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Technical Report

Overcoming two technical pitfalls in MRI of paediatric and adolescent sacroiliitis

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Introduction

Although a significant proportion of adults with sacroiliitis present with inflammatory back pain, this may be a late feature in children with active sacroiliitis, who can even be asymptomatic.[1,2] Clinical examination is known to be unreliable[2] and because of the difficulties in diagnosing sacroiliitis based on history and examination, imaging has become integral to establishing the diagnosis in children. The eventual functional status of those with juvenile-onset spondyloarthropathy is often worse than those who develop spondyloarthropathy as adults,[1] and in addition, axial disease is known to respond poorly to treatment with conventional DMARDs (disease-modifying anti-rheumatic drugs),[3–6] making the identification of children with sacroiliitis clinically relevant. With the increasing availability of anti-tumour necrosis factor drugs (anti-TNFs), there is also the opportunity to reduce symptoms and slow progression of disease, resulting in improved outcomes in these patients by using these as first-line agents for sacroiliitis.[1,4–6] Although these drugs are generally well tolerated, there are important side effects, and therefore, careful patient selection is required.[1]

Imaging with magnetic resonance imaging?

The complex structure and orientation of the sacroiliac joints poses unique challenges for imaging evaluation. Interpretation of the sacroiliac joints is even more challenging in the immature skeleton due to its smaller size and increased proportions of cartilage and marrow. It is universally accepted that coronal/oblique sequences provide the best visualisation of the sacroiliac joints, while additional axial imaging is also acquired in some institutions.[7,8]

What can magnetic resonance imaging show in sacroiliitis?

Despite reports of the imaging findings in paediatric sacroiliitis, there is a paucity of evidence regarding these, as the imaging itself is often used as proof for diagnosis.[8] Both acute and chronic manifestations of sacroiliitis can be seen on magnetic resonance imaging (MRI). Acute manifestations are more likely in children and adolescents and these include bone marrow oedema, osteitis (Fig 1), fluid within the sacroiliac joints, and synovitis. Chronic or structural

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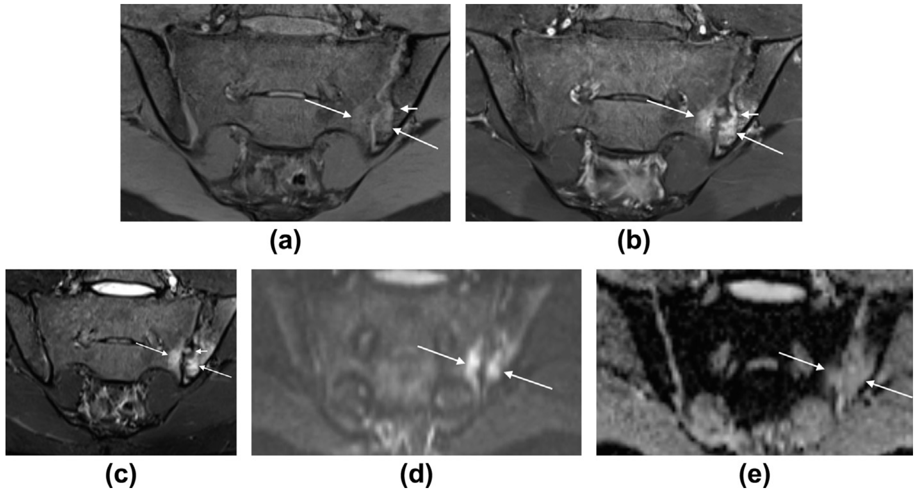


Figure 1 A 17-year-old male patient undergoing MRI for suspected sacroiliitis with MRI findings of active disease including erosion and oedema. T1 fat saturated pre- (a) and post-contrast (b) and STIR (c) images demonstrate broad-based erosion on the iliac side of the left sacroiliac joint (short arrow on all images). There is surrounding oedema on both sides of the joint (long arrows on all images) with enhancement in keeping with osteitis. (d) High b-value DWI image demonstrates high signal in the region of the previously mentioned oedema without a corresponding low ADC value (e), in keeping with free diffusion.

findings include erosions (Fig 1), sclerosis (Fig 2), fat deposition (Fig 2), or ankylosis.[9] This technical report aims to highlight two pitfalls in MRI of paediatric sacroiliac joints for sacroiliitis: the orientation of the coronal oblique imaging plane and the presence of haematopoietic marrow as mimickers of disease, and discuss simple mechanisms to avoid these pitfalls.

Materials and methods

A panel of three radiologists (one paediatric radiology consultant and two senior radiology registrars with a subspecialist interest in paediatric radiology) reviewed all sacroiliac joint MRI images retrospectively of children and adolescents over a 3-year period (2013–2016) performed at a dedicated children's hospital with an active rheumatology unit and serving as a regional paediatric tertiary referral centre in the UK. Inclusion criteria were all those <21 years of age referred for sacroiliac joint MRI with juvenile idiopathic arthritis to assess for sacroiliitis. Any incomplete or irretrievable studies were excluded.

As well as identifying features of sacroiliitis (collected for use in a different study assessing reliability in reporting MRI in children for suspected sacroiliitis) this review involved recording the quality of coronal oblique imaging planes and the spectrum of signal characteristics of normal red marrow. The number and percentage of incorrectly aligned coronal oblique studies was calculated. These were defined as coronal oblique sequences that did not demonstrate the full length of the synovial portion of the sacroiliac joint simultaneously and instead demonstrated the fibrous and synovial portions of the joint together. This was considered a potential mimic of disease where the fibrous part of the joint could be misinterpreted as erosions. By reviewing the planning scans for ideal studies, a method for optimal positioning was devised and is proposed in this technical report below. Patients with MRI demonstrating bilateral symmetric high signal in the peri-articular regions were selected to demonstrate the spectrum of appearances of normal red marrow seen adjacent to the joint. The literature was reviewed for ways to distinguish normal red marrow from oedema and these are proposed below.

Results

MRI of 102 sacroiliac joints was performed for suspected sacroiliitis in patients <21-years of age over the 3-year study period. Three studies were incomplete and therefore excluded resulting in 99 MRI examinations being reviewed for this study.

Coronal oblique alignment

Forty-five of the 99 MRI examinations, (45%) had poorly aligned coronal oblique images. The corrective measure proposed for achieving an optimal view of the synovial part of the joint over its full length, involves planning the coronal oblique along the anterior margin of S1–3, on the sagittal localiser (Fig 3). This accounts for the anterior location of the synovial portion of the joint and allows visualisation of the fibrous superoposterior component on more dorsal and separate imaging sections. The most anterior sections of an optimal coronal image can be likened to a "lobster tail" where S1, S2, and the superior portion of S3 are seen simultaneously (Fig 3), allowing evaluation of the full craniocaudal length of the synovial aspect of the joint and the bone surrounding it on the first few sequential slices.

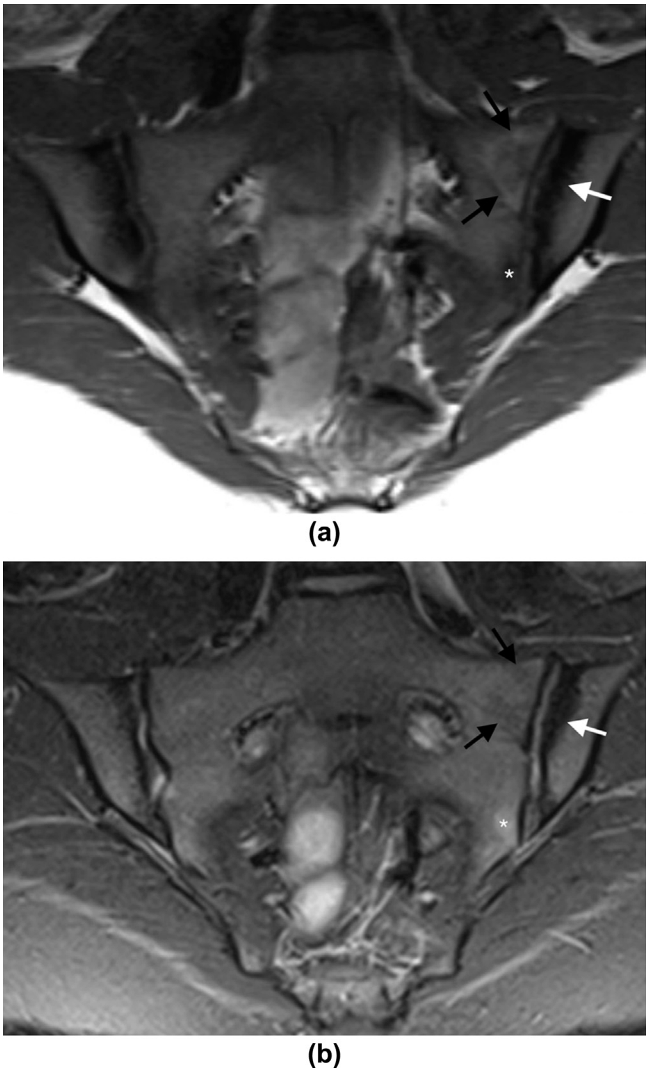


Figure 2 A 19-year-old female patient with clinically suspected sacroiliitis and structural chronic MRI features supporting the diagnosis. (a) T1 non-fat-saturated coronal oblique image demonstrates a focus of high signal on the sacral side of the superior left sacroiliac joint, in keeping with fatty proliferation (black arrows). There is a low signal band along the iliac margin of the left sacroiliac joint, in keeping with sclerosis (white arrow). (b) STIR coronal oblique image demonstrates suppression of signal confirming the region of fatty proliferation (black arrows). A linear band of low signal is again seen along the iliac margin of the left sacroiliac joint, confirming sclerosis (white arrow). There is also a focus of oedema on the sacral side of the inferior left sacroiliac joint, which is hypointense on the T1 image but more clearly demonstrated on this sequence (asterisk on all sequences).

Red marrow

Patients with bilateral high short tau inversion recovery (STIR) signal in the peri-articular regions due to normal red marrow that could be misinterpreted as bone marrow oedema were identified. This phenomenon was more predominant in younger children and reduced with increasing age as more red marrow converts to fatty marrow. Cases emphasising the appearances of red marrow are presented in the technical report below.

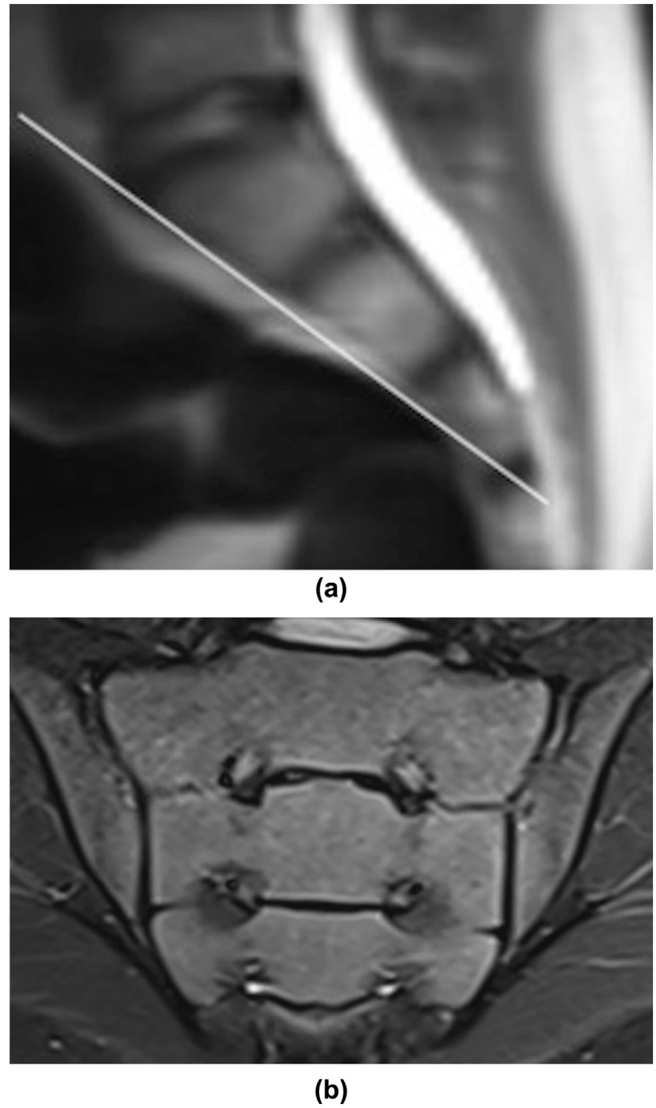


Figure 3 A 14-year-old boy with clinically suspected sacroiliitis for demonstrating ideal orientation of the coronal oblique images. (a) Optimal alignment of the coronal oblique plane is attained when the sequence is planned along the anterior aspect of the sacrum along S1–S3 (white line). (b) Note that in the resulting coronal oblique image, the S1–S3 vertebral bodies are seen simultaneously at the most anterior section giving the appearance of a “lobster tail”. The full craniocaudal length of the sacro-iliac joint can thus be displayed on the sequential sections in this plane.

Discussion

Pitfall 1—incorrect coronal oblique positioning, mimicking erosion

Although the merits of different sequences have been discussed within the limited literature, there is almost no discussion about the importance of good positional alignment. It is accepted that standard coronal oblique views should be obtained, but obtaining these views can be challenging and the quality of planes achieved is variable. In the present study, 45% of studies were poorly aligned or positioned. This is likely to be a widespread problem and something that needs to be addressed.

The aim of correct positioning is to provide visualisation of the length of the sacroiliac joint in the plane of imaging. This plane should correspond to the orientation of the anterior synovial part of the sacroiliac joint, which extends from S1 to S3. Coronal oblique views should therefore include S1, S2, and S3 on the same image at the anterior portion of the field. It has previously been recommended that optimal positioning can be achieved by planning the coronal oblique imaging along the axis of the sacrum on a sagittal planning view. This is often interpreted to mean aligning the plane along the central axis of the sacrum on the sagittal view; however, as S1 is the widest vertebra (from anterior to posterior) and the sacral vertebrae become progressively narrower inferiorly, using the central axis of the sacrum can result in visualisation of the posterior part of S1 and the fibrous component of the joint superiorly, simultaneously with the anterior part of S3, and the synovial part of the joint inferiorly. In addition, because the sacrum is concave anteriorly, a poorly planned coronal oblique plane may result in S1 being the only vertebra visualised on the first few images and S3–5 seen simultaneously on more posterior sections (Fig 4). When interpreting studies the fibrous component of the joint seen superiorly appears irregular compared to the synovial part visualised inferiorly, which can result in false-positive reports of erosions in the superior aspects of the joint. Therefore, positioning of the coronal oblique along the anterior margin of S1–3, on the sagittal localiser (Fig 3) accounts for the anterior location of the synovial portion of the joint ("lobster tail") and allows evaluation of this separately from the more superoposterior fibrous component of the joint.

Pitfall 2—the maturing paediatric skeleton: haematopoietic marrow misinterpreted as inflammatory oedema

Paediatric sacroiliac joints are more challenging to interpret than adult sacroiliac joints due to their immaturity.[2] Any red marrow that persists, presents as high signal

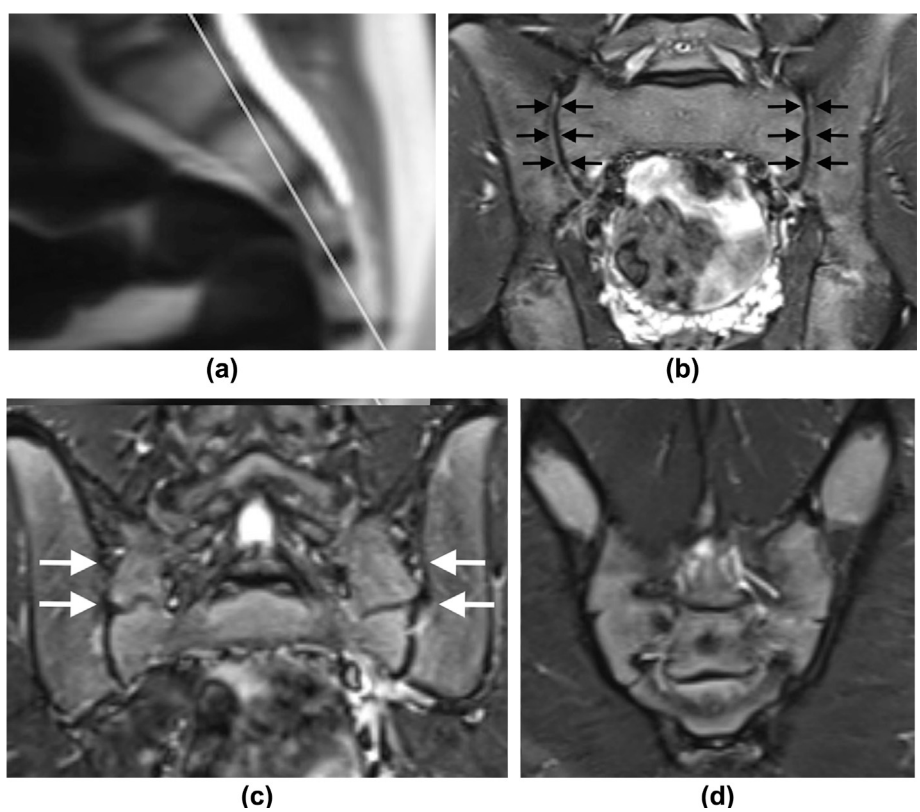
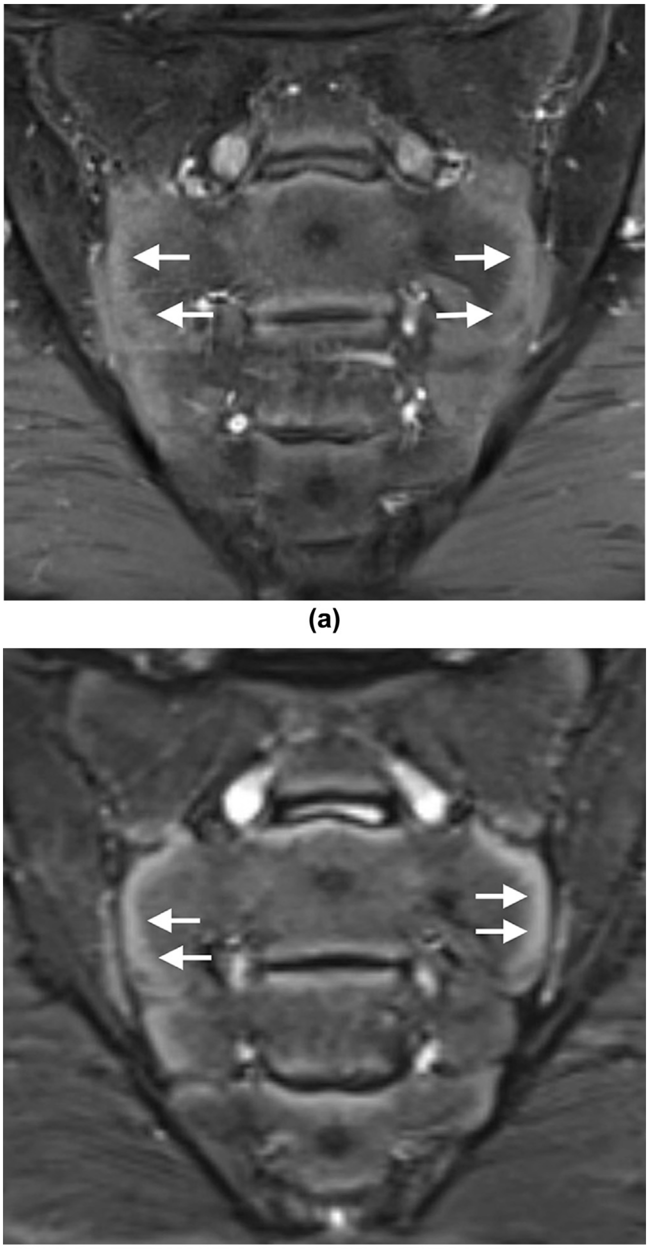


Figure 4 MRI of the sacroiliac joint in a 13-year-old female patient with incorrect positioning of the coronal oblique plane, which is aligned along the centre of an axis passing through S2, S3, and S4. (a) The planning of the coronal oblique plane is orientated along the axis of the S3–S4 vertebral bodies (white line), rather than S1–S3. (b) A representative image of the more anterior STIR coronal oblique section includes only the S1 vertebral body, and therefore, only shows a limited craniocaudal portion of the synovial part of the sacroiliac joint at this level (black arrows). (c) A more dorsal coronal oblique MRI section demonstrating the most posterior and inferior aspect of S1, which now includes the fibrous part of the joint (white arrows). The edges are less regular and can be misinterpreted as erosions, particularly on the iliac side of the joint. The most anterior and superior portion of S3 is now appearing in view and a more inferior craniocaudal extent of the synovial joint is imaged. (d) The most dorsal of the representative coronal oblique sections reflects the orientation of the coronal oblique plane along the axis of S2 and S3, as both vertebra are in plane. This results in an appearance resembling the rabbit mask in the film "Donnie Darko". Very little of the joint is visible in this image.



(a)

(b)

Figure 5 An 11-year-old boy with enthesitis-related arthritis and clinically suspected sacroiliitis demonstrating normal red marrow signal and distribution on MRI. (a) STIR coronal oblique image demonstrates a smooth symmetric linear band of high signal along the craniocaudal length (primarily on the sacral side) of both sacroiliac joints (arrows). (b) Corresponding T1-weighted fat-saturated post-contrast image demonstrates enhancement at the sites of previously noted high STIR signal (arrows) corresponding to normal cellular haematopoietic red marrow.

on STIR sequences, which can be misinterpreted as bone marrow oedema (Fig 5). Both red marrow and osteitis in association with inflammatory bone marrow oedema demonstrate enhancement following contrast medium administration (Fig 5). These can be differentiated using unenhanced T1 sequences, on which red marrow is iso-intense or slightly hyperintense to muscle, compared with

Table 1
MRI imaging characteristics of haematopoietic marrow compared with bone marrow oedema.

	STIR	T1	Contrast-enhanced T1	DWI	Pattern and location
Red marrow	Hyperintense	Isointense or slightly hyperintense to muscle	Demonstrates enhancement	Can demonstrate restricted or free diffusion	Smooth symmetric signal change along sacral margins of the sacroiliac joints
Bone marrow oedema	Hyperintense	Hypointense	Demonstrates enhancement	Demonstrates free diffusion	Often irregular, asymmetric signal change involving subchondral sacral and iliac portions of the sacroiliac joints

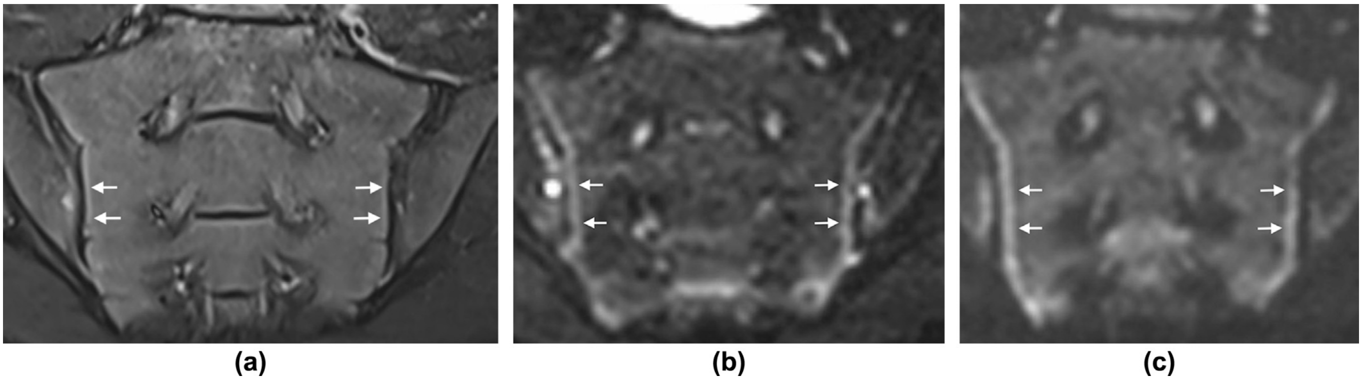


Figure 6 A 16-year-old boy with suspected sacroiliitis demonstrating the usefulness of DWI in demonstrating restricted diffusion of normal red marrow. (a) STIR coronal oblique image demonstrating linear high signal along the craniocaudal length on the sacral side of both sacroiliac joints related to cellular haematopoietic marrow (arrows). (b) Low and (c) high b-value DWI images in coronal oblique plane demonstrate increasing signal return along the sacral margin of the sacroiliac joint representing restricted diffusion due to high cellularity of haematopoietic marrow (arrows).

bone marrow oedema, which is of low signal. The presence of smooth, relatively symmetric high STIR signal with associated enhancement along the sacral margins of both sacroiliac joints should be interpreted as red marrow, as opposed to more asymmetric and irregular high signal of bone marrow oedema (Table 1).

Features differentiating red marrow from oedema

The need to differentiate red marrow from bone marrow oedema may be a good indication for performing diffusion-weighted imaging (DWI) in children and adolescents with suspected sacroiliitis. Both red marrow and bone marrow oedema show high signal with low b-values as these follow T2 signal principles. Bone marrow oedema exhibits free diffusion, and it was previously thought that red marrow results in restricted diffusion due to its high cellularity[10,11] (Fig 6); however, it has been recognised that this restriction is unpredictable, particularly in adolescents in whom red marrow can exhibit free diffusion.[12,13] Taking this into consideration, DWI can result in the confident diagnosis of red marrow rather than oedema in cases with restricted diffusion (Table 1). Conversely, DWI cannot differentiate between oedema and red marrow when there is free diffusion. In these cases, the presence or absence of symmetry and the pattern of high signal, in combination with any other signs of sacroiliitis become more important. The amount of red marrow decreases with skeletal maturity and is therefore not a major consideration for adult imaging other than in teenagers/young adults who may have persisting red marrow.

Conclusion

Sacroiliac joint MRI in children is challenging to perform and interpret, with multiple pitfalls in acquisition and reporting. There is limited evidence on the topic and much of the available literature is conflicting. We hope that this technical report will prompt radiologists and clinicians to plan the coronal oblique plane of imaging carefully along the anterior surface of the sacrum rather than the centre to avoid overcalling erosions and to consider the marrow maturation of the patient and signal intensity of red marrow as possible pitfall in the diagnosis of paediatric sacroiliitis. This will allow more meaningful comparisons to be made between studies and increase the quality of evidence in the future.

Conflict of interest

The authors declare no conflict of interest.

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