 10 was involved in 97% of the patients. Most commonly involved were two ribs followed by one rib and four ribs, respectively. Symptoms of SRS ranged between 1-60 months and lasted an average of 18.9 months. Hypermobility occurred in 8 patients and a traumatic inciting event occurred in 3 patients.

Before operation, patients averaged 3.0 imaging studies (range 0-10) and had previously seen 4.7 specialists (range 1-12). The two most common specialists seen were pain management and psychiatry/psychology (11 and 9 patients respectively). Analgesic medication use occurred in 90% of patients, with NSAIDs being most prominent (84%), followed by neuropathic medications (29%; examples include anticonvulsants, tricyclic antidepressants, muscle relaxants, benzodiazepines, and topical anesthetics), and 1 patient managed pain with narcotics. Of the invasive procedures noted, nerve blocks and esophagogastroduodenoscopy occurred most frequently (9 and 5 patients, respectively). Cryotherapy, radiofrequency ablation, and colonoscopy occurred in 1 patient each.

Table 1. Patient information regarding their demographics and disease burden.

Procedure

One pediatric surgeon performed the repair on all 31 patients. The average estimated blood loss was 6.7 mL and average operating time was 89.9 minutes. A lipoma was noted to be in the region of the key rib and it was removed on 1 patient intra-operatively. The average length of hospital stay was 1.2 days, with a range between 0 and 6 days. Around 84% of patients stayed between 0 and 1 days. Within 30 days, there was only 1 complication observed (functional neurologic disorder), which extended the hospitalization to 6 days. Recurrent pain was observed in 6 patients (19.4%). Eleven patients sought reoperation (two operations performed on seven patients (22.6%), three operations performed on three patients (9.7%), and five operations performed on one patient (3.2%)). Five of the reoperations occurred on the same side, three on a different side, and three in which a unilateral repair was expanded bilaterally. We performed six of the reoperations, never more than one reoperation per patient. Most reoperations occurred at outside facilities

and expanded to include reconstruction. No intraoperative transfusions were required and no intercostal nerve injuries occurred. No readmission or mortality was observed at one-year post-operation.

Table 2. Operative, hospitalization, and disease recurrence characteristics.

Follow-up

The standardized Örebro Musculoskeletal Pain Screening Questionnaire was administered at dedicated time points pre- and post-operatively to assess efficacy. Pain severity, the feeling of being tense and anxious, depression, and the belief that the pain will persist all decreased appropriately. The abilities to sleep and perform light work as well as optimism towards a chance at a normal life were all increased post-operatively. It should be noted that patients were increasingly lost to follow-up, resulting in reduced numbers of respondents. While this reduces the power and external validity of our study, the results maintained statistical significance throughout.

Table 3. Results from the standardized Örebro Musculoskeletal Pain Assessment at the predetermined time points of preoperation, 1-month post-operatively, 6 months post-operatively, and 12 months post-operatively.
Abbreviations: [a] indicates a score of 10 correspond with the worst quality of life for this question; [b] indicates a score of 10 correspond with the best quality of life for this question

Discussion

Slipping rib syndrome is an underdiagnosed, elusive condition with an extensive medical and financial burden more commonly due to misdiagnosis rather than rarity. It is caused by an intercostal cartilaginous abnormality, either traumatic or congenital, between the anterior false ribs. Due to its instability, there is hypermobility that allows the rib tip to impinge the adjacent intercostal nerve, producing pain. McBeath and Keene sought to replicate the gross anatomic causes via twenty healthy human rib 8-10 specimens, finding that such subluxation was unable to occur without incision of the fibrous intercostal tissue [8]. They concluded that incidental direct or indirect trauma must precipitate the pathology involved. Conversely, additional cadaveric studies by Lawsi *et al*. identified that only 18% of tenth ribs were attached to the ninth rib in 80 human specimens (compared with 100% of ninth ribs attaching to the eighth rib) [9]. This suggests a waning common costal cartilage that predisposes to progressive hypermobility until rib subluxation. Conversely, the failure of fusion may be normal anatomy.

Considering the intermittent and often vague presentation, diagnosis remains challenging. Numerous case reports have highlighted unnecessary referrals to cardiologists, gastroenterologists, and psychiatrists, as well as a host of imaging modalities (X-ray, CT, MRI, ultrasound, upper GI series, barium enemas) and procedures (cholecystectomy, laparotomy, laparoscopy) before concluding SRS [1, 10-11]. The treatment for slipped rib syndrome remains nearly as ambiguous as its diagnosis. Numerous conservative measures only demonstrated minimal or transient efficacy, including NSAIDs, anesthetics (topical or injected nerve block), steroids, and physical therapy [12-13]. The accepted definitive treatment for SRS is costal cartilage excision without rib resection, which is similar to the Ravitch procedure and takes care to avoid the neurovascular bundle. Since its inception in 1922 by Davies-Colley, there have only been minimal adjustments to the operation, such as laparoscopy and rib resection [14-15]. Despite boasting 72% cure rate, it does not come without costs in the way of technical difficulty, invasiveness, loss of structural stability, removal of the cartilage/rib's protective function, recurrent or continued pain, and a recurrence rate around 22-26% [14,16]. Thus, there is ample opportunity for improvement in surgical approach that most recently manifested through rib fixation via plates or sutures [6,17].

Hansen *et al*. reported positive early post-operative outcomes for suture fixation in the adult SRS population in 2020 [6]. The technical simplicity of the operation itself was desirable, as it was performed largely

without issue and well-tolerated in most patients. We sought to elucidate the efficacy of nonabsorbable suture fixation of the key rib in the pediatric SRS population. The average length of hospitalization was 1.2 days and the only complication noted was functional neurologic disorder, extending the patient's hospitalization to six days. Throughout our scheduled follow-ups, we were encouraged by decreased pain medication use and elimination of narcotic and neuropathic medications. Patients found improvements in pain severity, sleep, ability to perform light work, and optimism towards normality, as well as a reduction in depression and anxiety. Our results echo the positive early outcomes observed in Dr. Hansen's study with nonabsorbable suture fixation.

Figure 2. Results from the standardized Örebro Musculoskeletal Pain Assessment at the predetermined time points of preoperation, 1-month post-operatively, 6 months post-operatively, and 12 months post-operatively. Solid lines correspond with descriptors that indicate a better life with a lower score. Dashed lines correspond with descriptors that indicate a better life with a higher score.

While impressed with the initial success of this procedure, further analysis revealed only transient improvements in many patients. Six patients had recurrence of symptoms shortly post-operatively and eleven patients sought reoperation. We are unable to determine the exact cause of recurrence, but we hypothesize it is related to the durability of knot and suture integrity, increased activity/anatomical development in the pediatric population, and psychosomatic pain. Suture is known to break at lower tensile strengths as the material expires, not even accounting for in vivo variables [18]. As pediatric patients grow and their chest wall expands, this increases tension and possibly loosens the fixation over time. Our recurrence and reoperative rates mirror that in the literature, but it should be noted that we followed our cohort for a shorter duration [19]. Fraser *et al*. demonstrated that the time to reoperation is 1.6 years [19]. This highlights that our percentages may be an underestimation, as the majority of patients were lost to follow-up at one-year post-operation. Of note, the authors concluded success with costal cartilage resection, yet 41% were lost to follow-up, similar to our series.

SRS has been associated with psychiatric conditions (namely anxiety and depression) without clarity on how exacerbation of one affects the other [20-21]. Nearly 42% of our studied population had formal psychiatric diagnoses and 29% regularly met with a psychiatrist or psychologist. One patient had suicidal ideation. Additionally, our population was evaluated during the COVID-19 pandemic, when mental health was affecting children and adolescents at elevated rates [22-23]. Our child psychology team met with most of our patients preoperatively or postoperatively to discuss management of chronic pain syndromes and the possibility of central sensitization, wherein synaptic plasticity creates increased nociceptive responsiveness [24]. As with most chronic pain syndromes, the success of treatment largely depends on a multimodal approach and routine follow-up. This is exemplified by Ashar *et al*. in which routine pain reprocessing therapy provided significant, durable pain relief in patients with chronic back pain [25]. Along a similar vein, Spence described the case of an SRS patient that experienced relief from his recurrent symptoms (recalcitrant to injections and surgery) with the initiation of antidepressants [20]. Future directions could explore the efficacy of such psychological treatment in the SRS population, potentially avoiding surgery altogether.

Rib fixation with nonabsorbable sutures remains relatively understudied without sufficient power or evidence to recommend. Our study, along with similar SRS studies, is no different. Limitations of this study include a small patient population, no control group comparison, no long-term follow-up, selection bias, and not adjusting for confounders, such as psychiatric illnesses. Regarding selection bias, there was no blinding and limited follow-up. Only 20 patients (64.5%) followed-up at 6 months and 9 patients (29.0%) at 12 months. Many patients that sought reoperation discontinued care with us.

Conclusion

We do not believe sutured rib fixation in SRS patients currently has the durability or evidence for recommendation in the pediatric population. Further long-term evaluation is necessary to determine the exact efficacy involved with sutured rib fixation and other areas for potential improvement in the SRS treatment regimen. Given the variability in presentation, diagnosis, and treatment response, SRS requires a multimodal approach to treatment.

Acknowledgements

Author contributions: AP acquired and interpreted data, critically reviewed and revised the manuscript, and approved it in its final form. TCC acquired and interpreted data, drafted the manuscript, critically reviewed and revised the manuscript, and approved it in its final form. AEG performed analysis and interpretation of data. SRM and DRH performed psychological analysis. RTW provided guidance from a pediatric pain perspective. DBK conceptualized the study, supervised data acquisition, analysis, and interpretation, critically reviewed and revised the manuscript, and approved it in its final form.

Data sharing statement

Data available: No

Explanation: Given the relative scarcity with which this operation was performed at Mayo Clinic in the pediatric population, the authors elected not to share this information, even when deidentified, for concerns of a HIPAA violation. Aggregate patient data has been made available in the manuscript.

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Patient Demographics (n=31)	
Age	17.0 years (12-20 years)
Sex	
Male	7 (22.6%)
Female	24 (77.4%)
BMI (kg/m^2)	23.9 (17.8-32.3)
Laterality	
Right	5 (16.1%)
Left	11 (35.5%)
Bilateral	15 (48.4%)
Number of ribs involved	2.4 (1-5)
1 rib	7 (22.6%)
2 ribs	14 (45.2%)
3 ribs	3 (9.7%)
4 ribs	6 (19.4%)
5 ribs	1 (3.2%)
Rib 10 involvement	30 (96.8%)
Pain duration (months)	18.9 months (1-60 months)
Associated comorbidity	
Hypermobility	8 (25.8%)
Traumatic cause	3 (9.7%)
Specialists seen	4.7 (1-12)
Pain management	11 (35.5%)
Psychiatrist/psychologist	9 (29.0%)
Imaging studies performed	3.0 (0-10)
Medications	28 (90.3%)
NSAIDs	26 (83.9%)
Neuropathic	9 (29.0%)
Narcotics	1 (3.2%)
Invasive procedures	
Nerve blocks	9 (29.0%)
Cryotherapy	1 (3.2%)
Radiofrequency ablation	1 (3.2%)
Endoscopy	5 (16.1%)
Colonoscopy	1 (3.2%)

Table 1. Patient information regarding their demographics and disease burden.

Operation Characteristics	
Estimated blood loss (mL)	6.7 (0-20)
Operating time (min)	89.9 (32-232)
Length of stay	1.2 days (0-6)
0-1 days	26 (83.9%)
2-3 days	3 (9.7%)
4-6 days	2 (6.5%)
Complications	1 (3.2%)
Reoperations	11 (35.5%)
Two	7 (22.6%)
Three	3 (9.7%)
Five	1 (3.2%)
Reoperation laterality	
Same side	5 (16.1%)
Different side	3 (9.7%)
Unilateral to bilateral	3 (9.7%)
Recurrent pain	6 (19.4%)

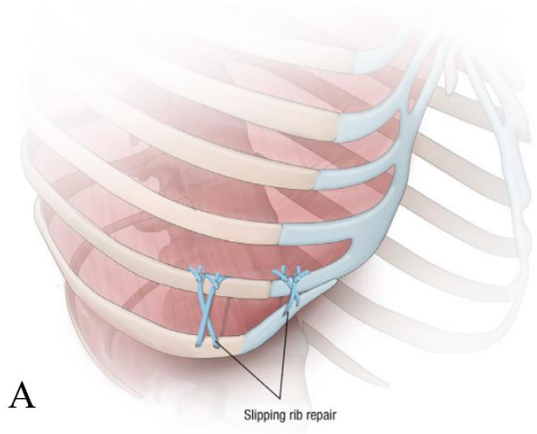
Table 2. Operative, hospitalization, and symptom recurrence characteristics.

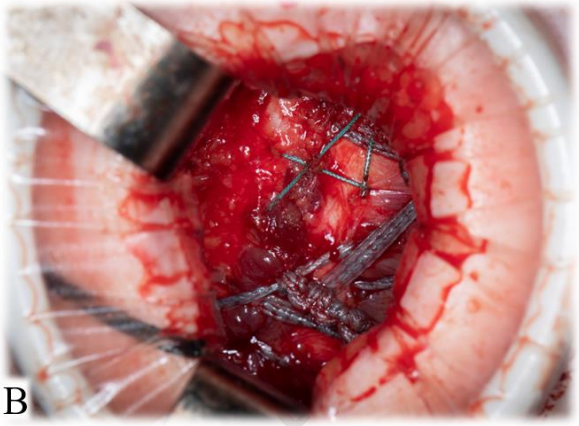
Örebro Musculoskeletal Pain Screening

Survey Question	Preoperation (n=30)	1-month post-operation (n=30)	6-months post-operation (n=20)	12-months post-operation (n=9)	p-value
Pain severity[a]	7.5	3.4	4.2	1.5	<0.001
Ability to do light work[b]	4.4	7.4	7.5	9.5	<0.001
Ability to sleep[b]	5.0	7.7	7.2	9.2	<0.001
Tense and anxious[a]	5.7	3.9	4.7	3.1	0.001
Depressed[a]	3.4	1.6	2.8	1.2	<0.001
Believe the pain will persist[a]	7.6	3.0	4.5	2.4	<0.001
Chance of normal life[b]	4.9	8.5	7.1	9.8	<0.001

Table 3. Results from the standardized Örebro Musculoskeletal Pain Assessment at the predetermined time points of preoperation, 1-month post-operatively, 6 months post-operatively, and 12 months post-operatively.

Abbreviations: [a] indicates a score of 10 correspond with the worst quality of life for this question; [b] indicates a score of 10 correspond with the best quality of life for this question





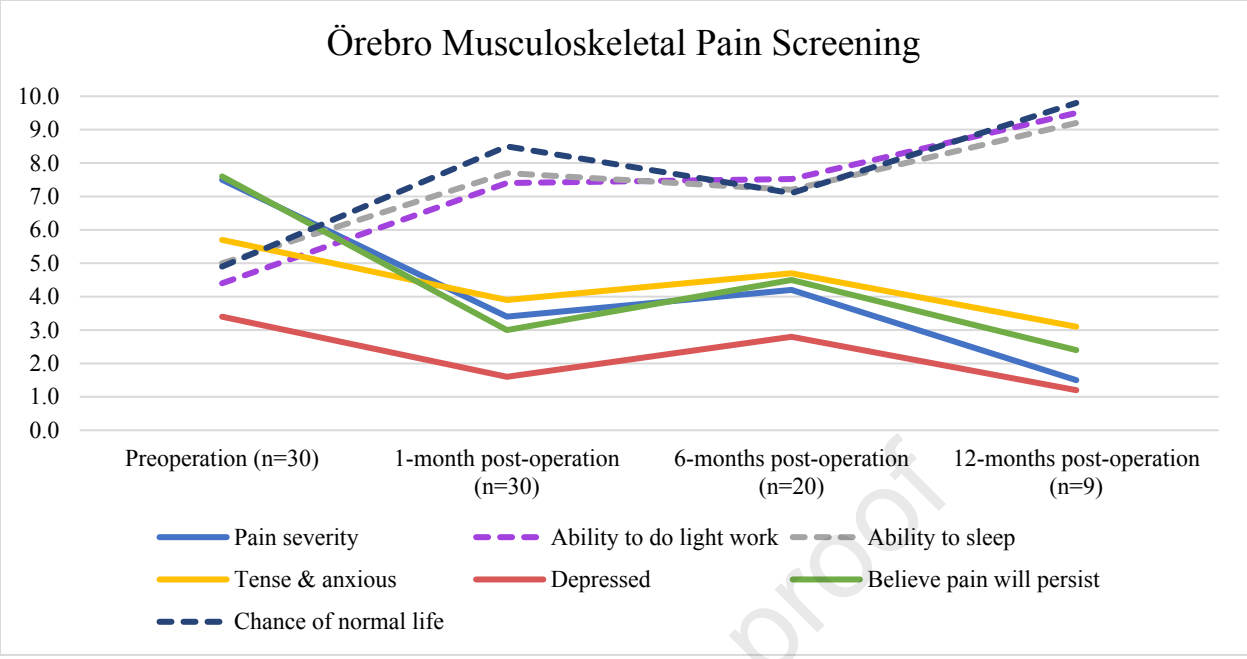


Figure 2. Results from the standardized Örebro Musculoskeletal Pain Assessment at the predetermined time points of preoperation, 1-month post-operatively, 6 months post-operatively, and 12 months post-operatively. Solid lines correspond with descriptors that indicate a better life with a lower score. Dashed lines correspond with descriptors that indicate a better life with a higher score.

Highlights:

1. What is currently known about this topic?
    i. The gold standard treatment for slipped rib syndrome is costal cartilage resection with or without rib resection. Minimally invasive restoration of normal anatomy via nonabsorbable sutures has been described in the adult population with encouraging results.
2. What new information is contained in this article?
    i. Pediatric patients with SRS demonstrated an early positive response to suture fixation without costal cartilage excision. Reoperation and recurrent pain remained significant in our cohort, putting into question the durability and long-term efficacy of this repair.