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Vertical rib plating for the treatment of slipping rib syndrome☆

Lisa E. McMahon [a,b,c,*], Nicole A. Salevitz [a], David M. Notrica [a,b,c]

[a] University of Arizona College of Medicine Phoenix, Phoenix, AZ, USA
[b] Phoenix Children's Hospital, Phoenix, AZ, USA
[c] Mayo Clinical School of Medicine, Phoenix, AZ, USA

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ABSTRACT

Background: Slipping rib syndrome (SRS) is a painful condition of hypermobile, detached lower costal cartilages impinging the intercostal nerves. While surgical resection of the cartilaginous rib is reported as definitive treatment, recurrent symptoms are common. We describe the addition of vertical bioabsorbable rib plating to decrease recurrence.

Methods: An IRB-approved (#17-098), single institution, retrospective chart review was performed for patients who presented with SRS from 2009 to 2019 at a single institution. Descriptive statistics were used to compare patients with and without bioabsorbable vertical plating.

Results: A total of 85 patients (71.8% female, mean age 17.7 years) underwent evaluation for SRS. Of the 70 who underwent surgery solely for SRS, 29 (41%) underwent vertical rib plating at initial surgery while 41 (58.6%) did not. Recurrent symptoms developed in 7 (17.1%) unplated patients, while only 1 (3.4%) plated patient had recurrent SRS (which occurred after a motor vehicle crash) ($p = 0.0116$). Of the 8 with recurrent symptoms, 3 underwent vertical plating at a subsequent operation.

Conclusion: Rate of recurrent symptoms after cartilage resection alone for SRS was 17.1%. The addition of vertical rib plating with bioabsorbable plates decreased recurrent symptoms and improved outcomes.

Level of evidence: II.

Slipping rib syndrome (SRS) is a painful condition of the costal margin owing to abnormal movement of the false ribs (8–10) related to unstable costal cartilaginous attachments (Fig. 1). This hypermotility can allow ribs to slip under the adjacent rib provoking pain and discomfort owing to irritation of the underlying intercostal nerve. Since its initial introduction into the medical literature in 1919 [1] SRS continues to be underdiagnosed despite diagnosis on physical examinations using the hooking maneuver [2,3] or radiographic diagnosis using dynamic ultrasound [4]. The painful hooking maneuver is not necessary for diagnosis, and slipping ribs can also be detected with careful palpation of the costal margin when the patient is supine with the knees bent, relaxing the abdominal wall without hooking the ribs. Despite these opportunities for detection, patients typically present after exhaustive testing fails to identify the diagnosis. [5].

Following surgical resection of the cartilaginous portion of the slipping ribs (Fig. 2), a high rate of recurrence is reported [6,7]. Approximately 26% of patients require reoperation [8], which is similar to our initial experience with just cartilage excision surgery. Resection of the malformed, unattached cartilages has been the standard procedure for SRS. Although bony rib resection may be performed for subluxation, the bony ribs are not themselves deformed and preventing subluxation without resection would offer the most directed solution. Thus, we developed a novel approach to reduce recurrence of SRS owing to bony rib subluxation without complete resection.

We introduce our experience with vertical rib plating using bioabsorbable plates in conjunction with excision of slipping cartilages for treatment of SRS.

1. Materials and methods

Following IRB approval (#17-098), a retrospective chart review was performed of all patients who presented with SRS to a single institution between January 1, 2009 and August 31, 2019. Demographic data, preoperative symptoms and examination, diagnostic studies, perioperative, postoperative, and follow up data were collected. The cohort included patients managed with conservative, nonsurgical pain control methods, cases managed with surgical intervention without plating, as well as those who underwent bioabsorbable plating (Poly-L/DL Lactide 70:30 blend; Biobridge™, Acute Innovations, Hillsboro, Oregon USA). Demographic data included patient's age, gender, race, experience with pain,

Abbreviations: SRS, slipping rib syndrome; IRB, internal review board; MIRPE, minimally invasive repair of pectus excavatum; IQR, interquartile ratio; Sig, significant; Abx, antibiotics; req, requiring; US, ultrasound.

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* Corresponding Author at: Phoenix Children's Hospital, 1919 E Thomas Road, Phoenix, AZ 85016. Tel.: +1 602 933 0016.
E-mail address: lmcmahon@phoenixchildrens.com (L.E. McMahon).

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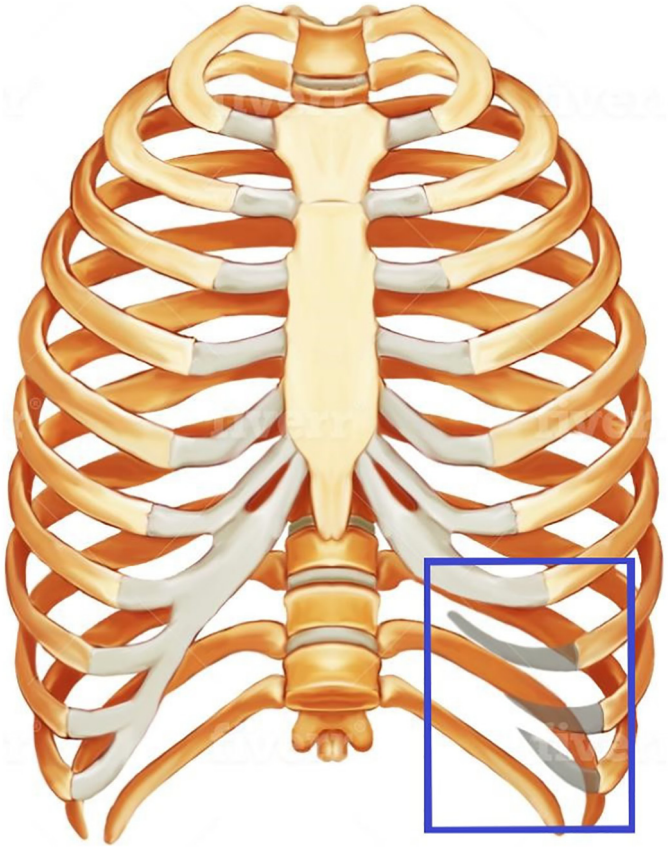

Fig. 1. The 8th–10th ribs are also called the false ribs since they do not directly attach to the sternum. These are the main ribs at risk for SRS.

athletic status, and activity limitations. Clinic visit and surgical notes were evaluated, as well as relevant imaging reports not limited to dynamic ultrasounds. Descriptive statistics were used to summarize patient demographics, clinical indications and clinical outcomes of surgical interventions for SRS. Mann–Whitney U Tests (with Yates correction) were used to assess significant differences in median values between the treatment and the control cohorts; χ^2 tests of independence were used to assess significant differences in patient proportions across demographics, clinical indications, complications and outcomes. Statistical significance was set at $p \leq 0.05$. All statistical analyses were completed in SPSS Version 26.0 (Armonk, NY). One surgeon (LEM) performed the vast majority of the operations, but four other pediatric surgeons also performed the procedures.

Fig. 2. The 8th and 9th costal cartilages are excised to the costochondral junction.

1.1. Description of the procedure

Using guidance from physical exam as well as dynamic ultrasound to localize slipping ribs, incisions and chest wall dissections were performed over areas of movement and pain. Intraoperative submuscular exam informed the extent of resection needed to excise the abnormal cartilage (Fig. 2) as well as whether further stabilization with bioabsorbable plating would be necessary. The decision to plate was based on the surgeon's ability to manually slip the affected bony rib over, under, or into the adjacent rib. Where medial portions of cartilage were removed in their entirety, care was taken protect surrounding structures and intercostal neurovascular bundles from injury. We resected the cartilages in their entirety, along with the perichondrium and do not advocate for perichondrial sparing owing to the high likelihood of cartilaginous regrowth.

As previously described [9], these plates are flexible and easy to manipulate when placed in a warm saline bath at 140 °F. Plates are attached to the bony portion of a superior nonsubluxing rib, and then across all involved bony ribs (typically 3–4 ribs). Plates are selected and cut to match ribs, and two #1 nonabsorbable sutures are placed into each rib. The plate is then parachuted down and secured to the ribs (Fig. 3). This technique assures the ribs are secured apart from each other and able to move in unison, but without subluxation or abutting each other. The holes within the plate allow suture to provide adequate stabilization without the need for screws (Fig. 4). Fascia and skin closure over the plate is simple and leaves excellent cosmetic results owing to the small incision.

2. Results

Of 85 patients who presented to this institution complaining of abnormal rib movement leading to diagnosis with SRS, 79 underwent surgical intervention. Additionally, 9 patients underwent minimally invasive repair of pectus excavatum (MIRPE) or another separate procedure such as rib flare repair at the same surgery; these patients had sim-

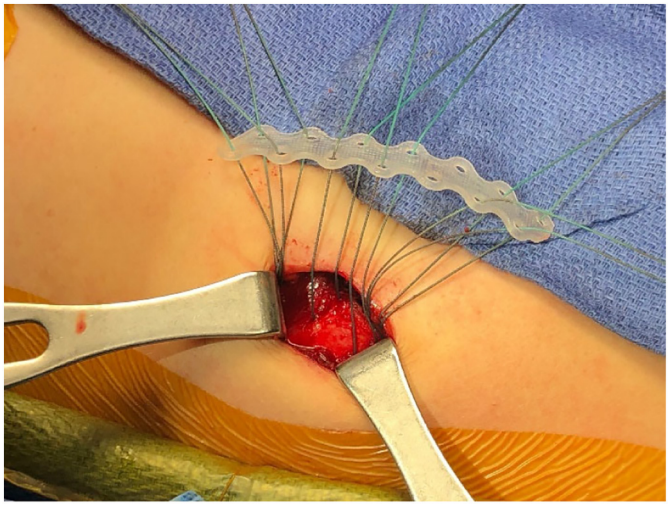

Fig. 3. The flexible bioabsorbable plate is fashioned to fit the chest wall. Two nonabsorbable sutures are placed on each rib and through the holes of the plate, and then parachuted down to the ribs, securing a neocostal margin.

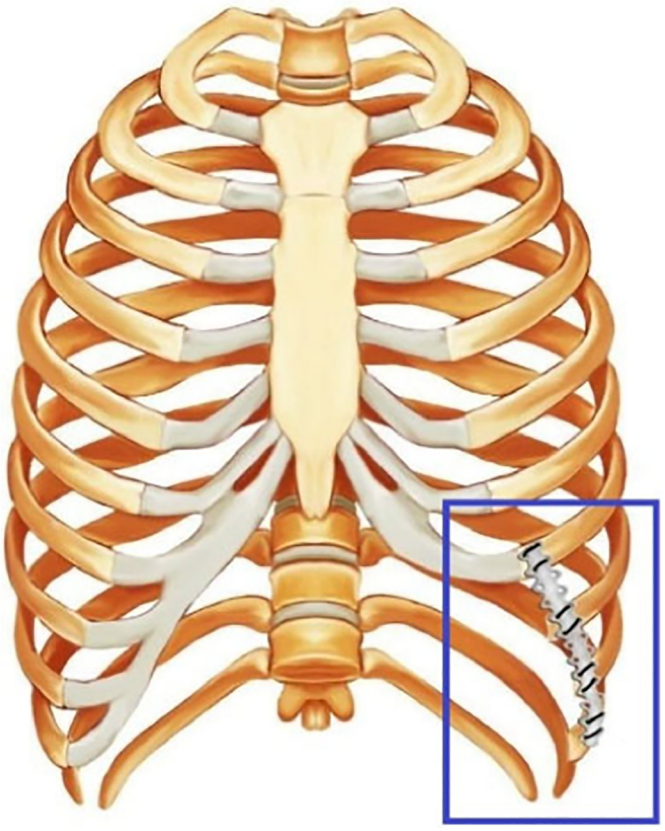

Fig. 4. The result of plating ribs 7–10 after removing the slipping ribs.

ilar complaints of rib pain or abnormal costal movement and all received SRS diagnosis with their initial consult. Their SRS procedure was performed during the same operation as the MIRPE, although one patient did have a contralateral repair of SRS one year after her initial operation. These 9 patients were excluded from the following measurements, leaving a cohort of 70 patients who were operated on for SRS only.

There were 6 patients who did not undergo a surgical procedure; 3 were recommended to have an operation and are awaiting scheduling while the other 3 are exhausting conservative management first. Non-operative management consisted of medical interventions for pain as well nerve blocks and physical therapy. These options were also undertaken by more than half of the patients who eventually underwent an operation; the predominant treatments were nonsteroidal anti-inflammatory medications (45, 64.3%), rest/stretching/heat (20, 28.6%), and some who sought pain relief from opioids (10, 14.3%). At least 46 (65.7%) had previously seen one or more specialists such as a pain management physician, spine specialist, gastroenterologist, or cardiologist before presenting at this institution.

In patients undergoing a unilateral procedure, plating extended the mean intraoperative time by 10.6 min and the median time by 28.5 min ($p = 0.24$). In bilateral cases, plating added 48.2 min to the mean operative time and 38 min to the median time ($p = 0.001$). Post-operative length of stay was 11 h longer in plated patients vs unplated patients ($p = 0.001$) (Table 1).

For surgical patients, the mean age at symptom onset was 15.8 years, but the mean age at diagnosis was 17.7 years old, indicating a long delay prior to reaching the correct diagnosis. The main symptom was thoracoabdominal pain, with 70 (100.0%) patients reporting discomfort that interfered with daily life, most rating their pain 6–7 on a 10-point scale. Dyspnea or pleuritic chest pain was an early symptom in 16 (22.9%) patients. Only 4 patients had been diagnosed with SRS at an outside facility prior to our evaluation, and 2 (50%) of these patients had already undergone 2–3 corrective procedures for SRS (without plating) which did not resolve the issue. Seven (10.0%) had gastrointestinal complaints such as GERD, biliary dyskinesia, recurrent gastritis, or pancreatic divisum.

Concomitant diagnosis was also common, and 40 patients (57.1%) had one or several additional diagnoses. Rib flare was associated in 22 (30.0%). Thirteen (18.6%) had deformities such as scoliosis, pectus excavatum or carinatum, or general joint hypermobility.

The majority of surgically managed patients were female (51, 72.9%) and self-identified as athletes (42, 60.0%), often participating in sports such as running, swimming, wrestling and martial arts. A minority (21, 30.0%) experienced inciting events that they felt corresponded to the onset of slipping rib symptoms of abnormal movement and pain. These events ranged from motor vehicle accidents to sports injuries to workplace strains from lifting heavy objects.

Preoperative diagnosis involved several techniques including physical exam, hooking maneuver, and dynamic ultrasound. Hooking maneuver was performed on 20 (28.6%) patients, with 17 (85.0%) of these showing abnormal movement. Physical exam without hooking showed abnormal movement with palpation in 62 (88.6%) patients. 8 (11.4%) of the remaining patients were found to have only pain or rib flare with physical exam palpation, though these patients then underwent dynamic ultrasound which confirmed slipping rib syndrome. Dynamic ultrasound was available at this institution starting March 2017 [11]. Of the 54 patients who underwent dynamic ultrasound, the imaging confirmed positive exam findings in 42 (77.8%) patients and detected abnormal movement in 7 (87.5%) patients who had an unremarkable physical exam. Only 4 (7.4%) patients had positive physical exams and no evidence of abnormal rib movement with the cartilages under- or overriding adjacent cartilages on dynamic ultrasound. These patients were among the first cohort of patients undergoing dynamic ultrasound.

Of the 70 patients who underwent an operation for SRS, 35 (50.0%) were completed before plating was adopted at this institution and, in the entire cohort, 40 (57.1%) patients did not undergo plating during their first operation. Addition of plating did not have any deleterious ef-

Table 1
Comparison of plated vs. unplated patients.

	Plated	Unplated	p value
Number of patients	29	41	
Operative time, unilateral (min)			
Mean	93.8	83.2	
Median [IQR]	98.0 [86.0, 99.5]	83.5 [67.0, 94.0]	0.24
Range	76–100	50–140	
Operative time, bilateral (min)			
Mean	157.3	109.2	
Median [IQR]	150 [138.0, 175]	112 [89.5, 126]	0.001*
Range	115–259	69–136	
Postoperative LOS (h)			
Mean	45.5	35.3	
Median [IQR]	43.5 [31, 52]	25 [24, 48]	0.001*
Complications	Sig pain: 4 Ileus: 1	Sig pain: 4 Urinary retention: 1 Seroma: 1 Testicular hematoma:1 Erythema req. abx: 2	
Laterality of operation			
Unilateral (%)	5 (17.2)	23 (56.1)	0.002*
Bilateral (%)	24 (82.8)	17 (41.5)	
Number of cartilages excised			
Mean	4.2	3.6	
Median	4	3.5	0.62
Recurrences (%)	1 (3.4)	7 (17.1)	0.0116*

Abbreviations: IQR = interquartile ratio, Sig = significant, abx = antibiotics, req. = requiring.

fect on postoperative complication rate, with both groups having similarly mild event profiles. Mean follow up from surgery was 2.97 years (range 8.1 months to 9.2 years). A total of 67 (83%) patients had in-person follow-up.

One patient who was plated experienced a recurrence of SRS. She returned to clinic 3 months postoperatively to report that her pain had returned following a motor vehicle crash that occurred 6 weeks after her procedure. Dynamic ultrasound was positive for SRS with slipping of ribs 8 and 9. Conservative management was pursued and further surgery is being considered 16 months later.

One plated patient was hit by a car while she was running 8 months after surgery. This patient returned to clinic complaining of pain and was found to have a fractured cartilage superior to the plated area on CT (computed tomography). Dynamic ultrasound did not demonstrate recurrent slipping ribs where she was plated. She underwent reoperation for repair of her fractured cartilage 13 months later and has done well since.

Seven (17.1%) of the 41 unplated patients experienced recurrence, defined as returned pain associated with abnormal movement of detached cartilage, requiring additional surgery on the ipsilateral side. All recurrences were confirmed with abnormal physical exam findings and the majority (71.4%) had positive dynamic ultrasounds. Of the seven unplated patients who experienced recurrences, the time between surgery and return of pain ranged from 1.5 months to 79 months (6.5 years). The mean time to recurrence was 13.9 months, with a median of 6 months. Six (85.7%) patients underwent more than one additional operation to remove other symptomatic cartilages or bony ribs. Three of these patients were eventually plated at reoperation, with good results to date [6].

No patients who were plated at their first surgery and did not have an accident with a vehicle experienced SRS recurrence.

In our cohort, only females recurred and those who had earlier onset of symptoms had a higher likelihood of recurrence (Table 2). One surgeon performed 53/70 of the procedures and had 6 of the recurrences, including the one recurrence in the patient who underwent plating at the initial procedure.

Table 2
Recurrence risk factors.

	Recurrence ($n = 8$) (11.4%)	No recurrence ($n = 62$) (88.6%)	p-value
Sex			
Female (n (%))	8 (11.4)	43 (69.4)	0.05*
Male (n (%))	0 (0.0)	19 (30.5)	
Athlete			
Yes (n (%))	6 (8.6)	36 (58.1)	0.15
No (n (%))	1 (1.4)	20 (32.3)	
Unknown (n (%))	1 (1.4)	6 (9.7)	
Inciting event			
Yes	2 (2.8)	19 (30.6)	0.27
No	6 (8.6)	43 (69.4)	
Age at symptom onset (years)			
Mean	12.5	16.2	
Median	13	16	
Range	10–16	10–26	0.012*
Age at diagnosis (years)			
Mean	14	18.2	
Median	14	17	
Range	10–21	10–27	0.017*
SRS on US			
Yes	4 (5.7)	41 (66.1)	0.14
No	2 (2.8)	7 (11.3)	
Unknown	0	1 (1.6)	
Initial surgery			
Unilateral	4 (5.7)	25 (40.3)	0.90
Bilateral	4 (5.7)	37 (59.7)	

Abbreviations: US = ultrasound.
* = statistically significant.

3. Discussion

Recurrence of SRS is unfortunately common after excision of slipping cartilages. This recurrence often comes in the form of persistently or newly hypermobile bony ribs evidenced on imaging studies such as dynamic US or physical exam findings such as palpation and the hooking maneuver. The returned motion is often associated with pain, leaving both the patient and surgeon frustrated. The adoption of vertical bioabsorbable plating to recreate a secure costal margin has shown great promise in this active population. Vertical plating, along with ensuring all of the mobile cartilages are removed, decreases rate of recurrence in these patients.

Bioabsorbable plates are commonly used in many operations, from other chest wall procedures [10] to facial fracture repair and orthopedic procedures such as clavicle fixations [11,12]. These plates have been found to be safe and reliable in pediatric populations, and have a superior material profile versus metal implants. Bioabsorbable plates have lower torsional stiffness with comparable compression stiffness, holding up well under physiologic forces [12]. Additionally, it is more likely for them to fail slowly through "elastic deformation". The plate is able to absorb more burden than the bone, putting patients at lower risk for screw–bone interface failure that often plagues metal implants [12]. As the plates are resorbed, a mild inflammatory response leaves behind scar tissue that helps to serve as a barrier between the ribs.

Plates are easily shaped to fit chest walls and they are lower profile than commonly used metal plates, with little risk of a visible ridge under the skin. Addition of the plates does not increase postoperative complications and was shown to decrease recurrence of SRS.

Plating did not increase the frequency of severe postoperative pain events. Although plating increased intraoperative time and length of stay, it decreased the recurrence rate significantly. Whereas the literature reports that nearly a fourth of patients will experience recurrence [8], plating resulted in a recurrence rate of 3.4% in this cohort.

There are limitations of this study. One is the length of follow-up in the plated patients. The earliest plating within this cohort occurred in January 2018, so further studies will be necessary to investigate long-term outcomes. This limitation is important, because although the bars have lost significant strength by a year, they are not completely resorbed until the second year. It will be important to investigate whether patients experience recurrent symptoms after this window, although our initial experience would suggest that this is minimal. Although this is the largest cohort of patients undergoing SRS surgery that has been reported, the group of plated patients is still limited in size; further studies with increased patient number should be pursued. Furthermore, multivariable analysis would be valuable as more results become available in the plated cohort in the midterm. Additionally, since many patients were not from the local area, only 83% of patients had follow-up after their initial postop visit.

The inclusion criteria for plating we have used are based on the intraoperative physical exam. If the bones are overly flexible and able to be easily manipulated above or below the adjacent rib after excision of the cartilage, they are plated. It is unclear that this is the best method to determine the need for plating. In addition, as our experience has increased, we have done a better job at excising all abnormally attached cartilages, thus likely decreasing the overall recurrence rate.

4. Conclusion

The diagnosis of SRS can be elusive and a significant delay between onset of symptoms and diagnosis is common. Moreover, recurrence after rib resection alone is 16.7%. Vertical rib plating with bioabsorbable plates significantly decreased the rate of recurrence in our early experience.

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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