Vereecke *et al. European Radiology* (2024) 34:5773–5782
https://doi.org/10.1007/s00330-024-10653-3

EUROPEAN SOCIETY OF RADIOLOGY
European Radiology

INVITED REVIEW

ESR Essentials: Imaging of sacroiliitis—practice recommendations by ESSR

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Abstract Sacroiliitis is commonly seen in patients with axial spondyloarthritis, in whom timely diagnosis and treatment are crucial to prevent irreversible structural damage. Imaging has a prominent place in the diagnostic process and several new imaging techniques have been examined for this purpose. We present a summary of updated evidence-based practice recommendations for imaging of sacroiliitis. MRI remains the imaging modality of choice for patients with suspected sacroiliitis, using at least four sequences: coronal oblique T1-weighted and fluid-sensitive sequences, a perpendicular axial oblique sequence, and a sequence for optimal evaluation of the bone-cartilage interface. Both active inflammatory and structural lesions should be described in the report, indicating location and extent. Radiography and CT, especially low-dose CT, are reasonable alternatives when MRI is unavailable, as patients are often young. This is particularly true to evaluate structural lesions, at which CT excels. Dual-energy CT with virtual non-calcium images can be used to depict bone marrow edema. Knowledge of normal imaging features in children (e.g., flaring, blurring, or irregular appearance of the articular surface) is essential for interpreting sacroiliac joint MRI in children because these normal processes can simulate disease.

Clinical relevance statement Sacroiliitis is a potentially debilitating disease if not diagnosed and treated promptly, before structural damage to the sacroiliac joints occurs. Imaging has a prominent place in the diagnostic process. We present a summary of practice recommendations for imaging of sacroiliitis, including several new imaging techniques.

Key Points

- *MRI is the modality of choice for suspected inflammatory sacroiliitis, including a joint-line-specific sequence for optimal evaluation of the bone-cartilage interface to improve detection of erosions.*
- *Radiography and CT (especially low-dose CT) are reasonable alternatives when MRI is unavailable.*
- *Knowledge of normal imaging features in children is mandatory for interpretation of MRI of pediatric sacroiliac joints.*

Keywords Sacroiliac joint, Sacroiliitis, Axial spondyloarthritis, Tomography (X-ray computed), Magnetic resonance imaging

This Article belongs to the ESR Essentials series guest edited by Marc Dewey (Berlin/Germany).

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Key recommendations

• MRI is the diagnostic imaging modality of choice for patients with suspected sacroiliitis, preferably using at least four sequences, in the coronal and axial oblique plane, including a sequence for optimal evaluation of the bone-cartilage interface (erosion-specific sequence) (level of evidence: moderate).

• Radiography and CT (especially low-dose CT) represent reasonable alternatives when MRI is equivocal, unavailable, or contraindicated (level of evidence: moderate). Dual-energy CT can be used to additionally depict inflammatory bone marrow edema when MRI is unavailable or contraindicated (level of evidence: low).

• When interpreting sacroiliac joint MRI in children, caution should be paid to the physiological differences with adults including flaring and blurring, since these normal processes can simulate disease (level of evidence: moderate).

Introduction

Sacroiliitis can be a manifestation of a variety of diseases, including axial spondyloarthritis (axSpA), which consists of a group of inflammatory rheumatic diseases. If left untreated, irreversible structural damage will often occur in axSpA patients; therefore, timely diagnosis and treatment are crucial [1]. Imaging including conventional radiography, computed tomography (CT), and magnetic resonance imaging (MRI) plays an important role in diagnosing and monitoring disease activity [2]. In this rapidly evolving field, numerous new imaging techniques have been developed and tested for imaging of sacroiliitis. We present a summary of updated, evidence-based, practice recommendations for imaging of sacroiliitis.

Imaging recommendations

Conventional radiography

In advanced axSpA, structural lesions of sacroiliitis, such as erosions, sclerosis, and ankylosis, can be detected on pelvic conventional radiographs. Indeed, pelvic radiography remains the first imaging modality recommended when sacroiliitis as part of axSpA is clinically suspected [3]. Pelvic radiographs have been obtained in diagnosing sacroiliitis in ankylosing spondylitis since 1930 and are a traditional part of the diagnostic work-up of patients with suspected axSpA. The modified New York criteria (mNYC) present a scoring scale of 0–4, with a threshold for unequivocal radiographic sacroiliitis (bilateral grade 2). However, the interpretation of pelvic radiographs is challenging even for experienced readers, with a large inter- and intra-observer variation in sacroiliitis scoring, especially for grade 1 and 2 mNYC scores in which neither individual nor workshop training of readers improved the assessment [4]. An additional disadvantage of conventional radiography is the use of ionizing radiation. Thus, data suggest that the use of sacroiliac joint (SIJ) radiographs for diagnosing axSpA is unreliable in general, especially in early disease, and that cross-sectional modalities like CT and MRI are more reliable and sensitive for diagnosing sacroiliitis (Fig. 1) [5, 6]. Furthermore, multiple cross-sectional modalities provide a 3D volume set of images, allowing multiplanar reformation as necessary. This offers multiple advantages including detection of very small lesions and easy recognition of other abnormalities such as anatomical variants [7].

The recommendations are summarized in Table 1.

Computed tomography

Traditionally, the role of CT in sacroiliitis imaging was limited due to its inability to detect active inflammation as well as its use of ionizing radiation. However, recent advancements, particularly in low-dose CT (ldCT) and dual-energy CT (DECT), have enhanced its application by compensating for these limitations.

CT is recognized as the reference standard for identifying structural lesions, including sclerosis, erosion, and ankylosis, the latter two being pivotal for differential diagnosis. It offers a fast acquisition without the need for contrast-medium application and with unrivaled isotropic acquisition and spatial resolution. A comparative analysis underscored CT's unparalleled specificity, albeit with a slight compromise in sensitivity compared to MRI [6]. CT, with its high accuracy and reliability in depicting structural lesions, offers straightforward interpretation, even for less experienced readers. Images should be available both in bone and soft tissue window, reformatted at least in coronal oblique and axial or axial oblique planes with a slice thickness of 1 to 2 mm.

A notable reduction in radiation dose of ldCT of the SIJ is achievable since cortical bone is a very high-contrast interface that is well depicted even with substantial dose reduction [8]. Further, noise reduction can be achieved using artificial intelligence reconstructions or specific filters, such as tin, enabling a dose reduction for SIJ below those used in standard pelvic radiography (Fig. 2) [9]. LdCT should be executed with a limited scan length for the SIJ and low-dose settings applied. In a standard patient, the tube voltage can often be reduced to 100 kVp without compromising image quality, enhancing contrast resolution. Automated tube current modulation is recommended to ensure diagnostic image quality, with 20 to 50 mAs typically resulting in acceptable image quality with modern reconstruction techniques.

DECT provides additional insights into different tissues present by making use of two separate X-ray photon

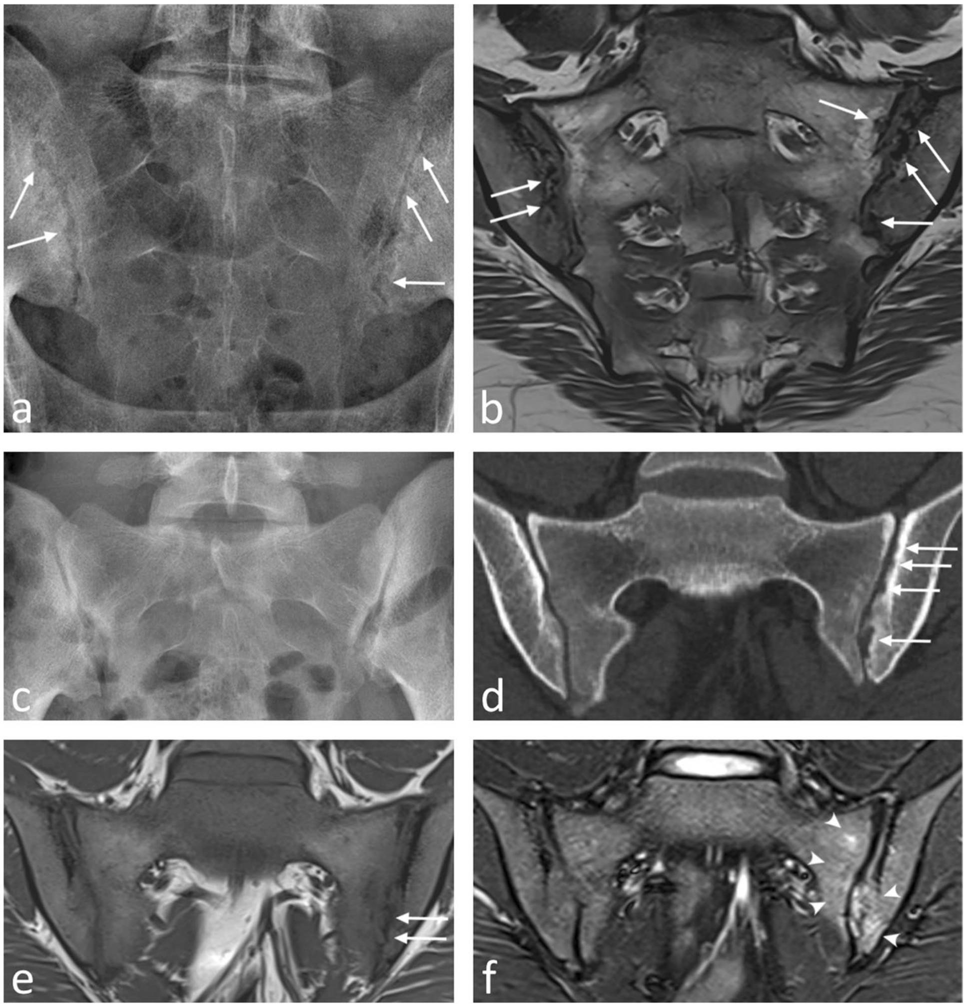

Fig. 1 Conventional radiography examples. **a** Conventional radiography of a 35-year-old woman with known bilateral sacroiliitis due to axial spondyloarthritis, illustrating numerous erosions (arrows). **b** Coronal oblique T1-weighted image confirms presence of these erosions (arrows). **c** Conventional radiography of an 18-year-old woman shows no clear structural abnormalities. However, coronal oblique (**d**) CT, (**e**) T1-weighted, and (**f**) short tau inversion recovery images obtained 3 months earlier depicted erosions (long arrows) and bone marrow edema (arrow heads) along the left sacroiliac joint, illustrating sacroiliitis with structural damage and active inflammation

energy spectra. Originally designed to detect the presence of crystal disease (e.g., gout), DECT can also detect bone marrow edema in contrast to normal marrow fat when using virtual non-calcium reconstructions, thereby indicating active inflammation (without the need for contrast media) when MRI is unavailable (Fig. 2) [10]. For DECT, total exposure should be akin to a standard CT scan, with measures like tin filtration recommended to increase spectral separation.

While CT is not generally the first-choice modality due to the comprehensive lesion assessment offered by MRI, there is an increasing role for modern low-dose or dual-energy CT, which offers much more useful information than radiographs, presenting a potential alternative.

Magnetic resonance imaging

Most patients with clinically suspected axSpA are young; therefore, imaging that avoids ionizing radiation is preferred. MRI does not use ionizing radiation and facilitates the detection of both active inflammatory and structural lesions. Active lesions can consist of periarticular bone marrow edema (osteitis), capsulitis, joint space enhancement, inflammation at the site of erosion, enthesitis, and/or joint space fluid; structural lesions may be visible in the form of erosion, fat lesion (also known as fat metaplasia), fat metaplasia in an erosion cavity (also known as backfill), sclerosis, ankylosis, and/or bone bud (Fig. 3) [11]. The imaging report of MRI of the SIJs should include a description of both active inflammatory

Table 1 Summary of practice recommendations for imaging of sacroiliitis. The level of evidence for each recommendation was determined using the "insights into imaging approach," published by Martí-Bonmatí [28]

Recommendation	Level of evidence	Reference(s)
Due to the low reliability of pelvic radiography for the diagnosis of sacroiliitis, it is preferable, if possible, to perform cross-sectional imaging modalities such as low-dose CT or MRI (especially in children) as initial imaging modalities in the work-up of a patient with suspected sacroiliitis	Moderate	[3–6, 8, 12, 18, 19]
It is reasonable to use CT for detecting sacroiliitis whenever MRI is unavailable, or MRI results are equivocal or not in line with clinical findings	Moderate	[5, 6]
Dual-energy CT may be considered for patients unable or unwilling to undergo MRI to demonstrate bone marrow edema in addition to structural lesions	Low	[10]
It might be reasonable to restrict the scan length of CT to the sacroiliac joints as additional coverage of the pelvis is unlikely to provide further information, but it results in higher radiation exposure	Low	[9]
When MRI is performed, it is reasonable for the scanning protocol to include at least four sequences: coronal oblique T1SE, coronal oblique STIR or T2FS, axial oblique sequence, and erosion-specific sequence	Moderate	[12–15]
It is appropriate to use at least two different imaging planes for MRI, preferably oblique coronal and oblique axial planes	Moderate	[12, 14]
The MRI report may include a description of both active inflammatory and structural lesions, describing their extent and precise location in the joint	Low	[3, 11, 12]
When interpreting sacroiliac joint MRI in children, caution should be paid to the physiological differences with adults, since these normal processes can simulate disease	Moderate	[21–23]

Abbreviations: *CT* computed tomography, *MRI* magnetic resonance imaging, *T1SE* T1-weighted spin echo, *STIR* short tau inversion recovery, *T2FS* T2-weighted fat-saturated

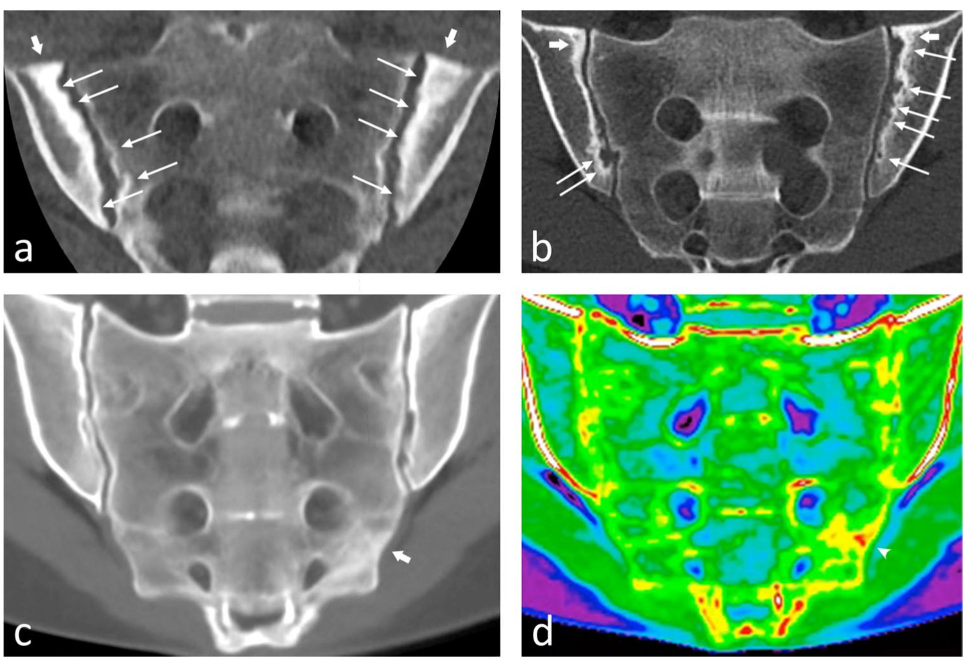

Fig. 2 Imaging examples of CT findings of the sacroiliac joints. **a** A 33-year-old male patient with axial spondyloarthritis and erosive sacroiliitis underwent low-dose CT of the sacroiliac joints, reconstructed with artificial intelligence. Despite a volume CT dose index (CTDIvol) of 0.3 mGy and dose length product (DLP) of 2.6 mGy*cm, sufficient image quality was achieved, showing sclerosis (short arrows) and erosion (long arrows), resulting in pseudo widening of the joint. **b** A 27-year-old man with known axial spondyloarthritis and bilateral sacroiliitis. Standard-dose CT with iterative reconstructions shows extensive erosions (long arrows) and bilateral sclerosis (short arrows). **c** Coronal oblique 70 kilo-electron-volt virtual monochromatic CT image and (**d**) corresponding color-coded dual-energy CT image (post-processing with virtual non-calcium reconstruction using a three-material-decomposition) of a 46-year-old female patient with chronic back pain after falling with the bicycle. While standard CT shows a mild sclerotic area (short arrow) but no cortical disruption, dual-energy CT reveals bone marrow edema (arrowhead) in a medullary bone fracture

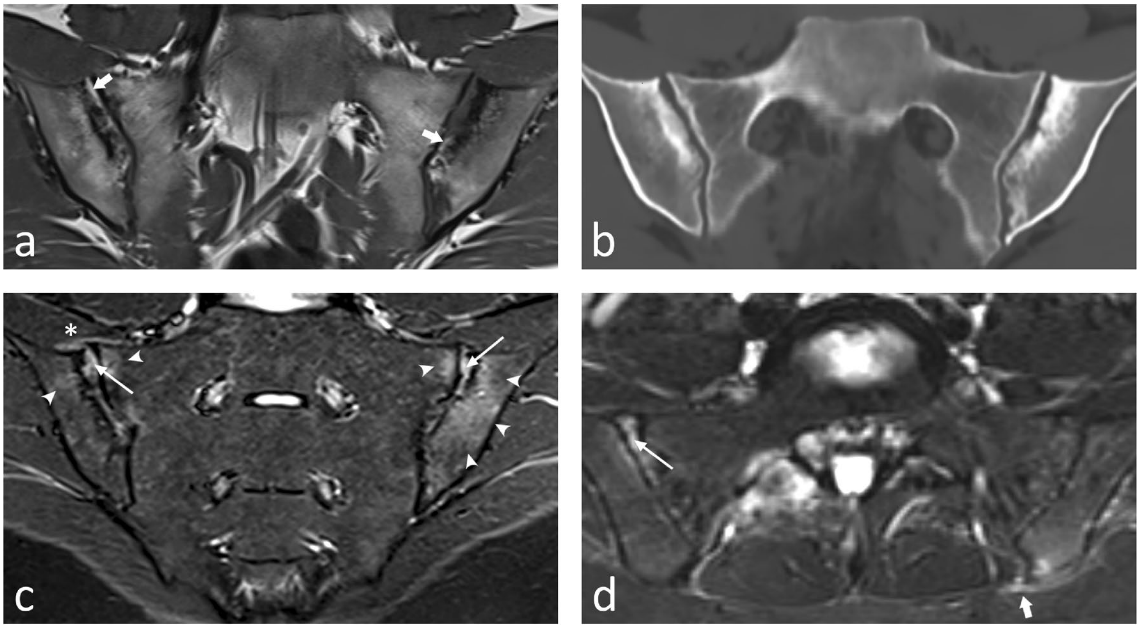

Fig. 3 MRI of the sacroiliac joints of a 25-year-old woman with chronic inflammatory lumbar pain demonstrating both active and structural lesions. **a** Coronal oblique T1-weighted spin echo image and (**b**) coronal oblique synthetic CT (sCT) image allow detection of structural lesions including extensive erosions and adjacent sclerosis along the subchondral bone on both iliac sides and the right sacral side (better seen on sCT), with T1 hyperintense areas of fat metaplasia in erosion cavities (also known as backfill) (arrows). **c** Coronal oblique and (**d**) axial short tau inversion recovery images depict bilateral areas of subchondral bone marrow edema (arrowheads), bilateral intra-articular fluid (long arrows), capsulitis of the right sacroiliac joint (asterisk), and left-sided enthesitis of the posterior sacroiliac ligaments (short arrow)

and structural lesions, along with their extent and precise location in the joint (sacral or iliac side, cartilaginous and/or ligamentous part) [12]. All lesions must be clearly present in a typical anatomical location [11].

All images should be reviewed at the same time, in the context of demographic, clinical, and laboratory information. Imaging findings suggestive of alternative diagnoses should be considered [11].

The latest revised ASAS definition of active sacroiliitis on MRI (a so-called positive MRI for the classification of axSpA) requires clear MRI evidence of bone marrow inflammation: Bone marrow edema is depicted as a hyperintense signal on fluid-sensitive sequences (e.g., short tau inversion recovery (STIR) and T2-weighted fat-saturated (T2FS) images), usually hypointense signal on T1-weighted images, or hyperintense signal on contrast-enhanced, T1-weighted, fat-saturated images (i.e., osteitis). This inflammation must be clearly present and located in the subchondral bone. Overall MRI appearance must be highly suggestive of axSpA [11].

It is important to note that this definition of ASAS-positive MRI is created for patient's inclusion into clinical studies and not for diagnostic use in everyday clinical practice. Bone marrow edema is not specific and may result from other entities as well. On the other hand, a patient with axSpA can present with clear structural MRI lesions, but without active inflammation of the SIJ, in which case the patient would not fulfill the ASAS-positive MRI definition. Therefore, the report should not include statements regarding this "ASAS MRI positivity," but rather comment on presence of active inflammation and/or structural damage [13].

Advised scan sequences

Images in at least two different imaging planes should be obtained, which can aid in identification of artifacts and differentiation of small lesions [11]. The SIJ should be evaluated in the coronal oblique and axial oblique plane [12, 14]. The coronal oblique imaging plane should be parallel to the posterior surface of the S2 vertebral body, and the axial oblique images should be perpendicular to these coronal oblique images [12]. The slice thickness should be 3 mm or less, with an interslice gap of 0.3 mm [12].

The MR study should contain at least four sequences: a coronal oblique T1-weighted sequence sensitive for (fat) alterations in bone marrow (e.g., T1 spin echo), a coronal oblique fluid-sensitive sequence for detection of inflammation (such as STIR or T2FS), a perpendicular axial oblique sequence, and, as per recent recommendations, a sequence for optimal evaluation of the bone-cartilage interface, in Table 1 referred to as an "erosion-specific sequence" [12–14]. Different types of sequences have been investigated for optimal depiction of the bone-cartilage interface. There are multiple reports of various three-dimensional gradient echo sequences (such as volumetric interpolated breath-hold examination) outperforming routine T1-weighted spin echo MRI for detection of erosions, with the added advantage of multiplanar reformatting [15]. Alternatively, susceptibility-weighted imaging (SWI) has shown comparable results, although further validation is warranted. Finally, synthetic CT-like images based on artificial intelligence with a deep learning algorithm can be used to evaluate the cortical bone (specifically erosions, sclerosis, and ankylosis) (Fig. 3) [15].

Presence of bone marrow edema can be seen without contrast administration. It can be helpful in difficult cases, to additionally detect joint space enhancement, or when tumor or infection is suspected [2, 11, 12].

Imaging of sacroiliitis in children

Unlike spondyloarthropathy in adults, which typically presents with inflammatory back pain and early axial involvement, most children with juvenile spondyloarthropathy (JSpA) present with enthesitis and arthritis of the lower extremities, while sacroiliitis is mainly seen in later stages of the disease. However, early identification of axial involvement in JSpA is crucial, as alternative approaches and treatment options are needed [16, 17].

MRI is the imaging modality of choice for detecting early sacroiliitis in JSpA; radiography should only be used when MRI is unavailable or contraindicated [18, 19]. Main MRI sequences used for imaging pediatric SIJ

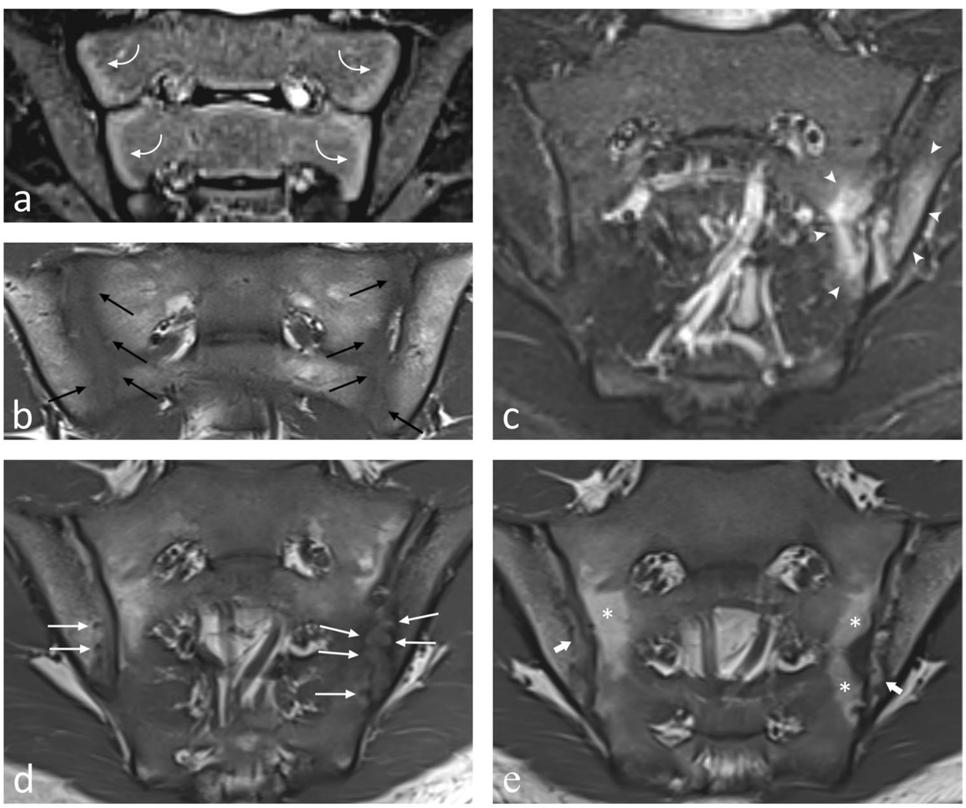

Fig. 4 MR imaging examples of normal and pathological sacroiliac joint (SIJ) findings in pediatric patients. **a** Coronal oblique short tau inversion recovery (STIR) image of a normal 12-year-old boy showing normal variability with subchondral high signal ("flaring") along the lateral apophyses of the sacrum (curved arrows). **b** Coronal oblique T1 image of a 14-year-old boy without back pain, sent for brain MRI because of headache and hypertension, showing normal variability with irregularities on both iliac and sacral side bilaterally (black arrows). **c** Coronal oblique STIR image of a 15-year-old boy with known spondyloarthritis and left-sided SIJ pain, showing active inflammation of the left SIJ with high signal in the joint space, bone marrow edema (arrowheads), and inflammation in erosion cavities on both iliac and sacral side of the left joint. **d** Corresponding coronal oblique T1-weighted image showing structural damage with erosions (long white arrows) and surrounding sclerosis on the iliac side of both SIJ and the left sacral side. **e** Coronal oblique T1-weighted image of the same patient, 5 months later, after treatment with etanercept showing bilateral periarticular fat metaplasia (asterisks), and areas of fat metaplasia in previous erosion cavities on the iliac side of both SIJ with surrounding sclerosis ("backfill") (short arrows)

are similar to those in adults. As the hips are commonly affected in children with juvenile idiopathic arthritis, they should be included in the axial sequences of the MRI study. The value of additional contrast-enhanced sequences for SIJ MRI in children is still unclear; however, most recent papers suggest a limited role of gadolinium for the detection of sacroiliitis [20, 21].

Interpreting SIJ MRI in children and adolescents is more challenging than in adults, since normal physiological changes occur during skeletal maturation, which can simulate disease (Fig. 4) [21]. On fluid-sensitive sequences, a rim of subchondral high T2 signal (so-called flaring) is commonly observed on normal pediatric SIJ images, often confused with bone marrow edema [22]. This high signal is typically symmetrical and predominant at the sacral side and disappears after closure of the segmental apophyses. Detecting erosions in children can also be challenging due to normal variability. Blurring or irregularity of pediatric SIJ articular margins—normal findings that can mimic erosions—is common in children [23]. Recognizing both normal and pathological signal changes in children is crucial to avoid these common pitfalls and thereby prevent a false-positive diagnosis of sacroiliitis.

Differential diagnosis

Multiple diseases of the SIJ may mimic axSpA both on imaging and in clinical presentation [24]. The location and the characteristics of the imaging features often provide a clue to the etiology. For example, sacroiliitis in axSpA or enteropathic arthropathy is usually bilateral and symmetric.

Mechanical strain can also cause bone marrow edema. In this case, it is often accompanied by degenerative changes such as osteophytes, dense sclerosis mainly on the iliac side, and narrowing of the joint space. Physiological regression of erythropoietic marrow with increasing age can mimic fat metaplasia seen in axSpA, adding to the difficulty in differentiating osteoarthritis from axSpA in the older patient [25]. Another common differential diagnosis is osteitis condensans ilii, a stress- and often pregnancy-related condition, typically with a bilateral triangular zone of sclerosis in the ilium and variable degrees of bone marrow edema, but without erosions or joint space narrowing (Fig. 5) [26].

Traumatic or insufficiency fractures of the sacrum cause bone marrow edema and can occasionally appear to cause focal articular surface erosion. The delineation of the fracture line or the distribution of the findings can help to differentiate these from axSpA [13].

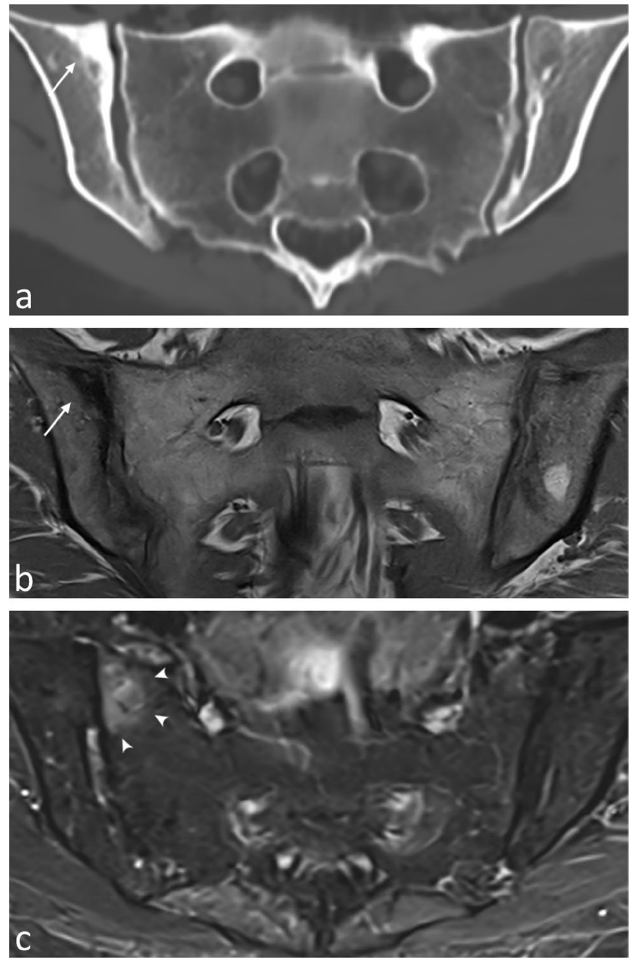

Fig. 5 MRI and CT images of a 54-year-old woman with mixed mechanical-inflammatory right-sided pelvic pain, due to osteitis condensans ilii with some bone marrow edema. **a** Coronal oblique synthetic CT and (**b**) T1-weigthed images show marked subchondral sclerosis (arrow) on the anterosuperior iliac side of the right sacroiliac joint, typical for osteitis condensans ilii. **c** Axial short tau inversion recovery image illustrates subchondral bone marrow edema (arrowheads) on the adjacent sacral side of the joint

Septic sacroiliitis can also mimic axSpA, although it is rare. MRI will demonstrate intra-articular fluid, bone marrow edema, and periarticular inflammation and abscess formation, especially during the early phase of the disease. Later radiologic changes of infectious sacroiliitis are extensive erosions and subsequent bony repair, with subchondral sclerosis and ankylosis occurring in chronic infection setting (Fig. 6).

Systemic diseases can also manifest themselves in the SIJ. Gout arthritis of the axial skeleton is usually best seen on CT and age, gender, nutrition, and other clinical

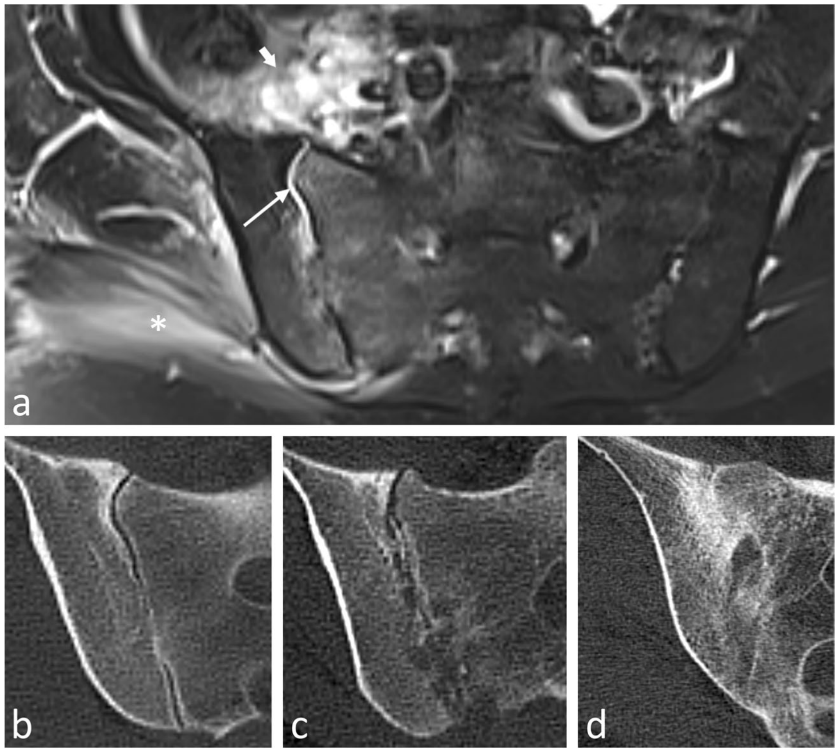

Fig. 6 MRI and CT images of a 46-year-old man with S. Aureus sepsis and bacteremia, right pelvic pain, and septic arthritis of the right sacroiliac joint (proven by biopsy). **a** Axial short tau inversion recovery image shows fluid (long arrow) in the right sacroiliac joint (SIJ) with extensive accompanying bone marrow edema on the iliac and sacral side of the joint, a large abscess in the psoas muscle anterior of the SIJ (short arrow), and edema in the right gluteus muscles (asterisk) due to myositis. **b** Axial oblique CT image at the time of diagnosis shows no erosions or other bony alterations. **c** Axial oblique CT image 1 month later depicts extensive erosive damage to the joint space, with multiple loose bone fragments. **d** Coronal oblique CT image 1 year after therapy illustrates subtotal ankylosis of the joint space of the SIJ due to repair processes with new bone formation

factors must be taken into account since these will impact the probability of this diagnosis [27].

Finally, neoplastic destructive processes can mimic axSpA by disrupting the normal cortical lining of the joint space.

Summary statement (Fig. 7)

Imaging has a prominent role in the diagnosis of sacroiliitis, which needs to be made as early in the disease process as possible to prevent irreversible damage. MRI remains the imaging technique of choice, allowing visualization of both active inflammatory lesions and structural changes. At least four sequences in two imaging planes should be performed, including a fluid-sensitive sequence and a sequence for optimal evaluation of the bone-cartilage interface (i.e., an erosion-specific sequence). Conventional radiography and CT are reasonable alternatives when MRI is unavailable or unequivocal. Low-dose CT is particularly interesting because most patients are young, and therefore, the radiation dose from ionizing radiation should be kept as low as possible. In addition, dual-energy CT allows visualization of bone marrow edema. Interpretation of MRI of the sacroiliac joints is more complicated in children, because multiple normal imaging findings can simulate disease (i.e., flaring, blurring, or irregular articular lining). Knowledge of the normal appearance of the joints is crucial for correct image interpretation.

Patient summary

Imaging is very important for the diagnosis of sacroiliitis, which is best diagnosed as early as possible to start treatment in a timely manner. MRI remains the imaging technique of choice because it allows visualization of active and structural lesions. Conventional radiography and CT are good alternatives when MRI is unclear or unavailable, especially thanks to recent developments in techniques

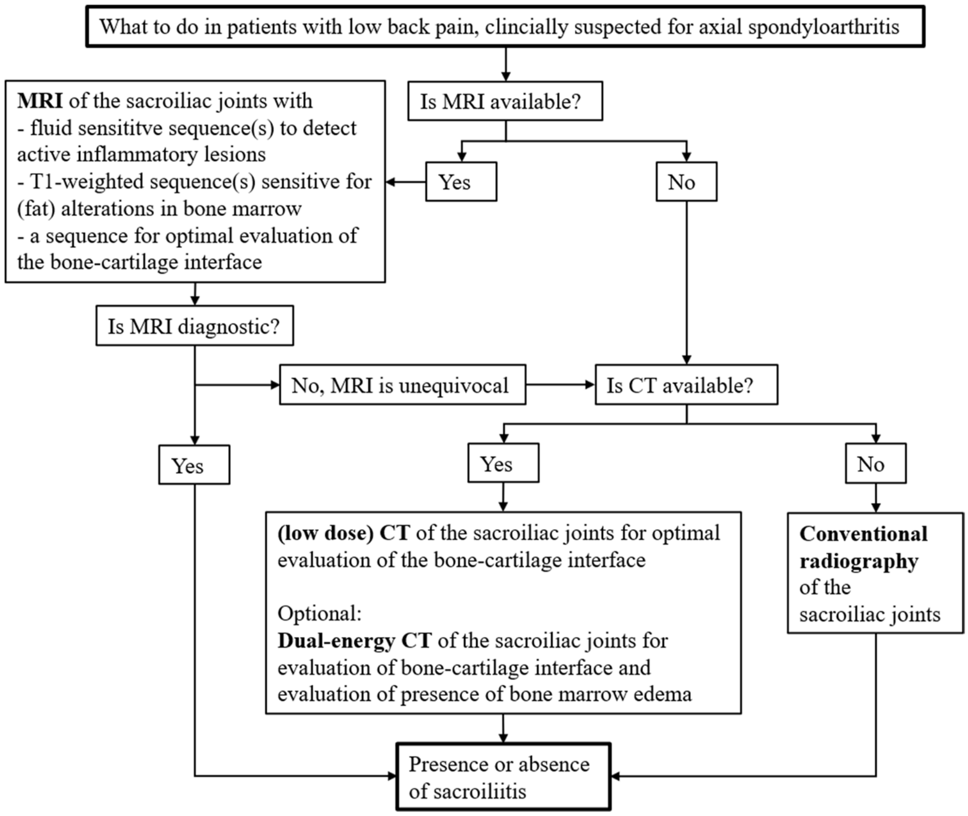

Fig. 7 Flowchart of the recommended imaging pathway of patients with clinical suspicion of axial spondyloarthritis

such as low-dose CT. The sacroiliac joints of children look different from those of adults, even when they are normal. Knowledge of this is important so as not to confuse these normal variants with disease.

Abbreviations

axSpA	Axial spondyloarthritis
DECT	Dual-energy CT
JSpA	Juvenile spondyloarthropathy
ldCT	Low-dose CT
mNYC	Modified New York criteria
SIJ	Sacroiliac joint
STIR	Short tau inversion recovery
T2FS	T2-weighted fat-saturated

Acknowledgements
This paper was endorsed by the Executive Council of the European Society of Radiology (ESR) and the Executive Committee of the European Society of Musculoskeletal Radiology (ESSR) in February 2024.

Funding
The authors state that this work has not received any funding.

Declarations

Guarantor
The scientific guarantor of this publication is Lennart Jans.

Conflict of interest
The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

Statistics and biometry
No complex statistical methods were necessary for this paper.

Informed consent
Written informed consent was not required.

Ethical approval
Institutional Review Board approval was not required.

Study subjects or cohorts overlap
Not applicable.

Methodology
evidence-based practice recommendations

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Received: 6 December 2023 Revised: 23 January 2024
Accepted: 25 January 2024 Published online: 9 March 2024

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