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CASE SERIES

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The use of dynamic ultrasound in the diagnosis of slipping rib syndrome

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1 | INTRODUCTION

Slipping rib syndrome (SRS) was first reported in 1919 by Cyriax.[1] The ribs move in relation to one other during normal biomechanical movements, such as breathing. The degree of stress and movement imparted on the ribs is increased during activities which require physical exertion, such as rowing, hockey, and athletics.[2] SRS refers to the mechanical impingement of an intercostal nerve by excessive excursion of one rib in relation to another, generally due to deficient fibrous attachment of the 8th, 9th, or 10th false ribs amongst other causes.[3-5] This can result in lower chest and/or upper abdominal symptoms including pain and clicking sensations. The diagnosis of SRS is notoriously difficult, due to the overlapping clinical presentation of other more common entities, including abdominal visceral diseases. Radiological investigations are often fruitless.[6,7] There is a purported predilection for young females, and an onset in those after a relevant episode of trauma.[8] We report three cases in which dynamic ultrasound is successfully used to target pathological ribs for therapeutic surgery when SRS is clinically suspected. Our series is unique as we have comprised a team of a Sonographer, consultant Radiologist, and a consultant Cardiothoracic Surgeon. This has proven effective in creating a pathway to provide accurate and expedited diagnosis with subsequent treatment for those with suspected SRS. Initially queried as a novel tool in this regard, we feel dynamic ultrasound in the hands of an experienced operator is the most reliable modality in the diagnosis of SRS.

2 | METHOD

Patients were first asked to describe their symptomology and site(s) of pain as best possible. A brief clinical examination was then performed with the patient resting in supine on a standard examination table to ascertain specific regions of interest through provocation testing, such as the Hook manoeuvre (manual ventrocranial mobilisation of the rib) and abdominal crunches. A Toshiba Aplio i800 ultrasound machine (Toshiba Medical Systems, Tochigi, Japan) using a high-frequency i18LX5 linear transducer (Toshiba Medical Systems, Tochigi, Japan) was used to obtain anatomical landmarks and count the number of ribs. The lowest visualised rib at the posterior flank was assumed to be the 12th in all cases; moving cranially, the next rib was counted as the 11th rib, the next the 10th rib, and so forth. Note was made of chondral bridge sites and any significant morphological anomalies of the chondral cartilages and rib tips; such as marked

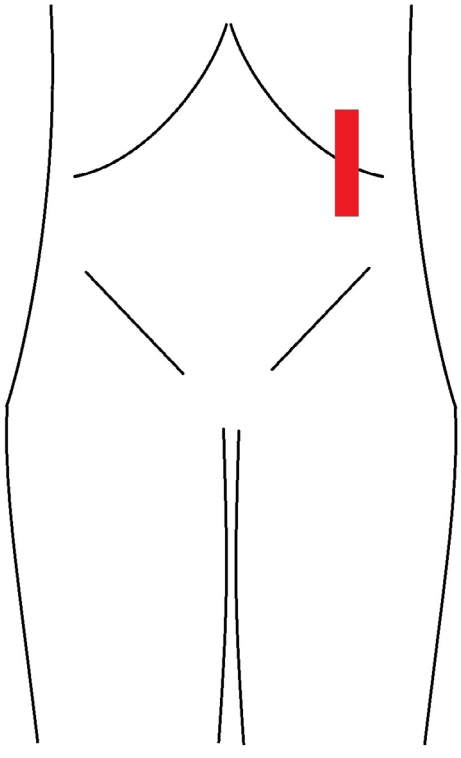


FIGURE 1 Red rectangular marker corresponds to probe position at anterior costal margin

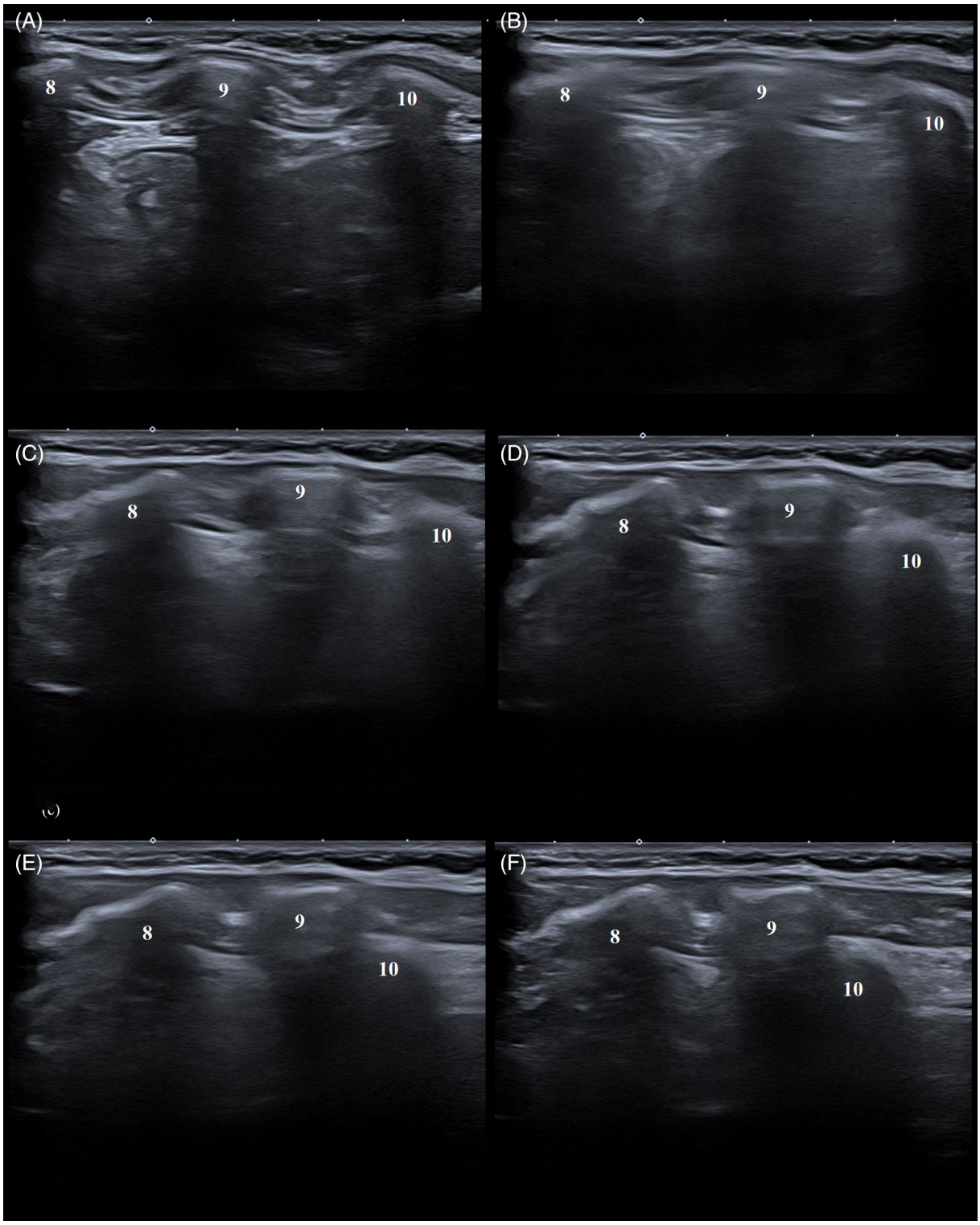


FIGURE 2 Excessive excursion of the 10th rib in relation to the 9th. A-F, Sagittal ultrasound over the left anterior costal margin. During abdominal flexion, the 10th rib demonstrates posterior and cranial translocation in relation to the 9th rib. Note the normal physiological movement between the 9th and 8th ribs, which remain in line with no subluxation. "10" = tenth rib, "9" = ninth rib, "8" = eight rib

change in angulation or bifurcations. To perform dynamic studies, the probe was positioned in short axis of the rib over the anterior costal margin on the symptomatic side at the suspected rib conflict – generally the 9th or 10th rib tip (approximately mid clavicular line) (Figure 1). With gentle pressure applied to the transducer to minimise slippage off the target site, the patient was asked to do a gradual abdominal crunch. As best achievable, the transducer was moved with the patient's costal margin, usually to a semi-oblique plane, to keep the desired rib in short axis view. If available, a 2nd clinician would assist the patient by placing a hand on their upper back to aid them in

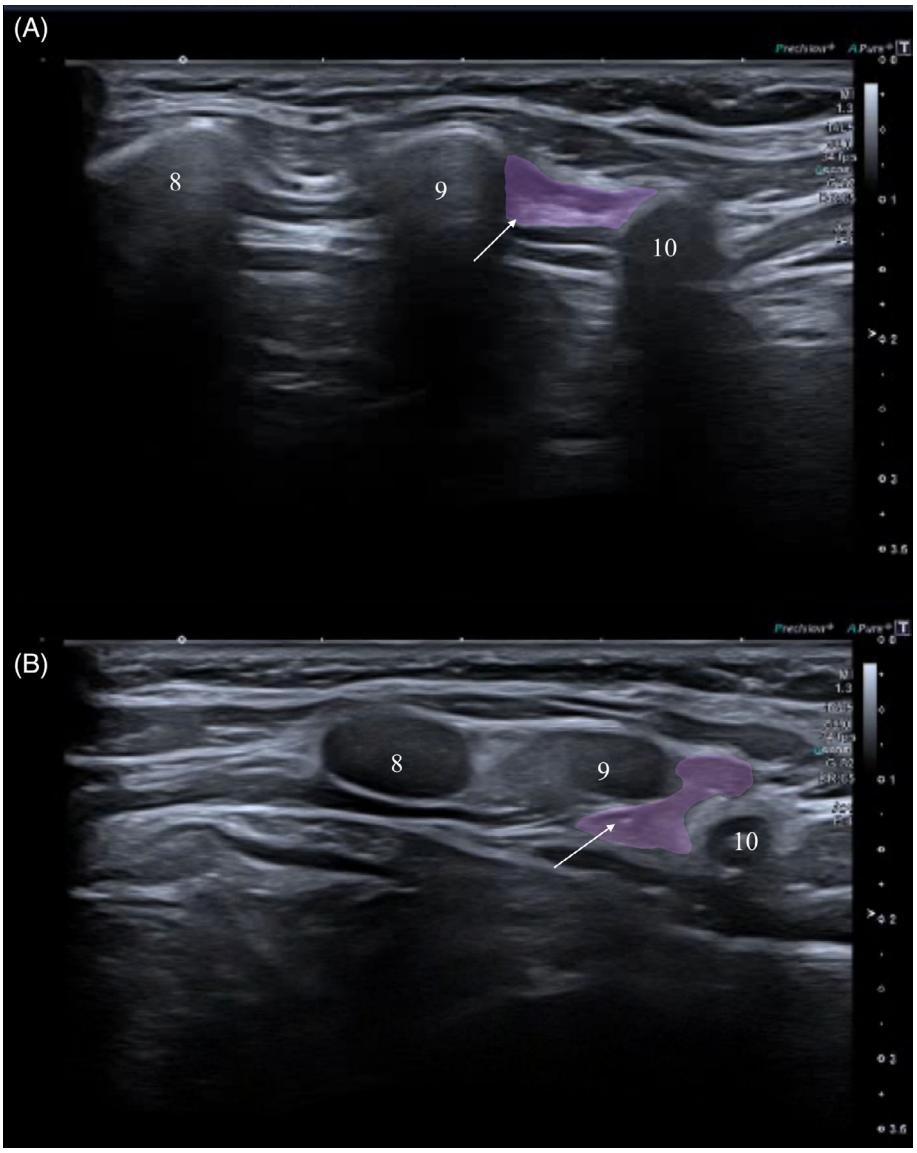


FIGURE 3 Dumbbell morphology of the intercostal muscle belly. Sagittal ultrasound of the left anterior costal margin comparing the appearance of the 9-10 intercostal muscle belly at rest A, and during maximal abdominal flexion B. The purple shading represents the muscle belly, that is compressed into a "dumbbell" shape. The solid white arrow corresponds to the intercostal neurovascular bundle

a smooth crunch manoeuvre. If applicable, the patient would also be asked to recreate any specific body movement and/or positioning they felt elicited the symptoms. This was often necessary to recreate the clicking/popping sensation when relevant. Abnormal movement of any chondral rib(s) was observed, including the surrounding soft tissue, and recorded using still images and the cineloop function. Colour Doppler interrogation was utilised to locate the intercostal neurovascular bundle and assess for areas of hyperaemia.

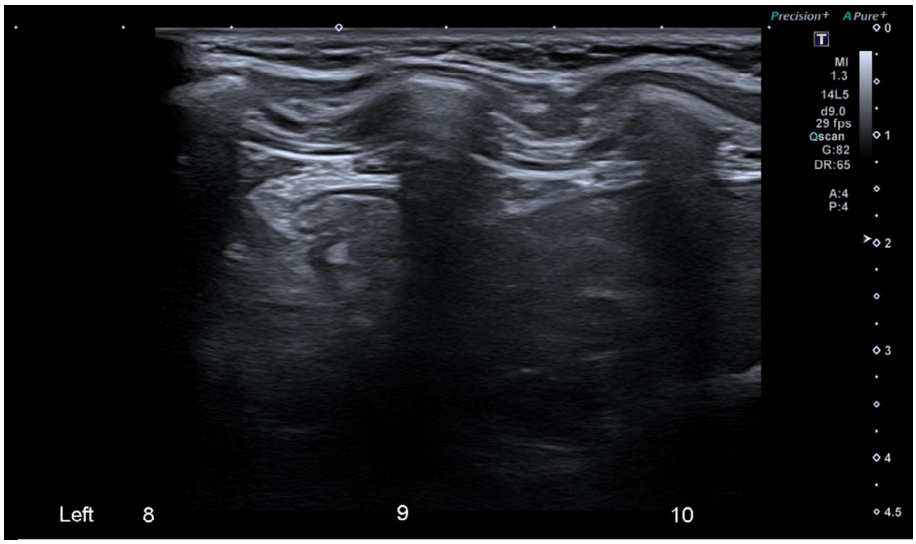
3 | CASE DESCRIPTION

3.1 | Case 1

A 27-year-old female patient first presented to her general practitioner approximately 7 years prior with left-sided chest pain. She felt it may have been aggravated by a manual job, in which she was required to move large boxes, and subsequently underwent various investigations such as x-ray, ultrasound, and MRI. A splenic cyst was identified in one study, and then removed via laparoscopic approach approximately 4 years prior. Unfortunately, the pain continued and she underwent further exploratory laparoscopy of the abdomen. The pain persisted and the patient was referred to our cardiothoracic specialist for further evaluation. Physical examination was unremarkable, most notably the Hook manoeuvre was negative. However, clinical suspicion remained and the patient was referred for a dynamic ultrasound. Sonographic evaluation demonstrated anterior left 9th and 10th rib conflict (Figures 2 and 3) (Video S1). The patient underwent excision of the left 10th anterior costal cartilage 2 months later (Figure 4) and reported complete resolution of symptoms on follow up.

3.2 | Case 2

A 20-year-old female presented to our cardiothoracic specialist after developing severe left-sided anterior lower costal margin pain. A



VIDEO S1 Sagittal cineloop over the right and left anterior costal margins shows a consecutive comparison of the normal (right) to abnormal (left). The first half of the video demonstrates normal physiological coaptation of the 8, 9, and 10 chondral ribs on the right side - note no anterior-posterior mobility. The subsequent video demonstrates an initially similar course of the ribs, however, the 10th rib is subluxated posteriorly and cranially under the 9th rib. Number annotations "8", "9", and "10", roughly correspond to the relevant rib that is inline in the image
Video content can be viewed at https://onlinelibrary.wiley.com/doi/10.1002/sono.12250

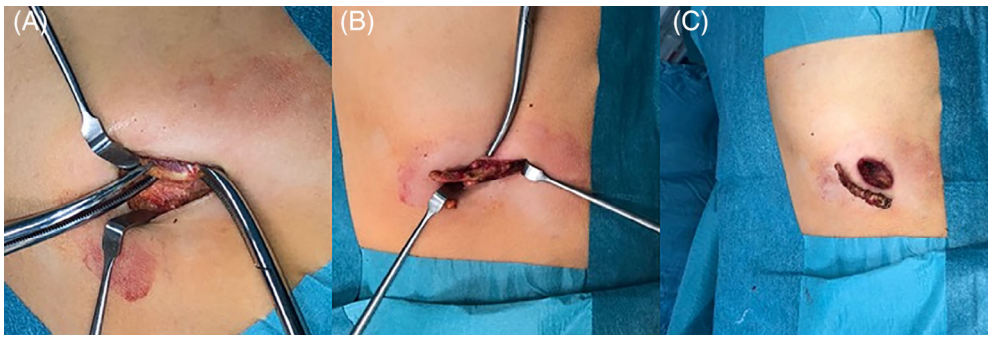


FIGURE 4 Intraoperative images. A, A small 2-3 cm incision is made over the target rib. B, The rib tip is gently coaxed away from the costal margin. C, The distal chondral rib is excised. The patient reported resolution of symptoms at follow-up

history of costochondritis in her early teens was noted; however, she had not experienced any problems since. The chest wall pain was initially investigated, treated, and interpreted to be due to an asthma attack. GP referral to a tertiary pain centre was sought after ongoing pain, at which a sports physician provided targeted trigger point injection that gave symptomatic relief for 3 weeks. The pain returned and became persistent. An ultrasound and MRI were performed at an external site and reported as normal. A referral was then made by the cardiothoracic team to our department for dynamic ultrasound. The scan identified the 9th rib tip as showing excessive dorsal and cranial excursion in relation to the 8th (Figure 5). The 9th left costal cartilage was intraoperatively noted as "floating below the costal margin", and then excised. A 2-week clinical follow-up reported good recovery and resolution of the specific pain over her left anterior costal margin.

3.3 | Case 3

A 13-year-old female was referred to our cardiothoracic specialist via paediatric surgery after developing pain in her left upper quadrant after an unremarkable general clinical exam. The patient reported the pain had been persistent over the previous 2 years and could be localised to the costal margin. The pain was exacerbated by jumping and twisting exercises, and she could produce a palpable, and faintly audible, "popping" sensation over the left anterior costal margin when performing certain manoeuvres. Subsequent dynamic ultrasound demonstrated significant posterior subluxation of the 9th chondral rib in relation to the 8th (Figures 6 and 7) (Video S2).

4 | DISCUSSION

Since its discovery by Cyriax in 1919, the diagnosis of SRS has been consistently documented as difficult, and theorised to be relatively underdiagnosed.[3,4,8,9] A recent ultrasound-centric study by Van Tassel et al points out that while around 400 cases have been reported in scientific literature, the entity of SRS remains unfamiliar to many health professionals.[4]

Patients often complain of vague, poorly localisable symptoms which can lead to delayed diagnosis: understood to be attributable to intercostal and visceral sympathetic innervation gathering at the same spinal cord levels, resulting in referred pain.[2,4] This is highlighted appropriately by a case in our series (case 1) in which the patient underwent two laparoscopies, one for the removal of a splenic cyst, to alleviate symptoms. Neither surgery had the desired outcome.

Many differential diagnoses exist when considering SRS due to the aforementioned reasons. Those reported include costochondritis, pleuritis, cholelithiasis, peptic ulcer, renal colic, appendicitis,

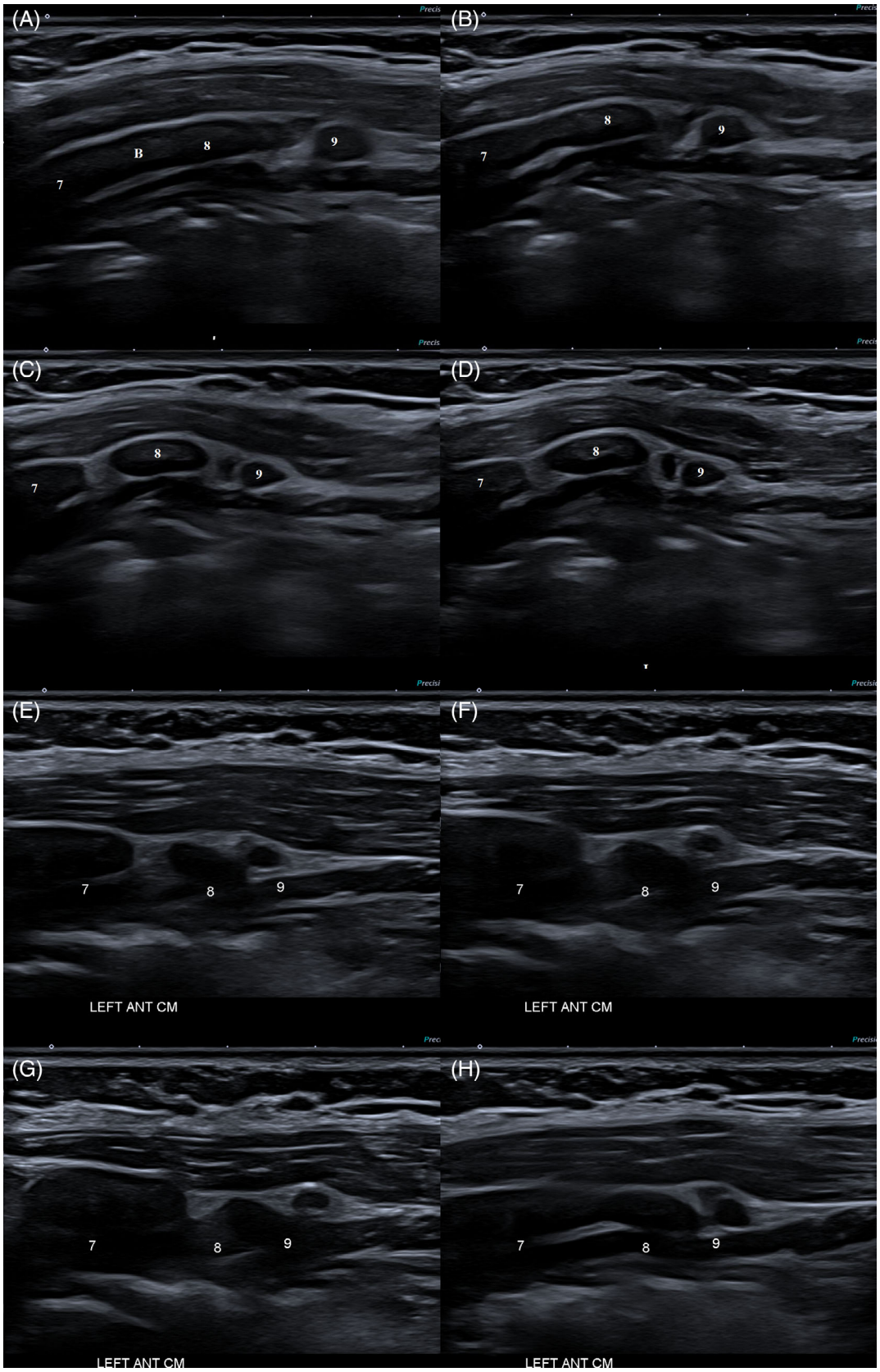


FIGURE 5 Subtle excessive excursion of a chondral rib tip. A-D, sagittal ultrasound of the left anterior costal margin demonstrates subtle hypermobility of the 9th rib tip. It is being forced posteriorly and compressing the intercostal tissues. Of note, there is a chondral bridge between the 7th and 8th rib at this level which is theorised to provide a rigid point on which the inferior rib is forced against. E-H, The 9th rib tip appears to be "floating" in a circular motion during provocation testing, implying inadequacy of the fibrous attachment. B = chondral bridge

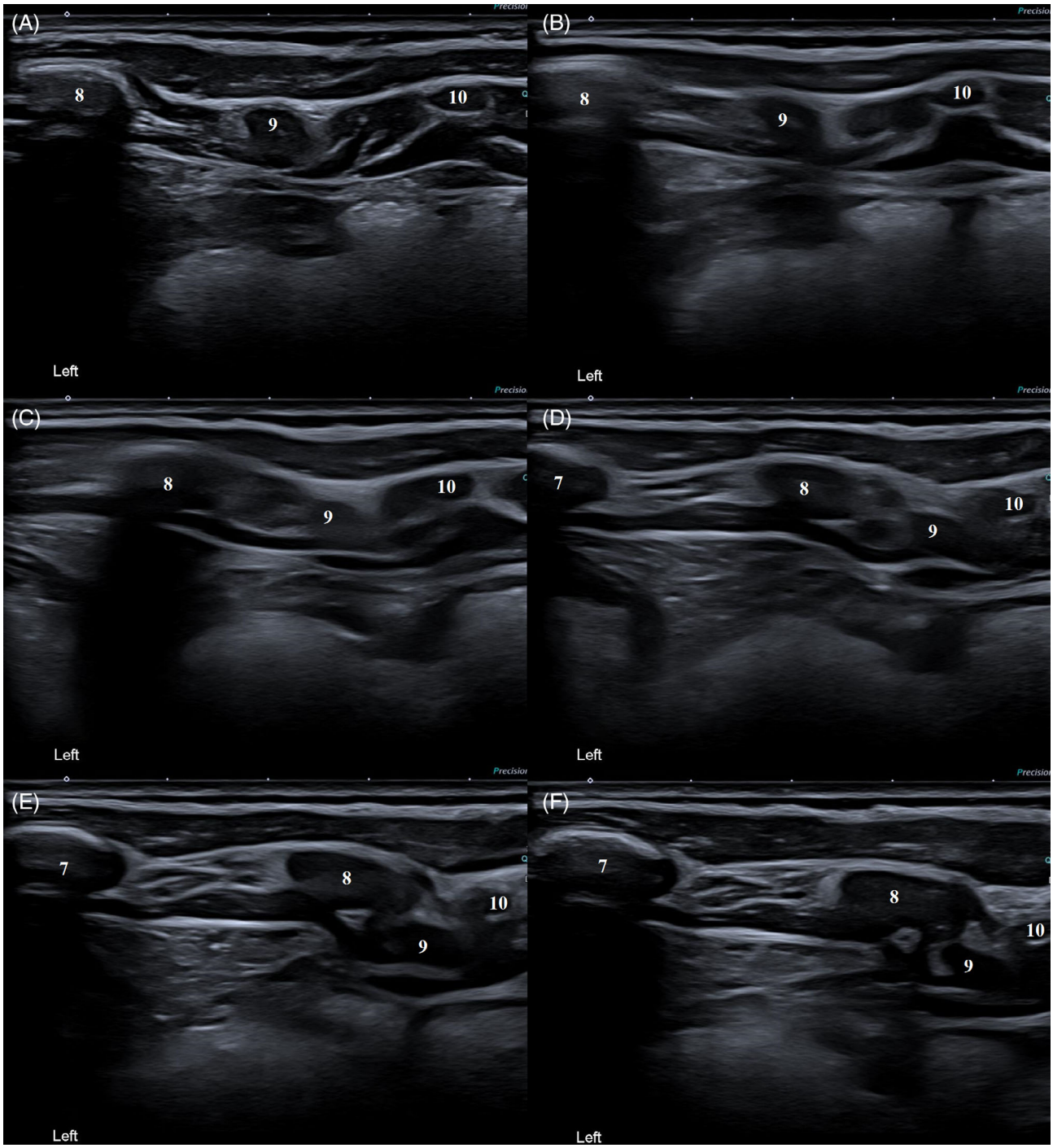


FIGURE 6 Marked subluxation of the 9th rib under the 8th. A-F, sagittal ultrasound of the left anterior costal margin demonstrates significant excursion of the 9th rib during abdominal flexion. The 9th rib is pushed posteriorly to sit under the 8th and 10th ribs. The transducer was placed over the site where a palpable "click" could be felt. The click was postulated to be caused by the intercostal muscle being crushed and then "herniating" anteriorly between the ribs

pancreatitis, nerve root lesions, pyelonephritis, and inflammatory bowel disease.[2,3,9,10]

Patients consistently undergo an array of diagnostic tests and procedures before arriving at the correct diagnosis of SRS.[11] In their retrospective study of 362 athletes with rib pain, Foley et al reported 54 diagnoses of SRS; the radiographic tests performed were 34 radiographs, 13 MRIs, 9 CTs, 4 bone scans, and 6 abdominal ultrasounds - only 1 of the CTs reported relevant abnormality.[2] A number of these include the use of ionising radiation; which is particularly troublesome as there is a predisposition for this condition to affect young adults and adolescents.[8] We do note, however, there is an inherent limitation with ultrasound in counting ribs and

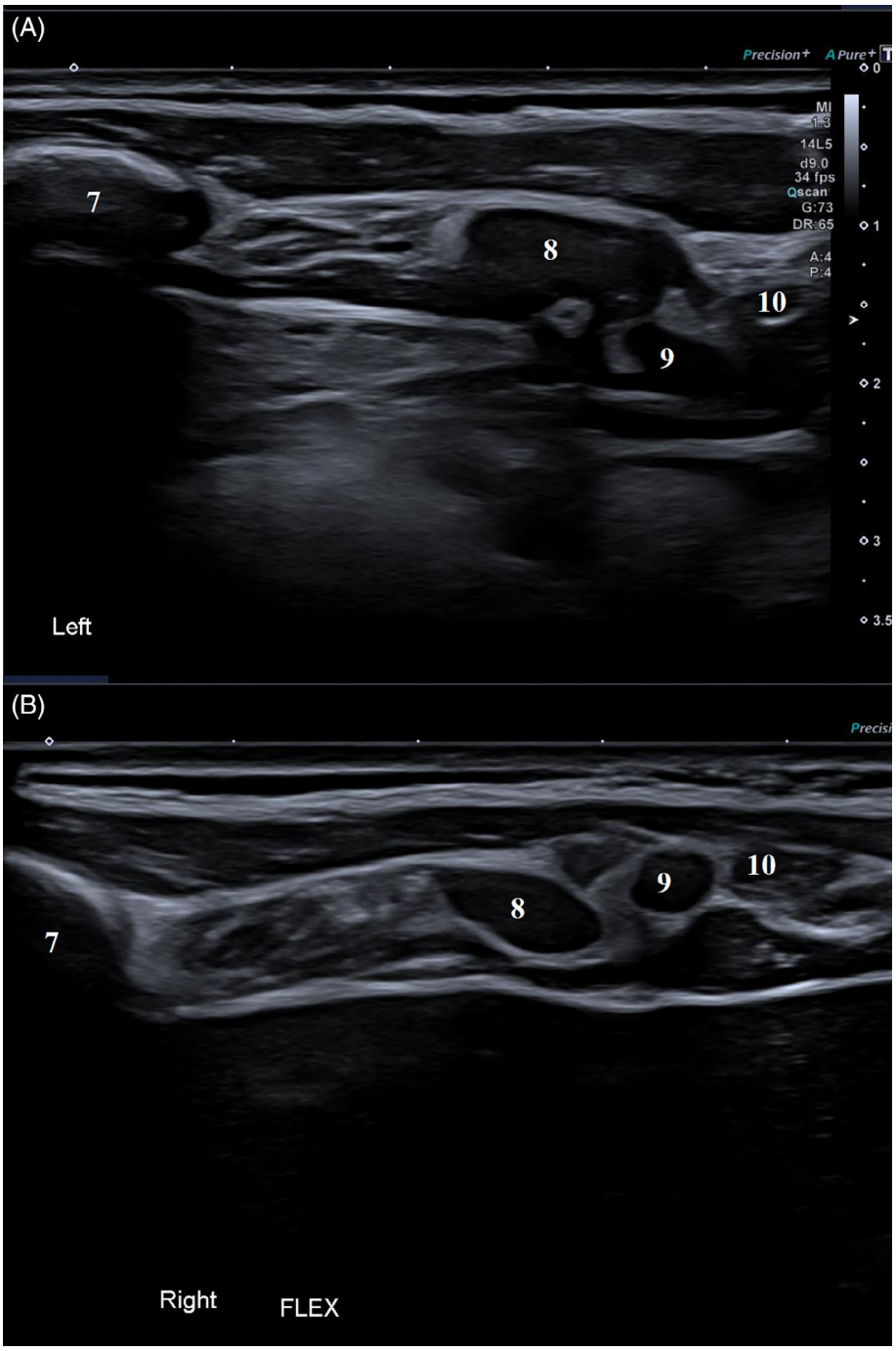
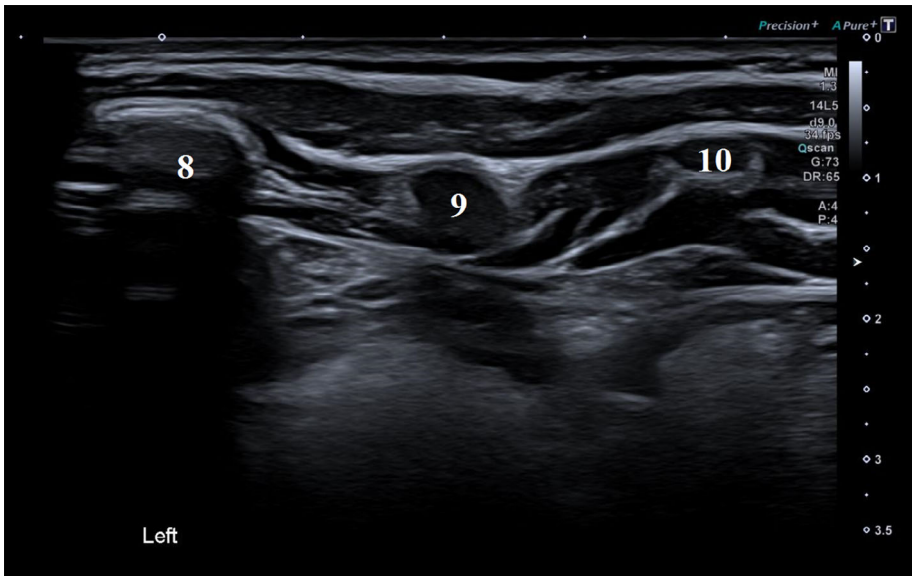


FIGURE 7 Sagittal ultrasound comparing chondral ribs at the same level during maximal abdominal flexion. A, Symptomatic left with posterior translocation of the 9th rib. B, The right side shows normal coaptation of the 8th, 9th, and 10th ribs. Neither deviate anteriorly or posteriorly over the superior rib

assessing gross anatomy. In our combined experiences we felt there was no generally agreed method for counting ribs sonographically. As there was good consistency of method and communication between both radiology and surgical teams, we found this was not a hindrance in patient outcomes for our case series - although there is potential for erroneous counting and thus more investigation into this area of the SRS work-up is needed in the future. Delineating prominent vertebral transverse processes versus a true 12th rib proved difficult in some instances. If appropriate, the use of cross-sectional imaging can be helpful in assuring the correct ribs are being targeted.

Our case series relied heavily on the use of dynamic ultrasound to assess the anterior chondral ribs. Sonographically, hypermobility of a rib was demonstrated during dynamic assessment as either increased anterior or posterior excursion of one chondral rib relative to its superior rib. Several methods have been suggested for provocation testing during dynamic ultrasound, these include pushing the rib(s) with the examiner's fingers, Valsalva, and abdominal crunch.[4] The location of the slippage has been proposed to be more likely in those areas where the superior ribs are more rigid, such as in the presence of a chondral bridge which restricts movement between two ribs; thus imparting an amplified mechanical force on the inferior rib.[3,7] Finding these



VIDEO S2 Sagittal cineloop over the left anterior costal margin at the level of an audible "click" as indicated by the patient. The 9th rib is hypermobile and squeezed posteriorly between the 8 and 10 chondral ribs. The intercostal soft tissue is being significantly compressed and displaced
Video content can be viewed at https://onlinelibrary.wiley.com/doi/10.1002/sono.12250

landmarks may aid the operator in being assured the correct site is being examined. Secondary findings may also be present and aid in a confident diagnosis, these included compression of the intercostal muscle resulting in a "dumbbell" appearance, as well as overall hyperechogenicity to the muscle belly suggesting fibrosis and/or localised inflammatory changes.[4]

In our experience, abdominal crunch was the most diagnostically valuable manoeuvre perhaps due to imparting the most force on the false ribs. However, it was also the most technically challenging as maintaining adequate probe contact and positioning during the movement is difficult. Nevertheless, studies have hailed the effectiveness of dynamic ultrasound in the correct diagnosis of SRS.[2-4,11]

Surgical treatment of SRS was first described by Davies-Colley in 1922 in which he successfully excised the terminal ends of the suspected pathological ribs.[12] Since this initial treatment, numerous therapeutic options have been successfully utilised: this includes conservative treatment with physiotherapy; and invasive procedures such as intercostal nerve blocks and surgical excision.[4,7,13] Surgical excision has been proposed as an effective treatment to potentially grant immediate and long-lasting relief,[13] and our cases support this.

5 | CONCLUSION

SRS is a chronically misdiagnosed condition that may be more common than initially thought. It is caused by disruption to the fibrous attachment of the 8th, 9th, or 10th chondral rib(s), allowing for hypermobility of a chondral rib relative to its superior rib. It is notoriously difficult to diagnose, likely attributable to the shared thoracic nerve roots of the visceral sympathetics and intercostal nerves, painting a complex clinical picture. Without dynamic ultrasound, radiographic studies are largely futile in providing information relevant to the condition. When used appropriately, sonographic assessment can accurately locate the pathological rib tip, which can then be targeted for surgical excision if appropriate. We consider dynamic ultrasound the modality of choice for diagnosing SRS.

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CONFLICT OF INTEREST

No conflicts of interest.

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