Imaging Atlas of Axial Spondyloarthritis

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An Essential Imaging In Rheumatology & CARE Arthritis Ltd Initiative

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Foreword

Spondyloarthritis (SpA) is an umbrella term used to describe a group of joint disorders that have in common inflammation of the sacroiliac joint (SIJ), spinal joints, and entheses in association with the presence of the HLA-B27 gene. This group includes ankylosing spondylitis (AS), psoriatic arthritis, reactive arthritis, juvenile SpA, arthritis associated with inflammatory bowel disease (enteropathic arthritis), and undifferentiated SpA. Ankylosis of the SIJ and spine is a hallmark of disease and may lead to significant functional disability.

Recent classification criteria have broadly subdivided this group of disorders into two subgroups based on the primary site of manifestations of the disease. Patients classified as having axial spondyloarthritis (axSpA) present primarily with signs and symptoms of axial inflammation, such as inflammatory back pain. Those classified as having peripheral spondyloarthritis (pSpA) present primarily with signs and symptoms of peripheral inflammation, such as large joint synovitis and enthesitis at peripheral locations.

SpA is common with AS, occurring in about 0.5% of the Caucasian population, whereas the prevalence of SpA as a group is about 1.5-2%, and is a significant health concern given early onset of the disease, often in the third decade. Diagnostic delay averages 8-9 years because back pain is frequent in the population, physical findings are often not evident until later in the disease, and diagnostic lab evaluation is limited to the insensitive and non-specific C-reactive protein (CRP).

In AS, 75-95% of patients are HLA-B27 positive, whereas in axial SpA associated with psoriasis and colitis the prevalence is much lower (42-75%). Therefore, the absence of HLA-B27 cannot be used to exclude SpA, and can lead to delayed or missed diagnosis. On the other hand, given that HLA-B27 occurs in 6-10% of the background population, and that non-specific back pain is extremely common, the majority of patients with positive HLA-B27 and back pain do not have SpA. In fact, AS accounts for no more than 5% of all patients presenting with chronic back pain. HLA-B27 therefore although clinically useful has limited diagnostic utility.

Plain radiographic assessment of the SIJ remains the cornerstone of diagnostic assessment, however has poor sensitivity with early structural changes of sacroiliitis overlapping with degenerative disease. Definite radiographic findings of sacroiliitis may therefore only be evident after several years of follow up. During this time patients may experience significant symptoms and functional disability that impairs quality of life and ability to work. Prospective studies have shown that only 10-15% of patients develop radiographic sacroiliitis (i.e. structural changes) after 2 years, about 40% after 5 years, and about 60% after 10 years.

CT is the imaging gold standard for demonstrating structural changes at the SIJ but is not routinely used as first line imaging due to the inherent radiation exposure and inability to identify the acute inflammatory components of the disease.

MRI evidence of inflammation currently represents our best measure of disease activity in axSpA. Consequently, MRI evidence of inflammation has been incorporated into the ASAS classification criteria for axSpA. There are currently *no established diagnostic criteria* although multiple classification criteria have been developed for axial SpA.

Classification criteria are based on the assessment of a group of patients with a known disease to identify similar characteristics to create a homogenous group with high specificity but often low sensitivity for the disease, are predominantly used in clinical trials and cannot be simply translated into diagnostic criteria due to inherent low sensitivity. Diagnostic criteria on the other hand allow for identification of a disease within members of the general population. Diagnostic criteria have a high sensitivity but often lower specificity and are used for diagnosis of the individual patient. The imaging diagnosis of axSpA using MRI should be based on simultaneous assessment of a T1-weighted and a fat-suppressed T2 weighted sequence so that both the inflammatory as well as the structural lesions can be evaluated in a contextual manner.

The *classification criteria of active sacroiliitis is not intended for diagnostic evaluation* because of the frequent presence of minor degrees of bone marrow edema (BME) in the SIJ of healthy individuals, sports enthusiast and those with increased mechanical stress across the SIJs. BME related to degenerative disease is one of the commonest etiologies. Additional etiologies of BME at the SIJs include osteitis condensans ilii (OCI), trauma, malignancy, infection, malignancy and alternative rheumatic and metabolic disease.

The indispensable role of MRI in the diagnostic work-up of axial SpA, accompanied by the many potential pitfalls have led us to propose an i*maging categorization system for MRI reporting in clinical practice* and is detailed within this atlas.

The current gold standard for diagnosis of axial SpA is the expert opinion of a rheumatologist based on the clinical, laboratory and imaging findings. The lack of an objective gold standard hampers clinical diagnosis and clinical studies.

Clinical assessments of disease activity cannot substitute for MRI imaging features of active inflammation. Moreover, growing evidence supports a role for MRI as a prognostic tool in identifying which patients are likely to develop structural changes on radiography such as ankylosis. The objective evidence of inflammation provided by either MRI or CRP assessment is also an important factor in selecting patients with early axSpA for treatment with expensive biological therapy. If both of these assessments are negative the patient is not likely to respond to such treatment. Consequently, MRI assessment provides clinically-relevant information beyond mere evaluation of diagnosis.

With the growing importance of MRI to the clinician major challenges have emerged focused not only on access to this technology but also ensuring that the information acquired is understood and utilized appropriately. Rheumatologists and radiologists are increasingly working in silos because of the worldwide adoption of DICOM as the medical imaging format and communication of information that occurs remotely. Assessment of DICOM

images requires the use of special software and training that rheumatologists do not receive and non-specialist radiologists may not receive dedicated training in recognizing imaging abnormalities related to axSpA. This can be addressed by increasing interaction between the specialities and use of available resources, including this atlas, to foster increased understanding of the clinical and imaging findings of this complex disease.

This atlas aims to meet the educational needs of both rheumatologists and radiologists by proving an extensive array of images that illustrate the diverse pathology that occurs in the SIJ and spine in patients with axSpA. While the primary focus is on MRI there are also examples of plain radiographic and CT findings to highlight the comparative advantages and disadvantages of different imaging modalities. Additional images also illustrate the potential pitfalls of MRI and abnormalities that can be confused with axSpA. Ultimately, the aim is to facilitate an informed dialogue between the rheumatologist and radiologist.

Additional freely available resources to supplement this atlas with additional case presentations and imaging findings are available as follows:

ESIMR (Essential Imaging In Rheumatology) App: UnRavelling Spondyloarthropathy

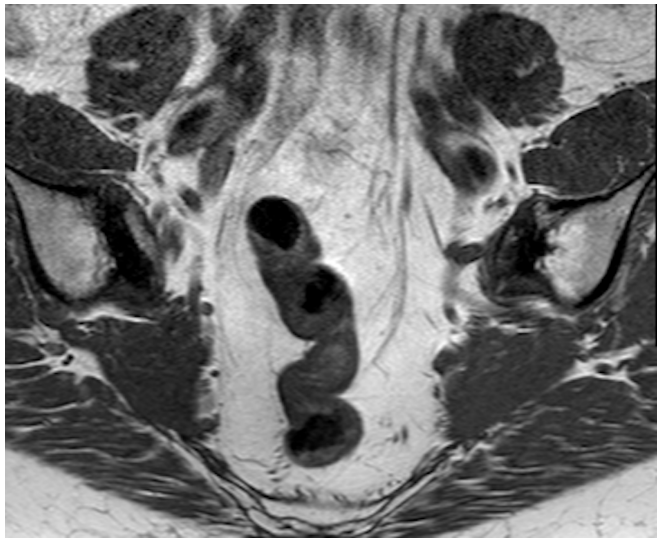
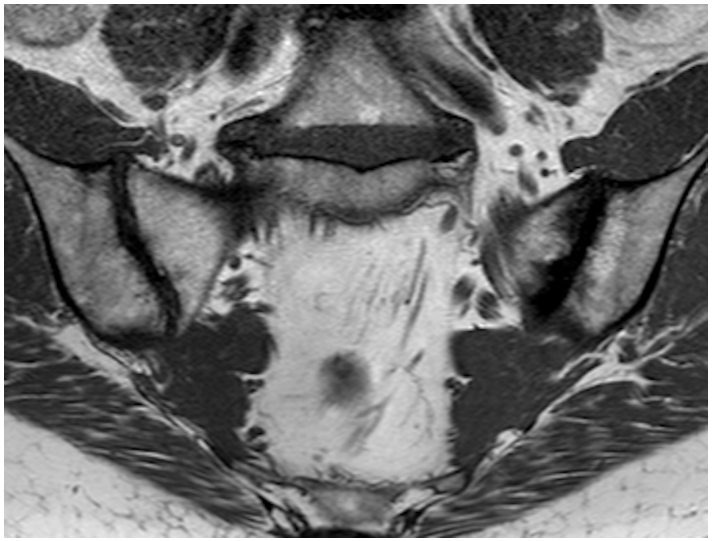
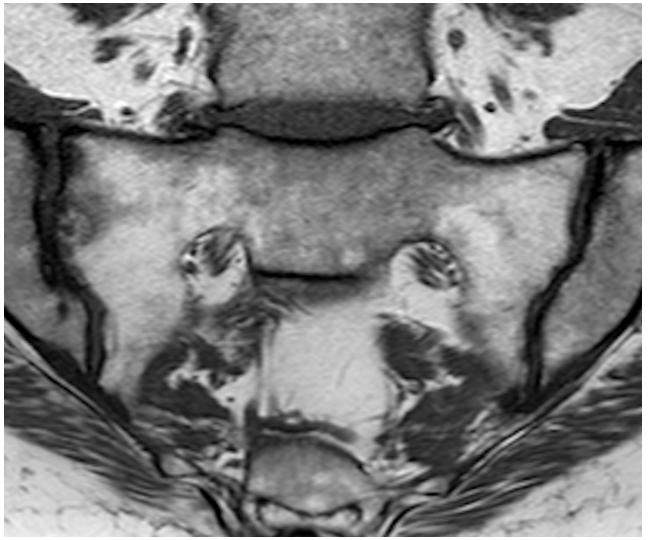
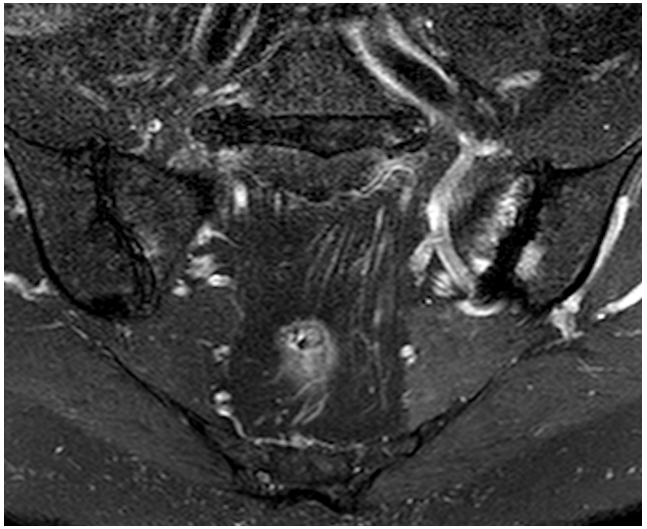
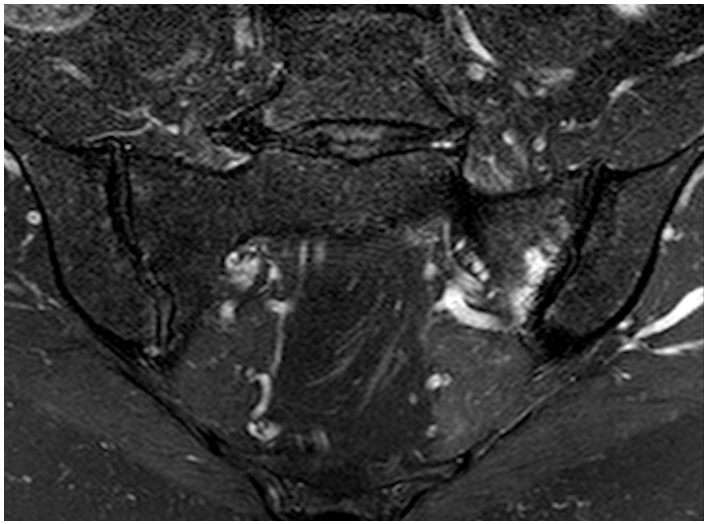
(available for mobile and desktop download on iOS and Android App Store)

CareArthritis.com

Clinical Case Challenge

The following cases are a selection of clinical cases referred from rheumatologists for clinically suspected axial spondyloarthritis. A brief clinical history will accompany representative images. Document your diagnosis for each case and repeat this exercise after you have reviewed the atlas . The final imaging findings and diagnosis are revealed at the end of the atlas with an accompanying discussion.

Case 1

51 yr old female, longstanding inflammatory type back pain with recent worsening .

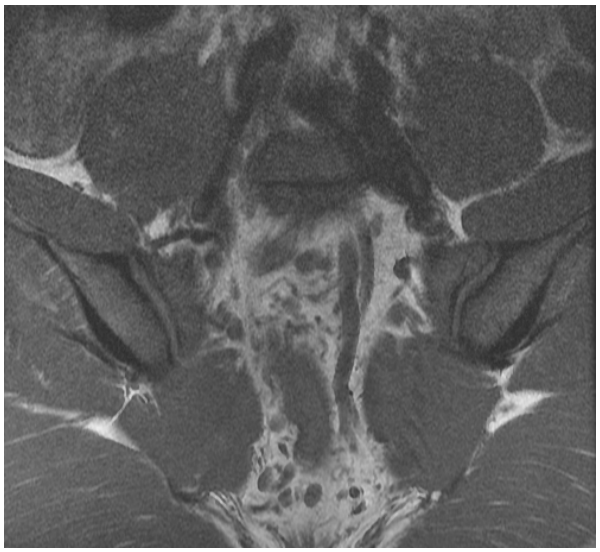
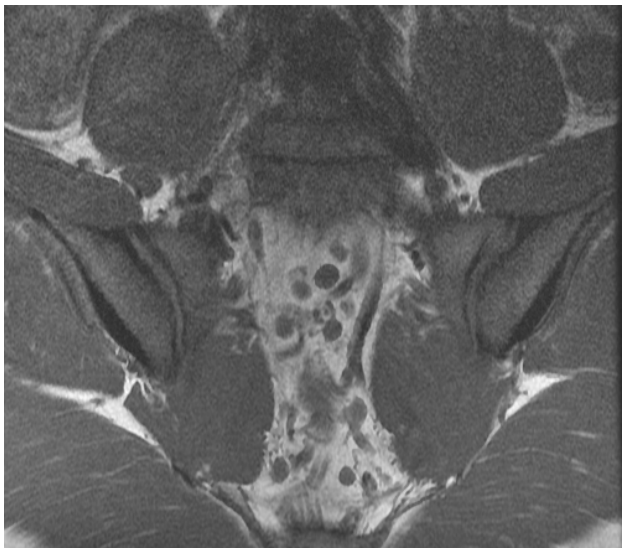
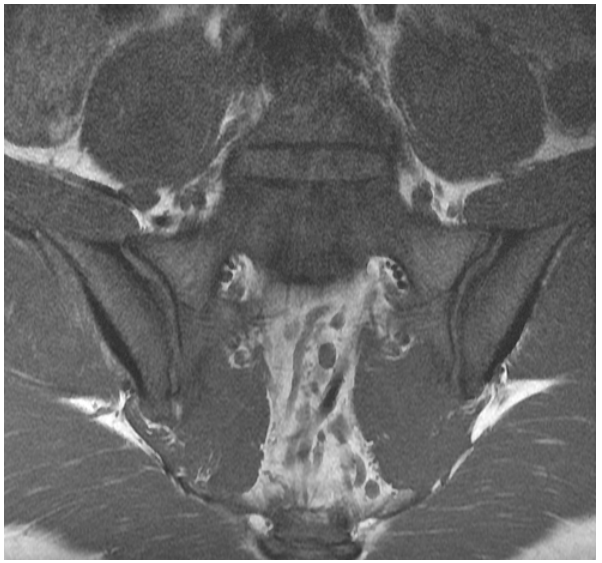
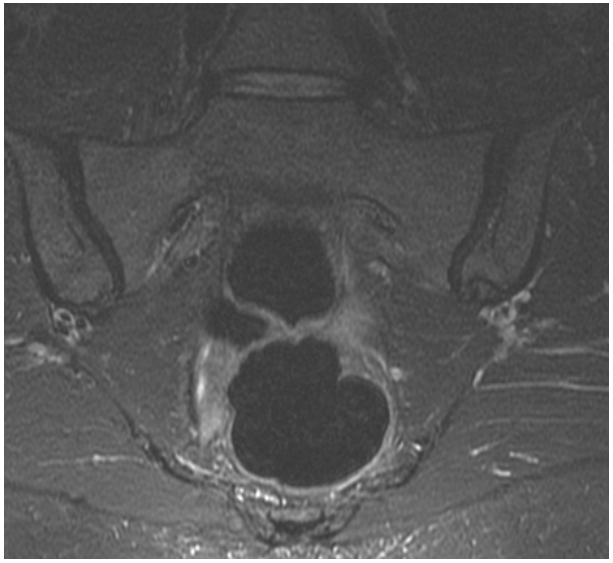
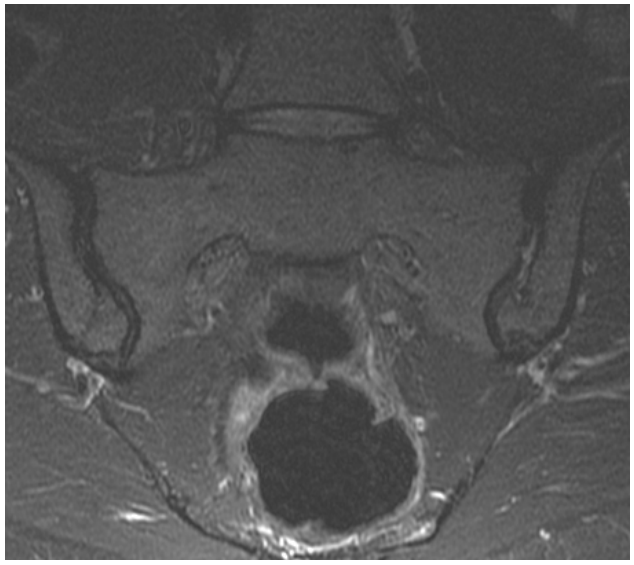
No additional diagnostic imaging findings were present on the remaining MRI of the SIJs and whole spine.

Name the type of imaging, sequences and plane of imaging

What are the imaging findings

What is your diagnosis

Case 2

21 yr old male, recent onset inflammatory type back pain, family history AS.

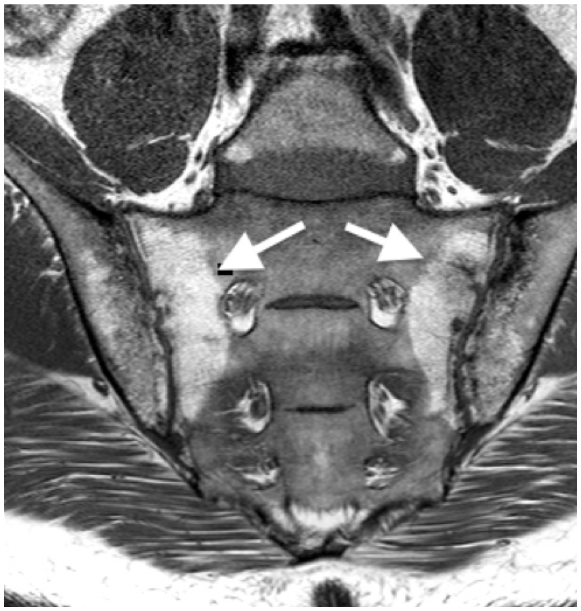
No additional diagnostic imaging findings were present on the remaining MRI of the SIJs and whole spine.

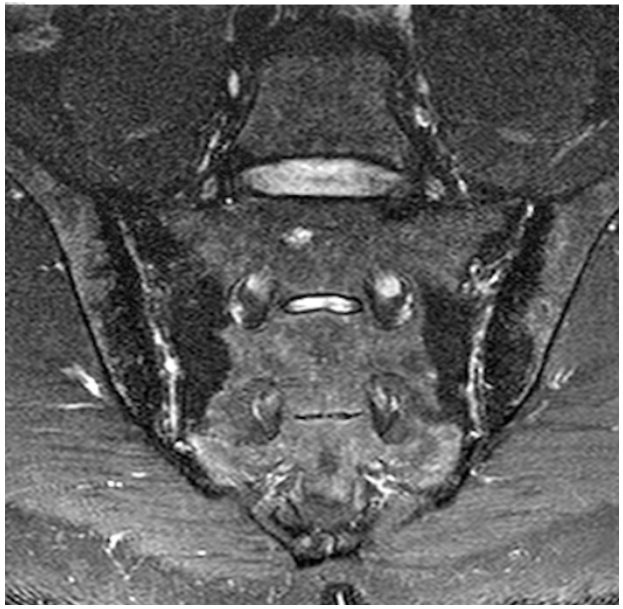
Name the type of imaging, sequences and plane of imaging

What are the imaging findings

What is your diagnosis

Case 3





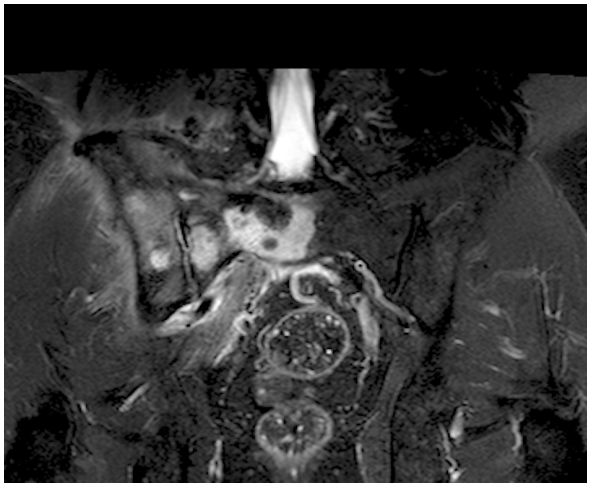
24 yr old female, HLA B27 positive, 5-6 years inflammatory type back pain, family history AS.

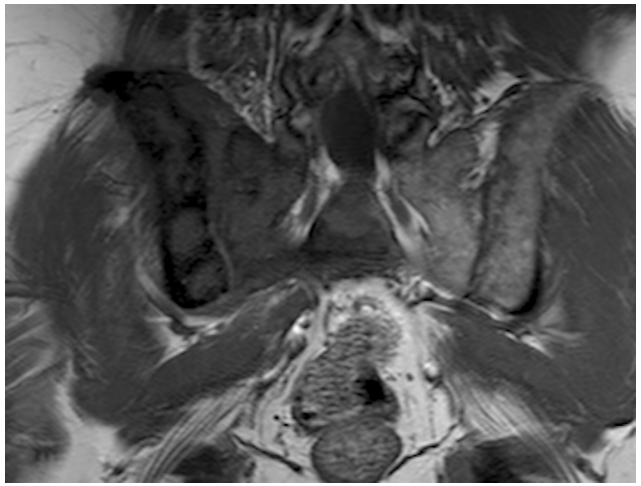
Name the type of imaging, sequences and plane of imaging

What are the imaging findings

What is your diagnosis

Case 4





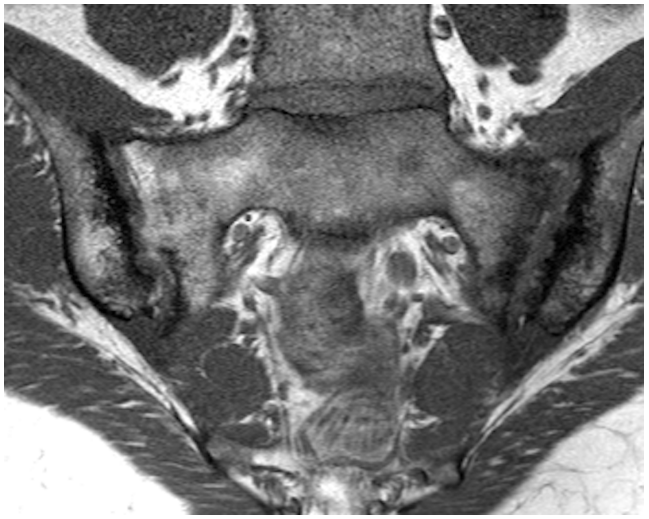
55 Male, pain right aspect pelvis, remainder history withheld

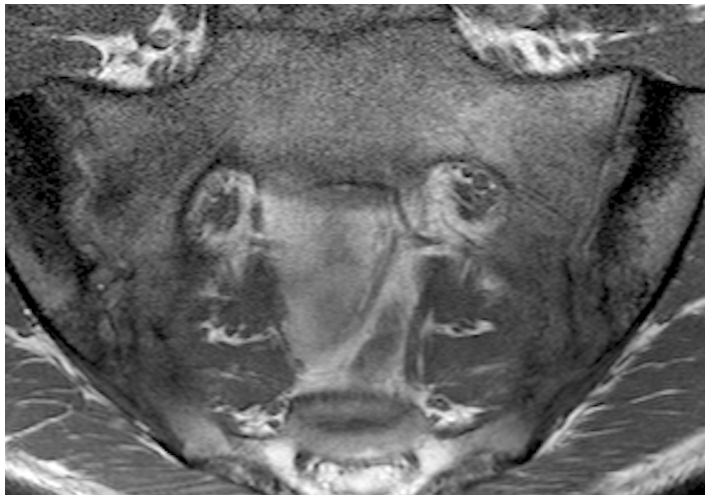
Name the type of imaging, sequences

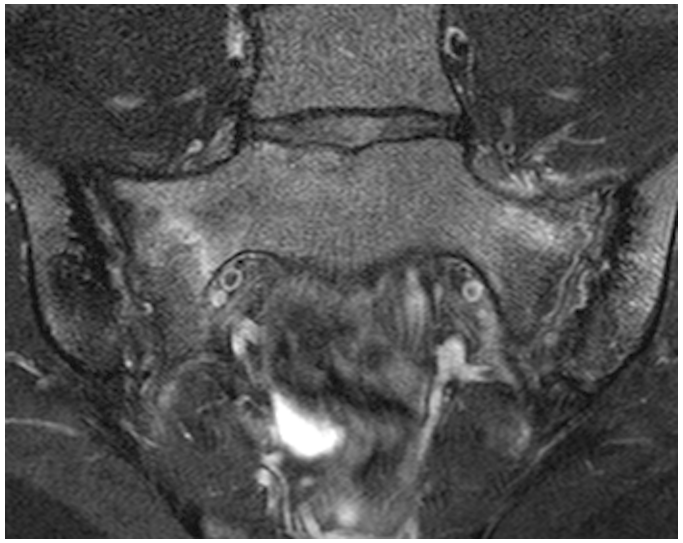
What are the imaging findings

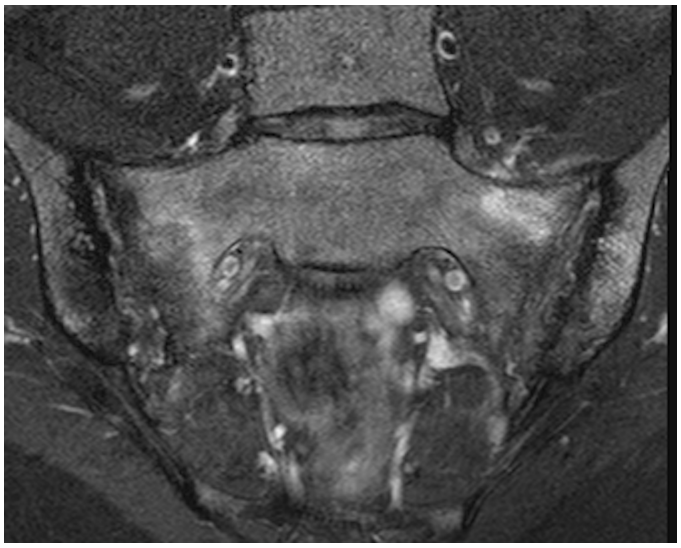
What is your diagnosis

Case 5









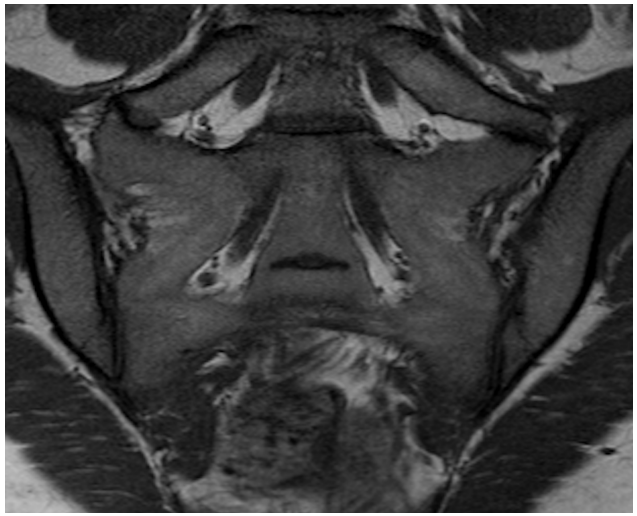
Clinical History: 22 M,
Inflammatory back pain for 3 years,
family history of
psoriasis

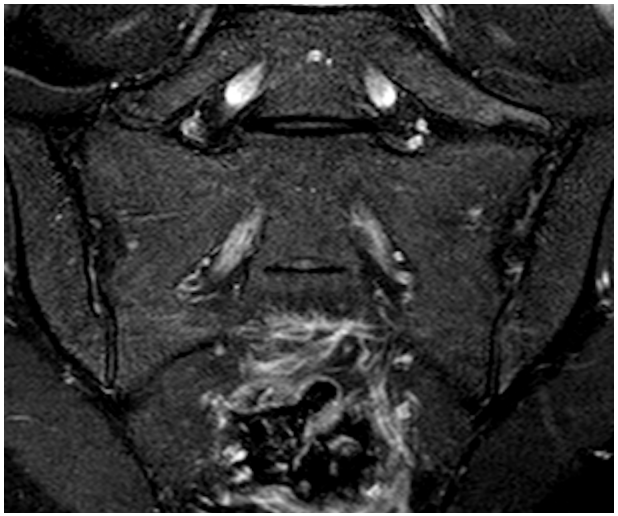
Name the type of imaging,
sequences and plane of imaging

What are the imaging findings

What is your diagnosis

Case 6





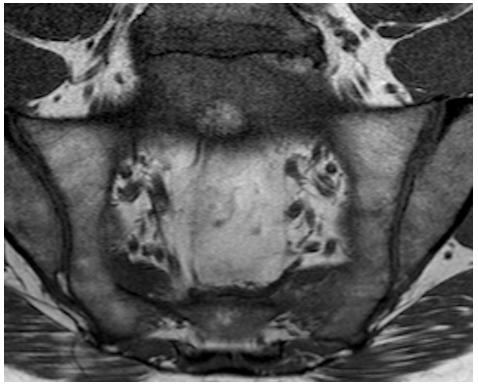
Clinical History: 23F, Neck and IBP
,
Fhx AS, HLA B27 -

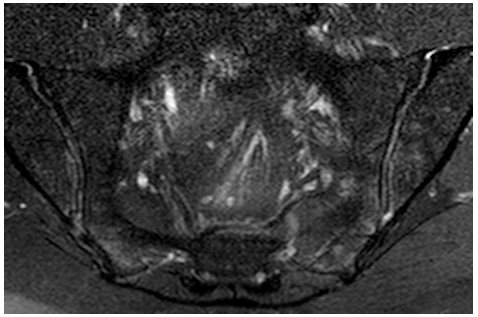
Name the type of imaging, sequences and plane of imaging

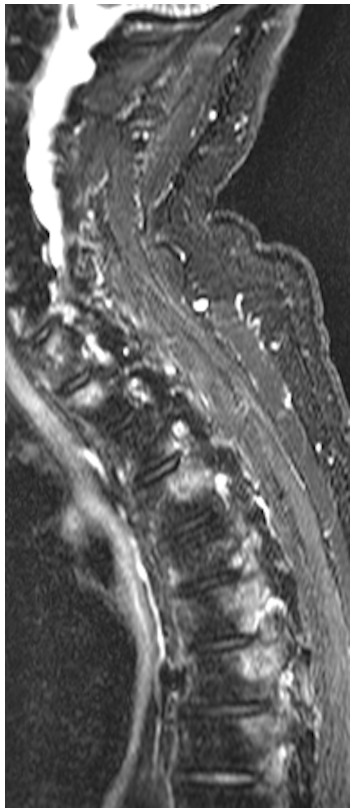
What are the imaging findings

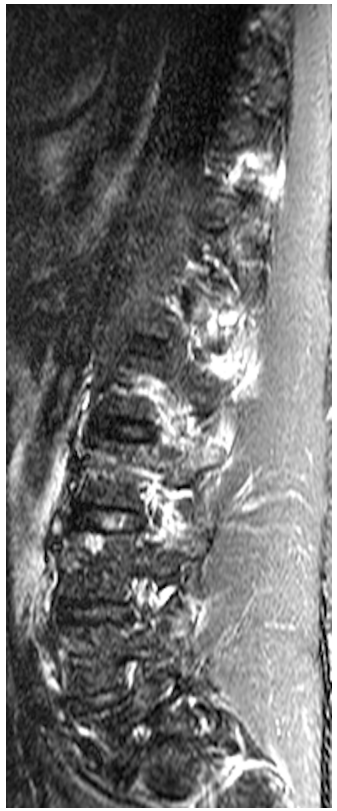
What is your diagnosis

Case 7









Clinical History: 35M, peripheral psoriatic arthritis with IBP

Name the type of imaging, sequences and plane of imaging

What are the imaging findings

What is your diagnosis

Notes

Introduction

WHAT ARE THE SPONDYLOARTHRITHIDES?

- The seronegative spondyloarthrIthis (SpA) are a group of chronic autoimmune inflammatory joint diseases
- Seronegative implies no association with rheumatoid factor
- Predominantly affects the axial skeleton (spine and sacroiliac joints)
- Often accompanied by a peripheral arthritis
- Ankylosing Spondylitis (AS) is the prototype of the SpA. We will use AS throughout this presentation as our archetype which includes:

Psoriatic Arthritis **Reactive Arthritis**

Entheropathic Arthritis **Juvenile SpA**

Undifferentiated SpA

- Onset generally occurs in young adulthood
- Often insidious onset with periods of relapse and remittance
- In many cases it is a progressive disease with increased limitation of spinal mobility
- Often presents with inflammatory back pain, enthesitis, peripheral joint synovitis, uveitis
- Inflammatory Back Pain has several definitions with variable sensitivity and specificity and include the Calin, Berlin and ASAS criteria. The Calin criteria include insidious onset, morning symptoms, duration of > 3 months ,age of onset < 45yrs and symptoms relieved with exercise.
- Peripheral joint synovitis may present before or after axial presentation. Usually oligoarthritis, asymmetrical with lower limb dominance. The hips, knees, ankles and MTPJs are the commonest affected joints.
- Anterior uveitis occurs in up to 1/3 patients, presents with pain, redness and photophobia. Usually unilateral and may be recurrent.
- With Ankylosing Spondylitis as the model for SpA, the time from initial symptom presentation to final diagnosis can be up to 9 years (symptoms often relapse and remit, may be low grade and often thought to be attributed to muscular strain injuries/degenerative disease by patients/clinicians. Delay in diagnosis has significant negative implications for patient's well-being
- Treatment with anti-TNF agents is most effective earlier in the course of the disease before structural changes occur.

DEMOGRAPHIC AS

- Ankylosing spondylitis (AS) is more common in men (2:1)
- Men develop chronic radiographic findings earlier than women
- Majority of patients present in middle age although disease often commences in late teens and twenties
- 75% present between 20-45 years of age
- 20% before the age of 20
- 5% after 45 years of age

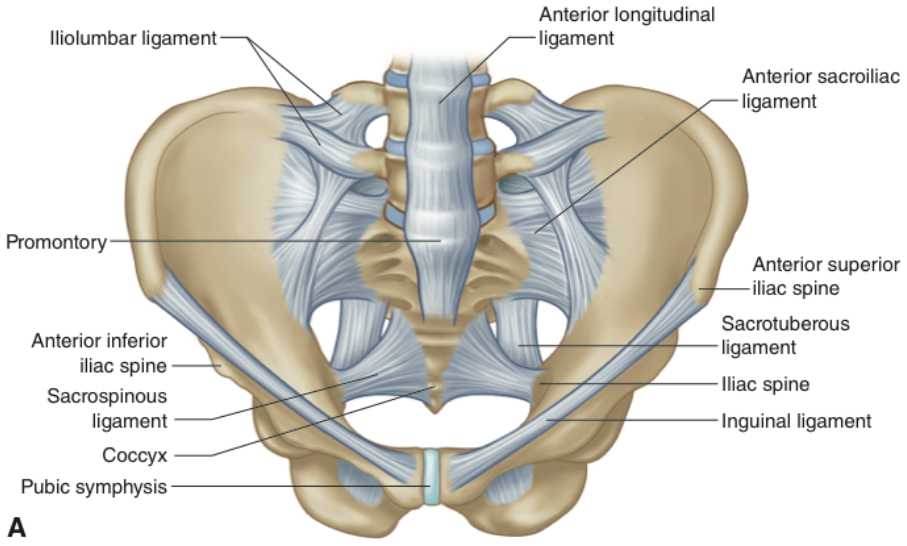
PREVALENCE

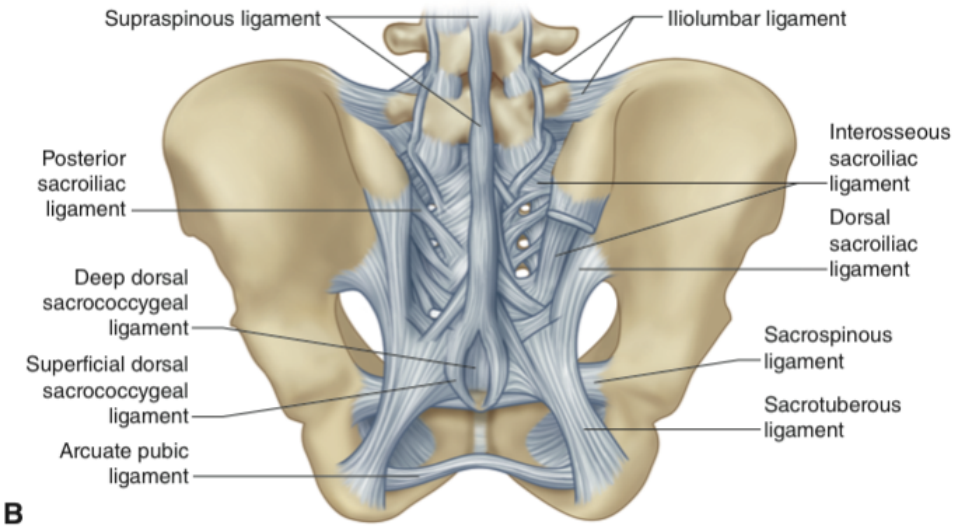
- Varies between ethnic populations (Highest in European ancestry, 1.4%)
- Overall prevalence in the United States of SpA is as high as 1.3%
- 0.2% - 0.5% for ankylosing spondylitis
- 0.4% for psoriatic arthritis
- 0.065% for enteropathic peripheral arthritis
- 0.05% - 0.25% for enteropathic axial arthritis

PREDISPOSITIONS

- Closely linked with HLA-B27 status: constitutes 20% of total disease risk for SpA
- 5% of HLA-B27 positive individuals will develop AS
- 75-95% of patients with AS are HLA-B27 positive
- 42-75% with psoriatic arthritis or inflammatory back disease are HLA-B27 positive
- HLA-B27 status predisposes greater risk to certain populations
- Up to 100 variants of HLA-B27 described, some of which demonstrate a greater predisposition to AS
- 12% risk of developing AS in HLA-B27 positive primary relatives of patient with AS
- Theorized that HLA-B27 positive patients with SpA have interacted with an environmental factor/s, likely infectious, causing an inflammatory response at the cartilage-bone interface
- Other genetic predispositions include ERAP1 and Interlukin 23 receptor.

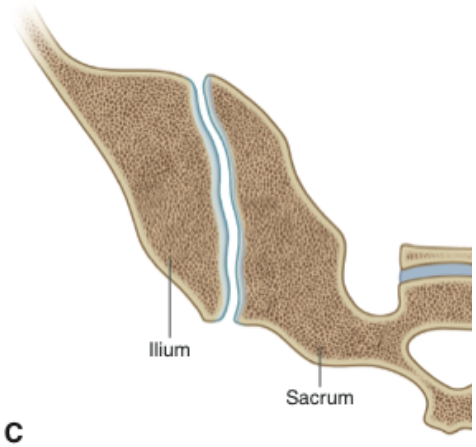
Anatomy & Imaging-Sacroiliac Joints



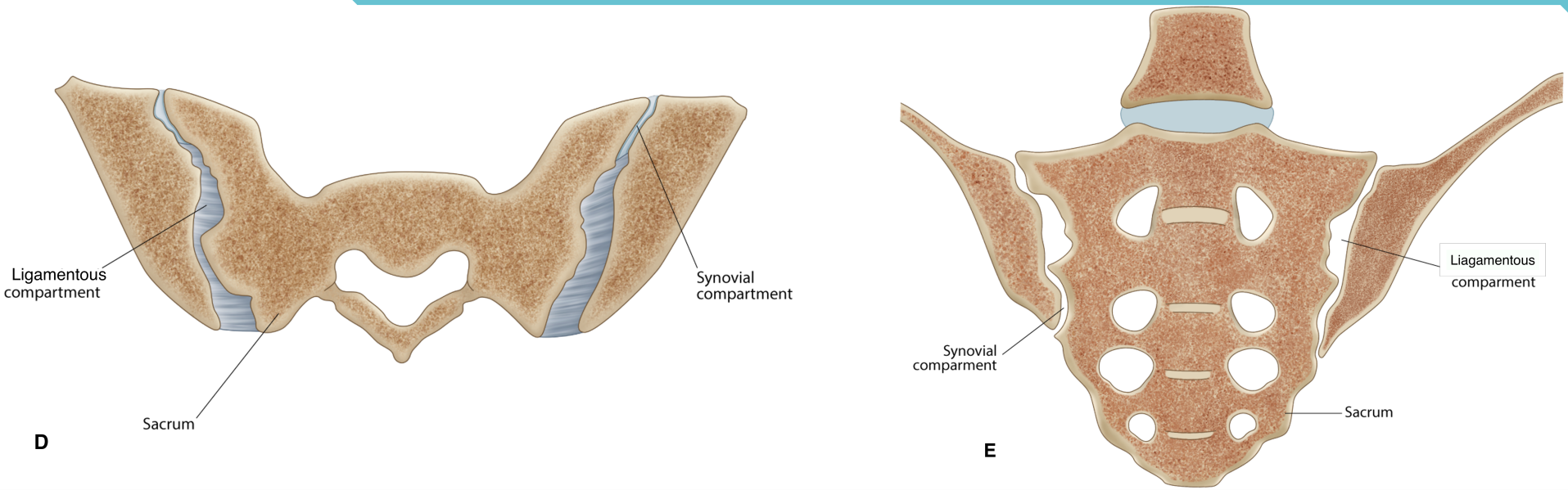


A. Illustration of the normal anatomy of the sacroiliac joints with overlying ligaments - Anterior view, B - Posterior view & C-Axial cut through right sacroiliac joint demonstrating normal interdigitations of the articulation.

Traditionally, the SIJs were considered to consist of a smaller posterior and superior ligamentous or entheseal compartment and a larger anterior and inferior cartilaginous compartment. More recent research would indicate the articulation is best classified as a symphysis rather than a true synovial joint. The articular surface of the sacrum is C or L-shaped, opening dorsally. The sacrum is composed primarily of S1-S3 vertebral elements with the S1 providing the largest element.



In the standing position the the sacrum is titled forward with the S1 orientated almost vertically extending obliquely and sagittally from craniolateral to slightly caudomedial. The iliac component of the articulation has a corresponding convexity aligning with the concavity of the sacrum.The articulation is surrounded by numerous ligaments including the strong iliolumbar ligament, the anterior longitudinal ligament and the thin ventral sacroiliac ligament. Posteriorly the interosseous ligament, the strongest ligament in the body, is divided into two



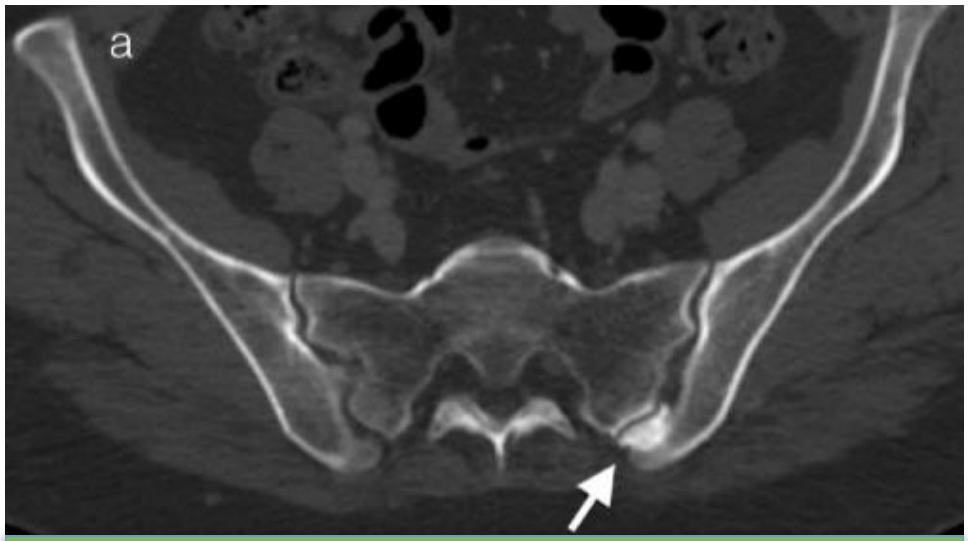
D. Axial illustration SIJ at a higher level than (C) demonstrating both the synovial and ligamentous compartments & E- corresponding Coronal Illustration

components, a deep portion directly posterior to the sacroiliac joint and a superficial portion. Fat and a rich array of vessels are interposed between the ligamentous fibres More posteriorly lie the short and long dorsal sacroiliac ligaments. The articular surface at the centre of the SIJs has hyaline cartilage with fibrocartilage only at the periphery. The periphery of the cartilage, with the exception of the distal third of the iliac cartilage, blends with the stabilizing ligaments and forms a wide margin of fibrocartilage. A small synovial recess exists at the ventral aspect of the distal third of the iliac aspect of the joint. Note that synovium is only present at the periphery of the inferior third of the cartilaginous portion of the joint.

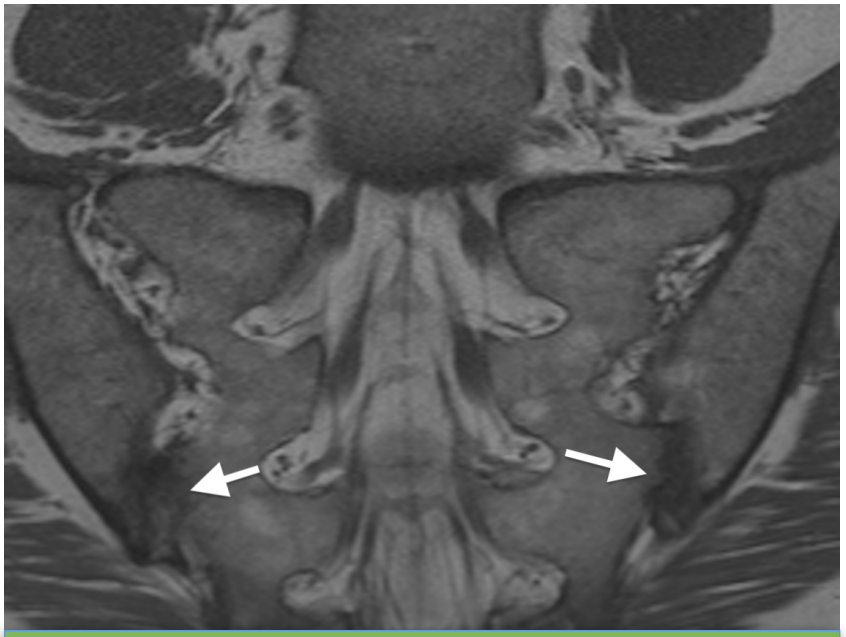
Central sacral cartilage can measure up to 2.1 mm whereas the iliac cartilage measures up to 1.2 mm. The articular margins of the sacrum and iliac bones are irregular with interdigitations, which limit mobility and enhance the strength of these joints. There are irregular bony pits, dorsal to the articular surface, at the site of ligamentous attachment, the dorsal syndesmosis.

The SIJs demonstrate have limited mobility, this is particularly true in males with 40% less mobility than females. Mobility increases in pregnancy and in multiparous women. The normal SIJ can demonstrate considerable variability, particularly with increasing age. Under the age of 30 years, the SIJ's are usually symmetric in appearance. A higher prevalence of asymmetric non-uniform joint space narrowing and ill-defined subchondral sclerosis has been observed in women, obese and multiparous females than in age matched males, and individuals of normal weight and non-multiparous respectively.

Anatomical Variants



Left symptomatic accessory facet joint (arrow) on axial CT with prominent reactive subchondral sclerosis on the iliac aspect. Can occur in up to 13% of articulations, usually at the level of the second sacral segment and may be bilateral. Occasionally the articulations are fused.



Bilateral accessory facet joints (arrows) on semicoronal T1 MRI with mild to moderate reactive subchondral sclerosis

Multiple anatomical variants have been observed in patients undergoing pelvic CT and MRI. These include: accessory articulations, bipartite iliac bony plate, iliosacral complex, partial synostosis and semicircular defects which may occur on either side of the articulation. Accessory articulations are the commonest variant and occur within the ligamentous compartment.

Sacroiliac Radiograph

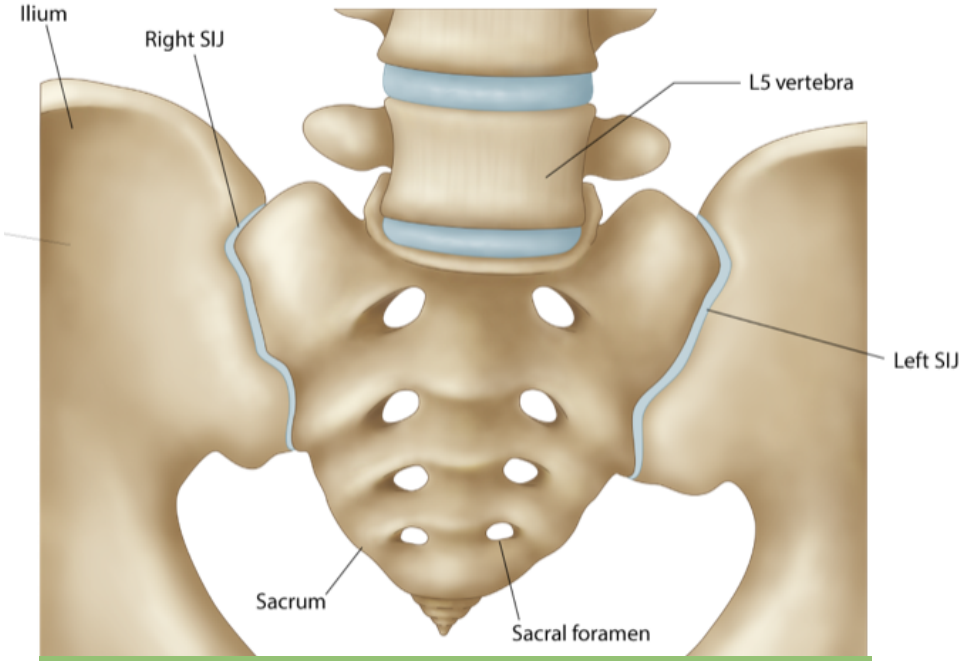
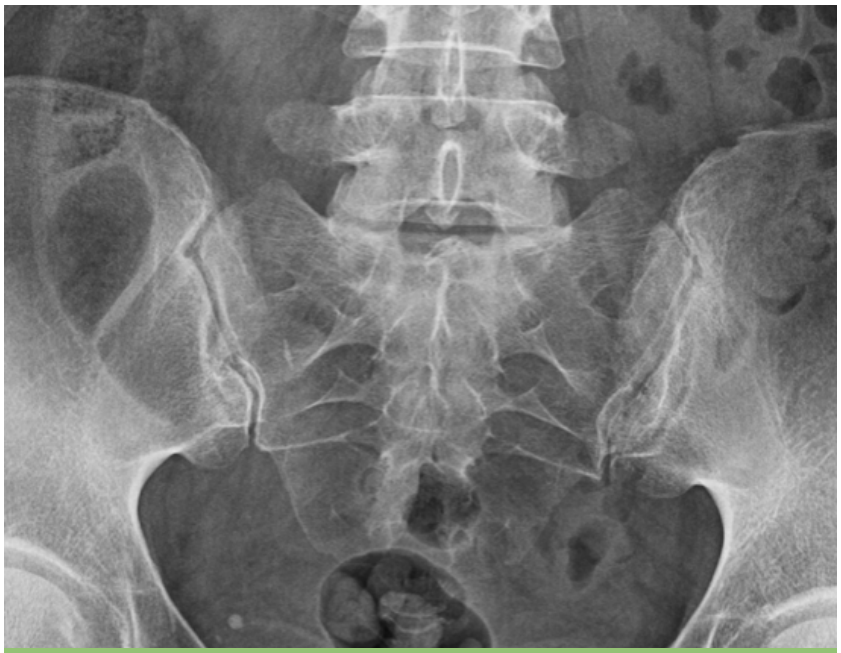


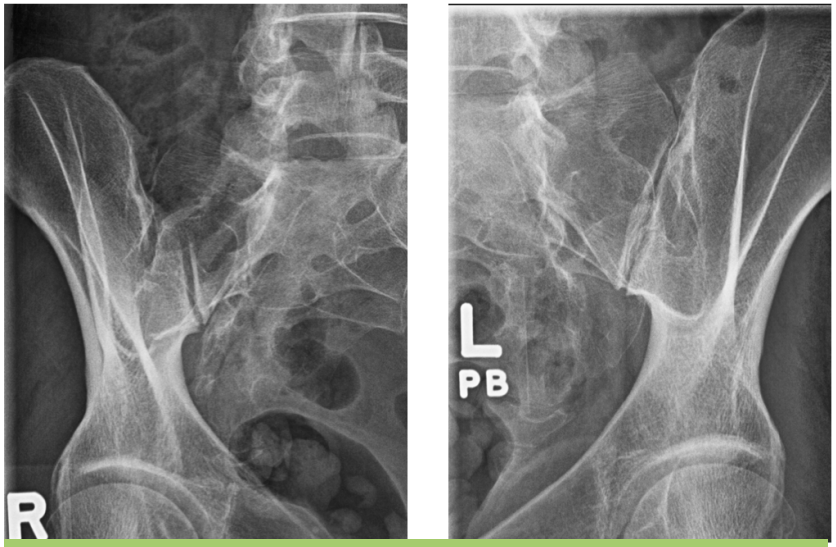
Illustration Normal Sacroiliac Joints



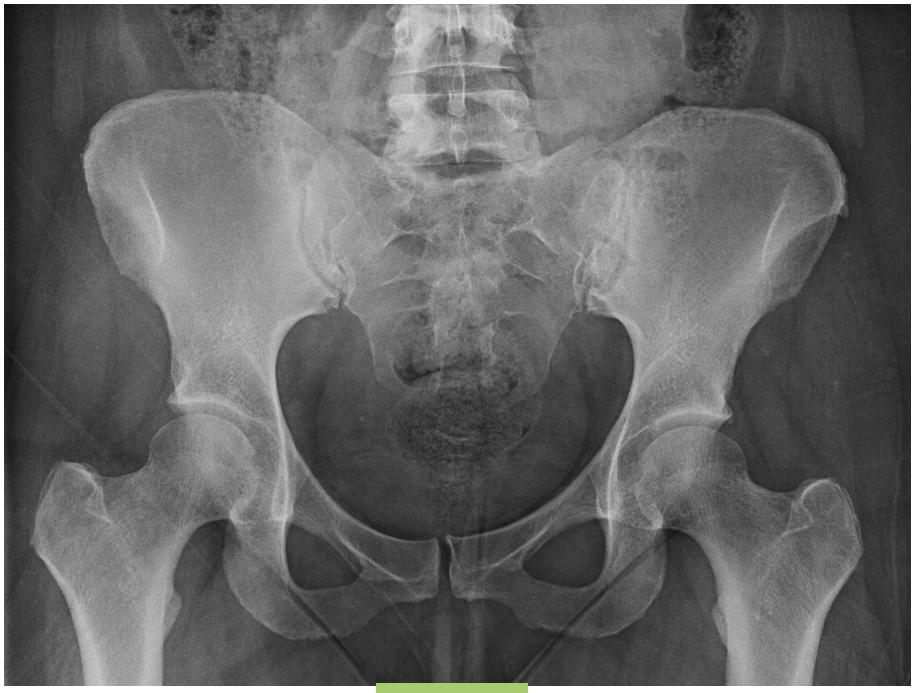
AP Normal Sacroiliac Joints

Plain radiography has and continues to play an important role in the investigation of SII and is an integral part in the diagnosis of AS. Multiple radiographic studies are available for the assessment of the sacroiliac joints include dedicated AP, Ferguson view (AP with cranial angulation tube) and PA views. PA views incur a lower radiation dose. Additional bilateral oblique views can be obtained without additional diagnostic yield and are not routinely recommended given the significant radiation exposure.

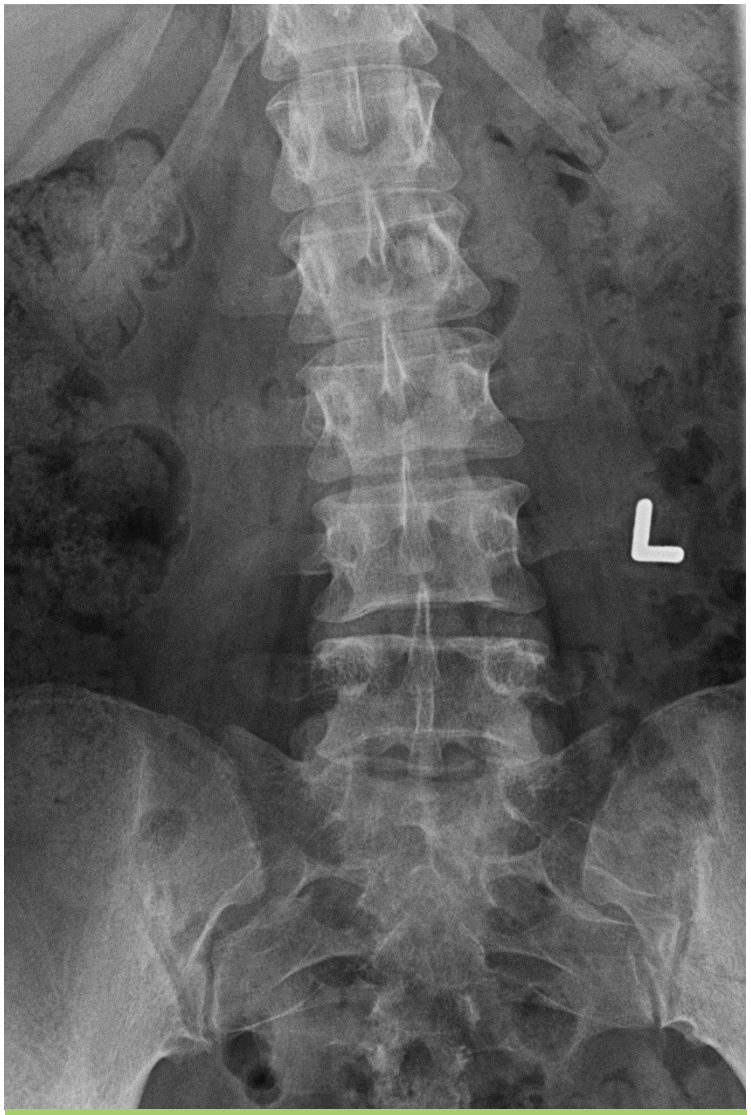
Some centres advocate a baseline AP of the pelvis. This allows for a combined assessment of the sacroiliac joints and the hip joints, the latter may be involved in up to 25% of patients with SpA. Note that a dedicated AP of the lumbar spine often includes a diagnostic assessment of the SIJ and may not require any further radiographs. The anatomy of the sacroiliac joint, due to its oblique nature and overlap of the sacral and iliac components, has led to significant inter and intra observer variations particularly in the interpretation of early SII. Therefore obtaining additional projections is not recommended and in equivocal cases further evaluation with MRI is advised.



Right & Left Oblique Radiographs SIJ



AP Pelvis



AP Lumbar spine with clear demonstration SIJs

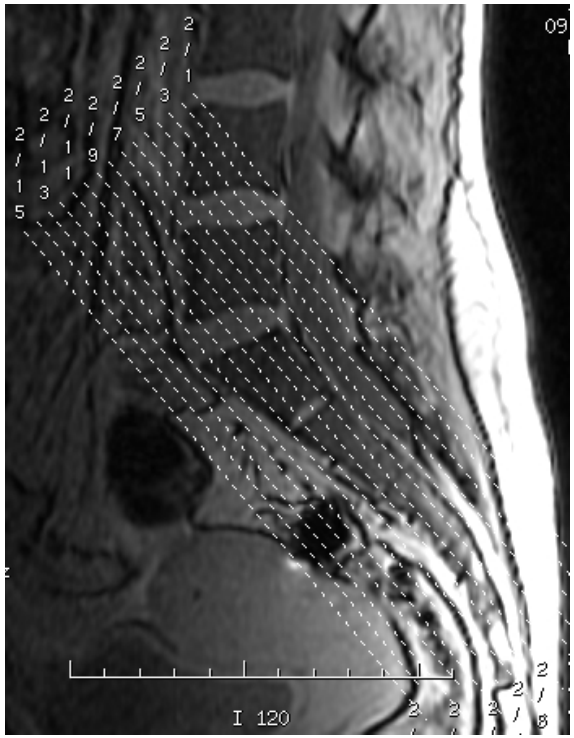
SACROILIAC MRI

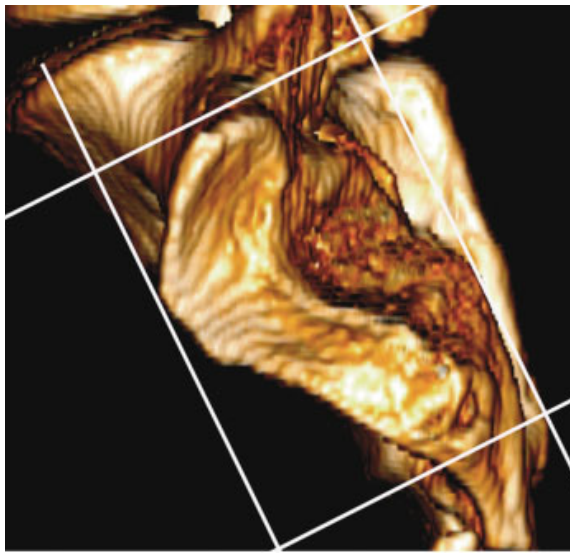
MRI is the imaging gold standard for sacroiliitis. MRI is non-ionizing, provides excellent anatomical detail and delineation of both inflammatory and structural changes of sacroiliitis. The MRI acquisition begins with a set of localizer images which are rapidly acquired slices with low resolution to allow for localizing the region to be imaged and the setting of parameters such as field of view, slice thickness etc.

The top right is a sagittal image of the lower lumbar spine and sacrum acquired from the localizer sequence. As one is interested in assessing the sacroiliac joints in the highest detail possible, anatomy anterior and posterior to the SIJs is superfluous. Therefore we acquire only the area of interest and align the image acquisition to the required anatomical plane, in this case we can see 15 continuous lines have been aligned in a semi-coronal plane, parallel to the sacroiliac joints lines.

Note that the first semicoronal images are just anterior to the joint, this ensures the whole joint is included. In addition it is important to recognize that the *first anatomical component of the SIJ is the superior aspect of the joint* and the inferior aspect is visualized only on later images.
Consecutive 3mm slices (15-20) through cartilaginous portion of SIJ with semi-coronal T1 and STIR sequences. See Imaging Acquisition protocol for MRI of SIJ at www.carearthritis.com

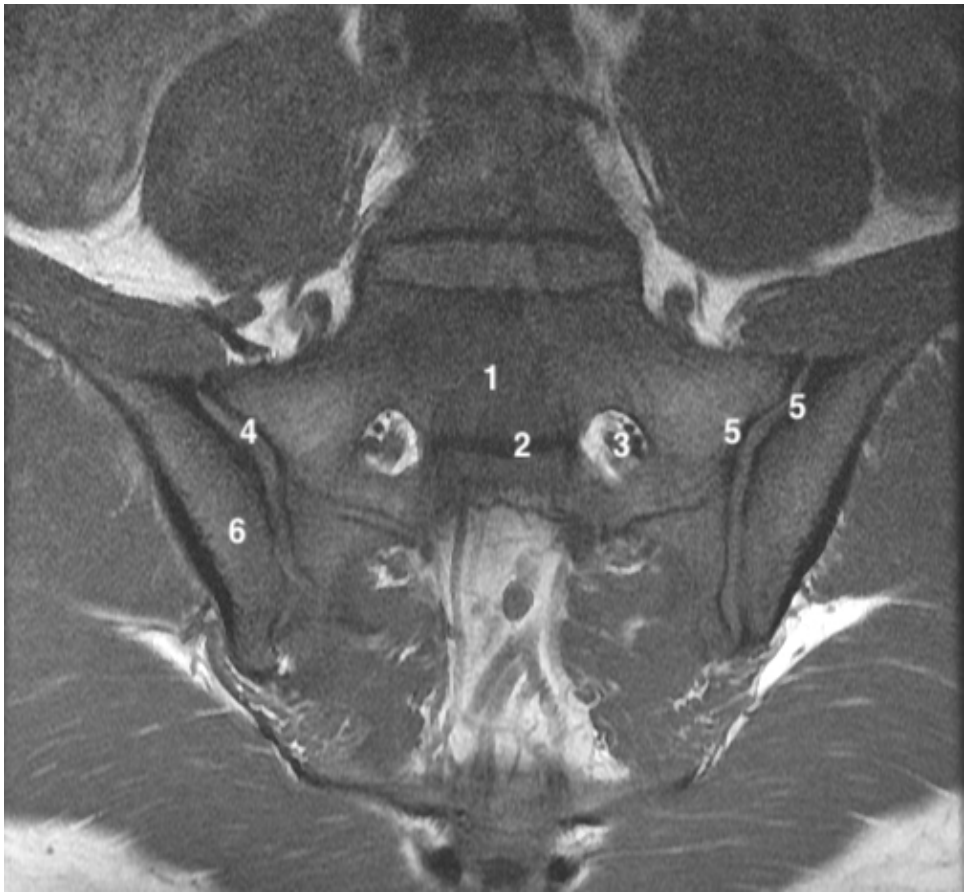
See Imaging Acquisition protocol for MRI of SIJ at





Sagittal localizer (top image) and a 3-D reconstruction demonstrating plane of interest in evaluating the SIJs

Standard Semicoronal T1 Sequence



CORONAL T1 Mid Articulation

1-1st Sacral body

2-Vestigal disc between S1 and S2

3- Lt S1/2 Sacral Neural foramina with exiting left S1 nerve root, adjacent vessels and surrounding fat

4 -Rt sacroiliac joint cartilage

5- Subchondral bone plate

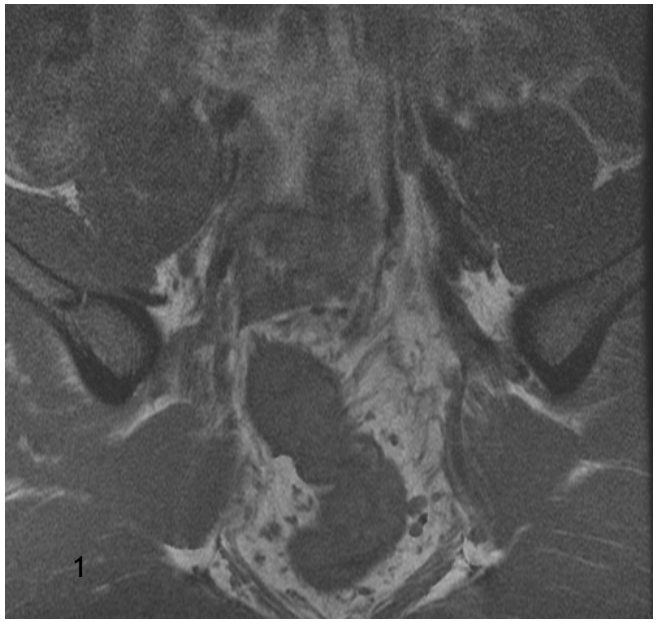
6-Subchondral normal marrow

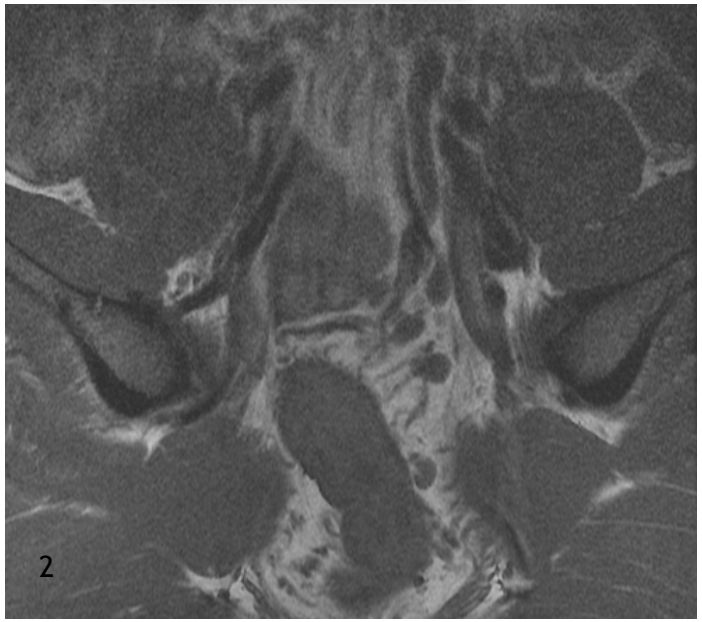
Standard semicoronal T1 sequence (without fat saturation) is excellent in assessing the normal anatomy of the SIJs.

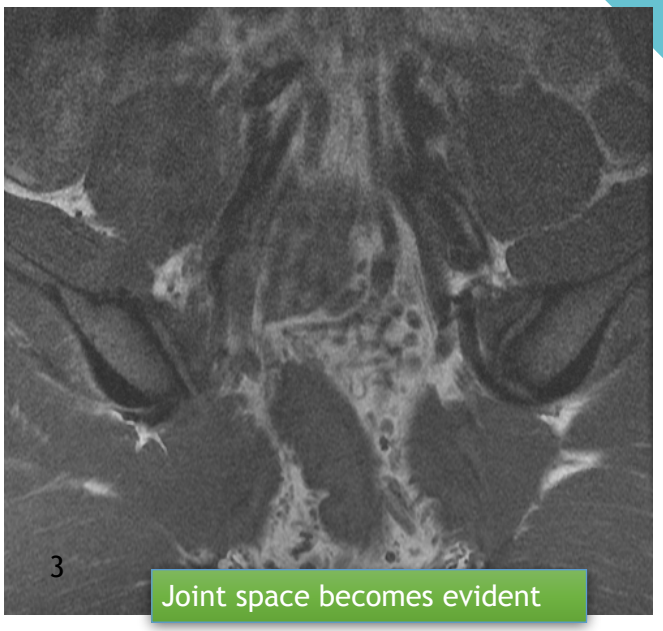
The *joint space* is low signal intensity (SI) and may not be visible. The articular cartilage is low to intermediate signal intensity (gray)
The *subchondral bone plate* is seen as a thin linear uninterrupted low SI line deep to the cartilage.

Deep to the subchondral bone plate is the *subchondral bone marrow* which can vary in signal intensity depending on the age of the patient, in younger patients there is more abundant red marrow which is of intermediate SI and slightly higher than muscle which is replaced by increasingly fatty marrow as one ages and becomes higher in SI. The *normal subchondral marrow should be of similar SI to the sacral marrow at the level of the sacral foramina*.

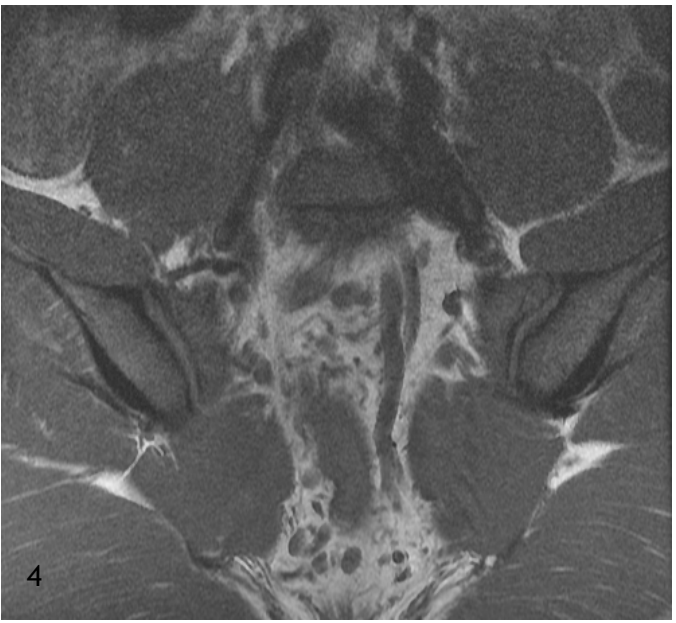
Semicoronal T1 sequence

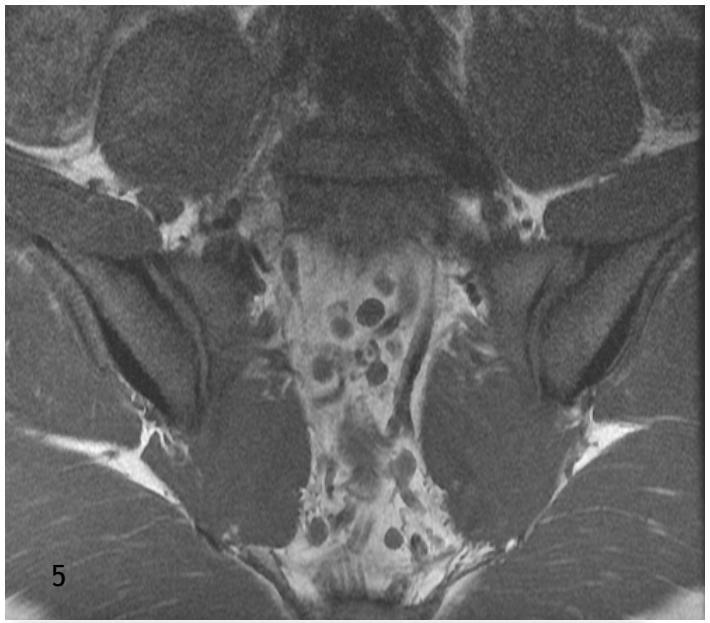


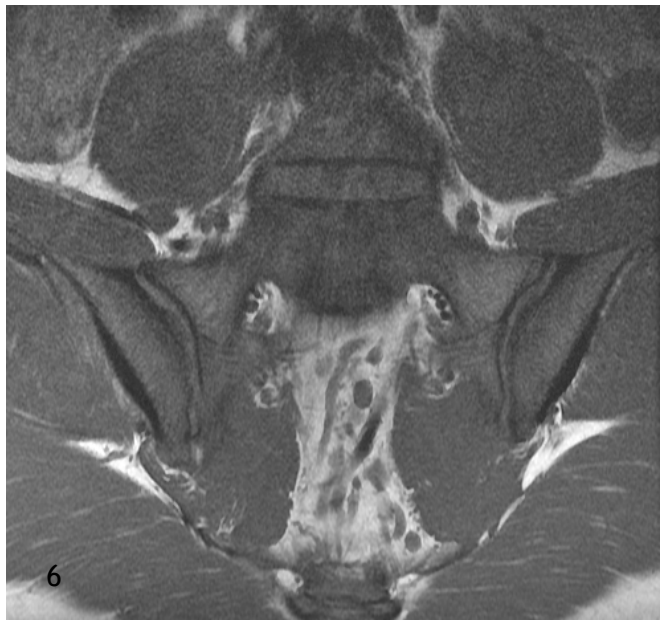




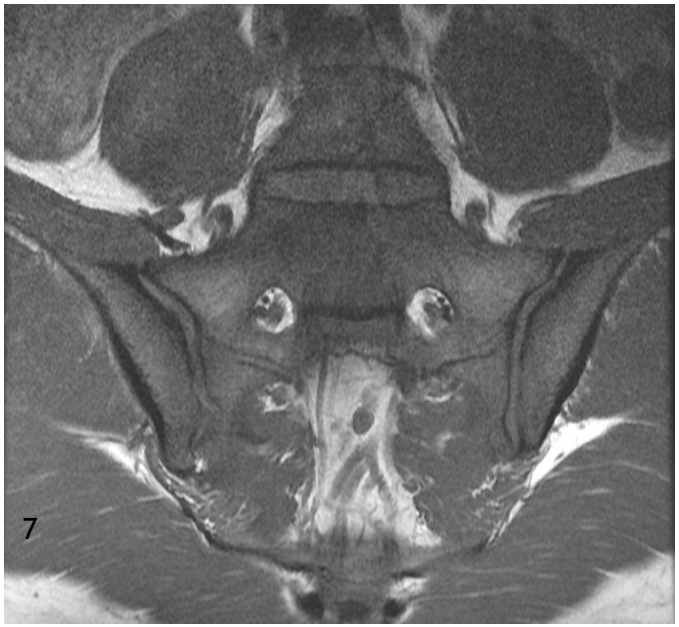
Joint space becomes evident

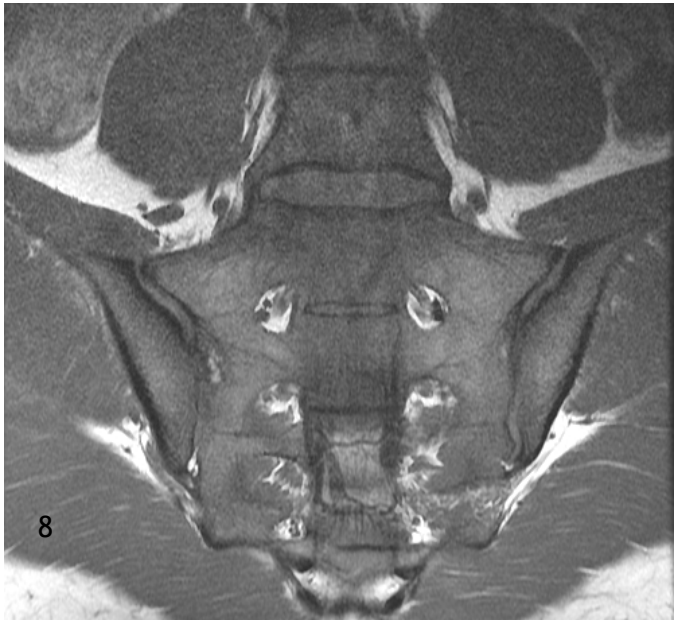


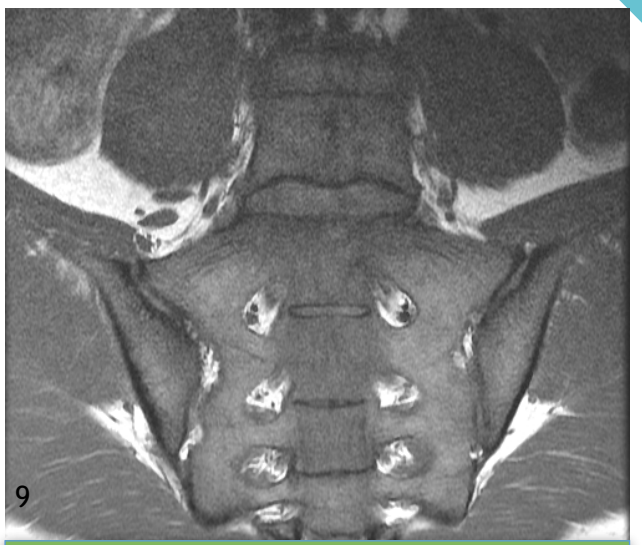




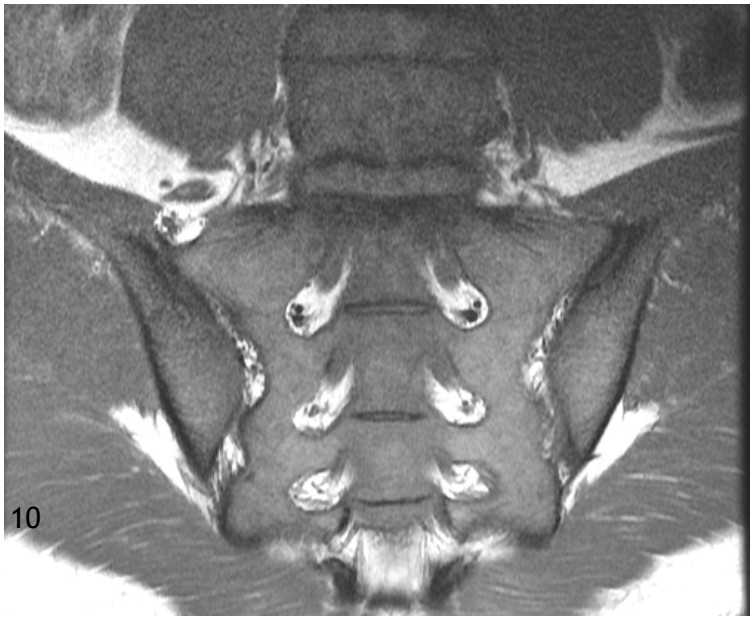
Coronal T1 SIJ (from anterior to posterior)

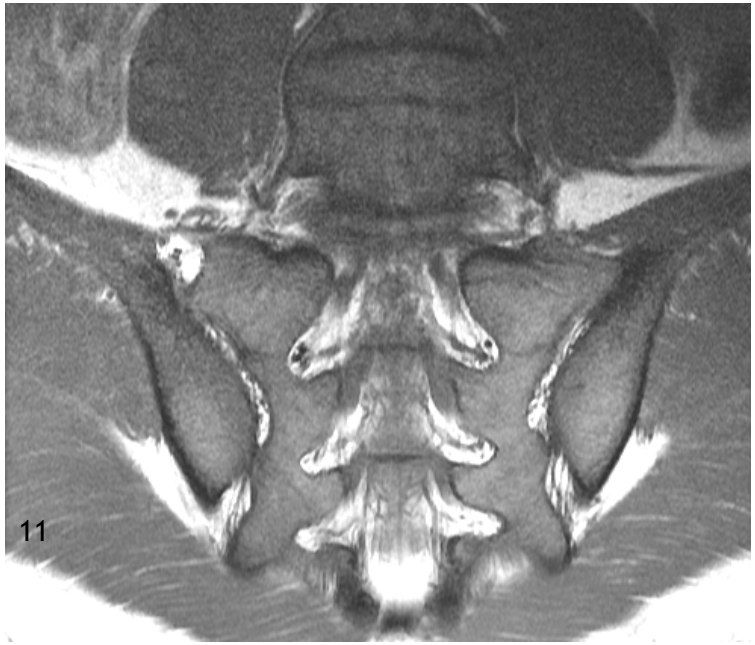




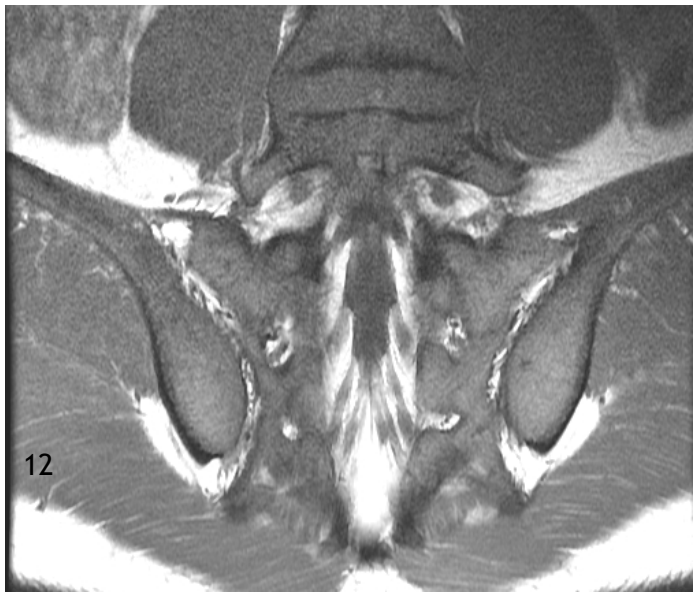


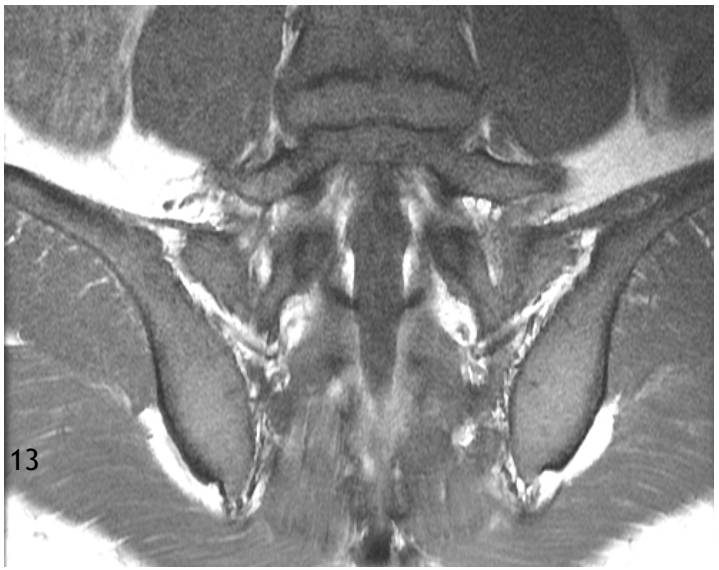
Transition between joint and ligamentous compartments



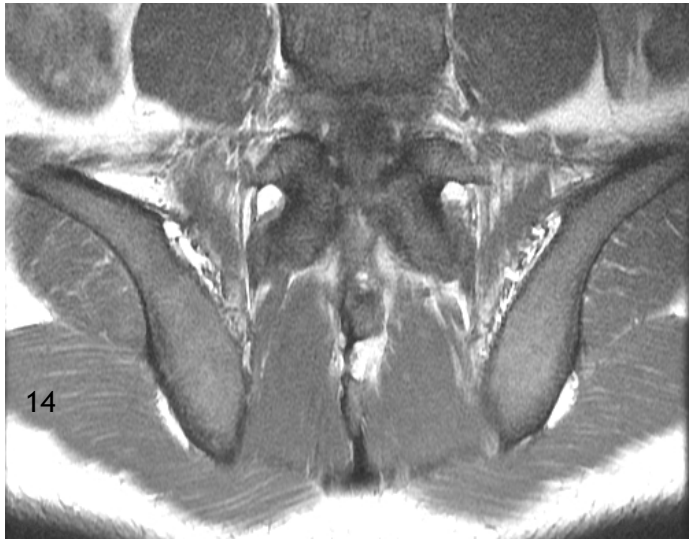


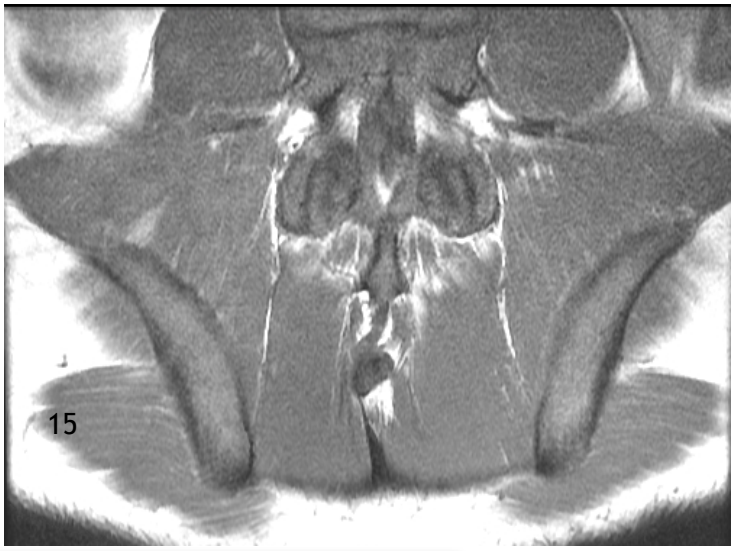
Coronal T1 SIJ (from anterior to posterior) continued



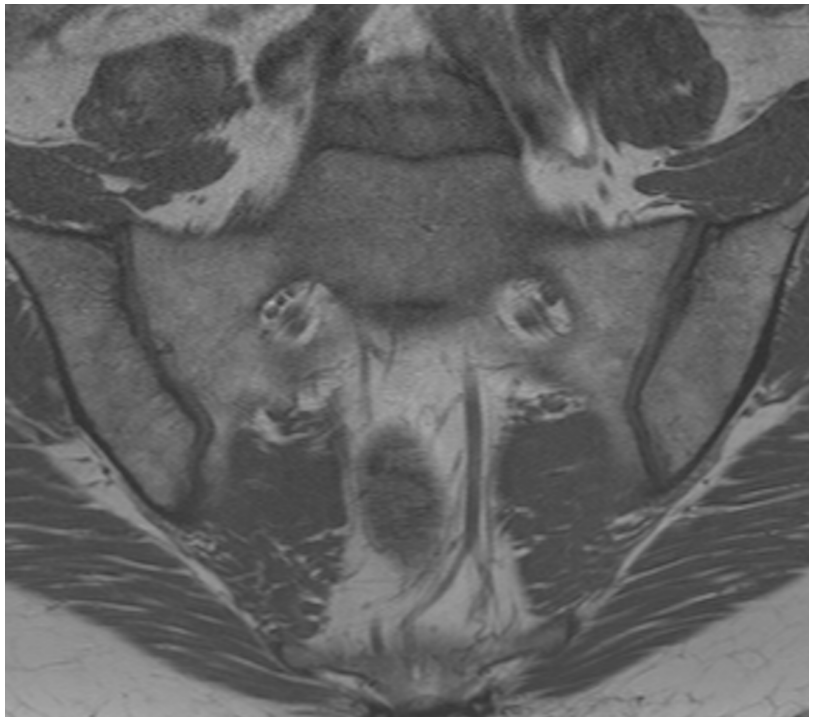


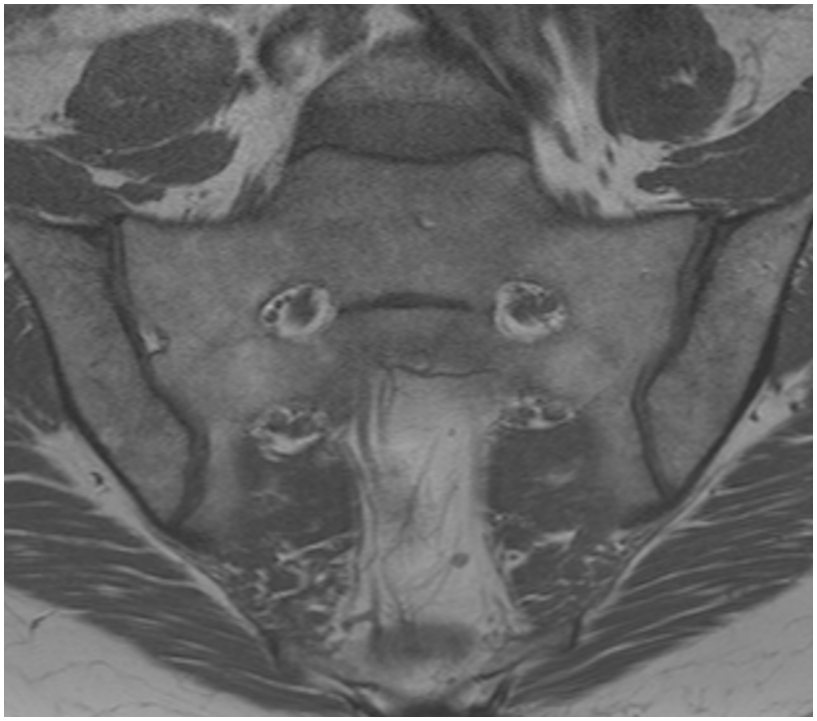
Note that a complete study includes the whole ligamentous compartment

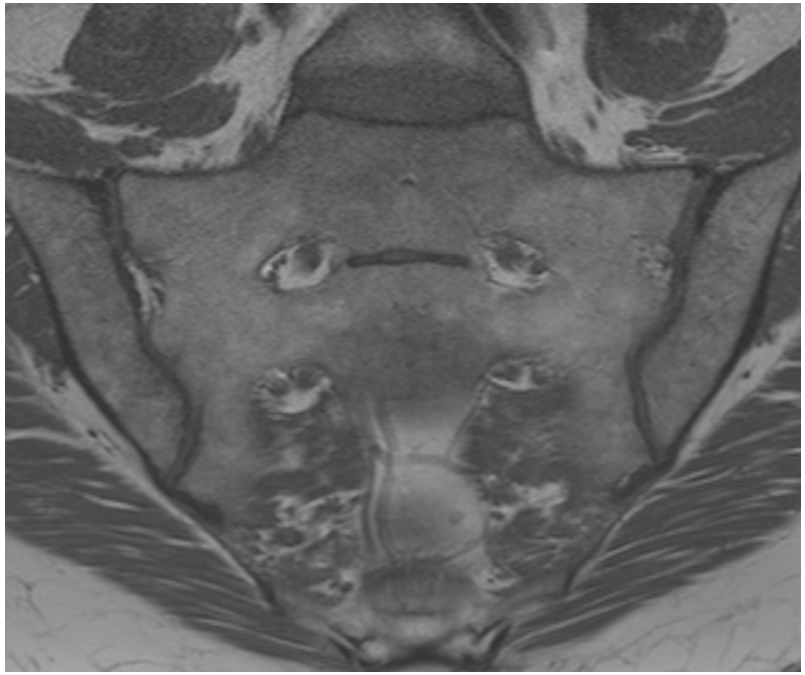




Coronal T1 SIJ (from anterior to posterior) continued





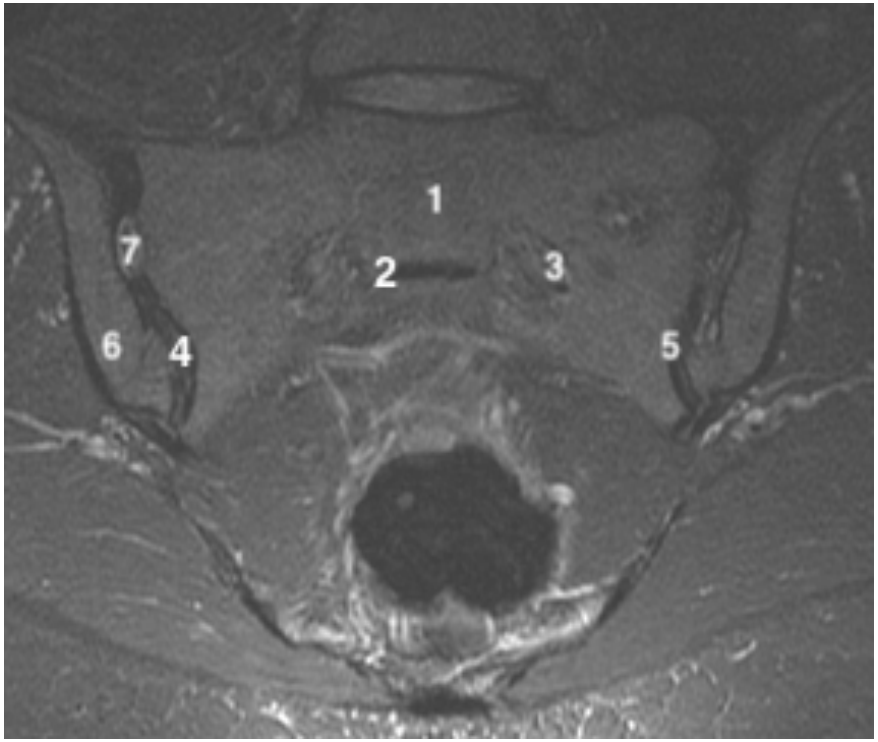


Additional normal Coronal T1 SIJs, notice the marrow signal intensity is brighter than in the previous case, this is the directly related to the normal variable proportion of periarticular fat and hemopoietic cells in the marrow which varies as one ages.The normal marrow should be similar to that within the sacrum centrally.

Semi-Coronal T2 FS SIJ

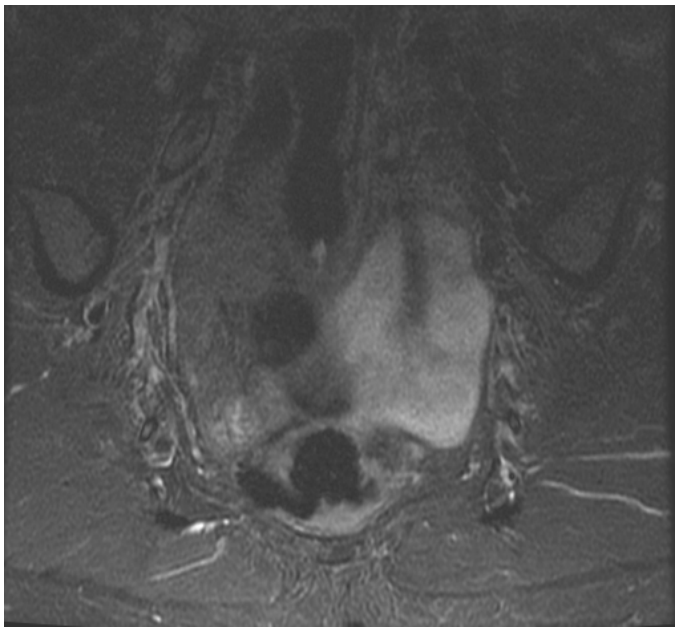
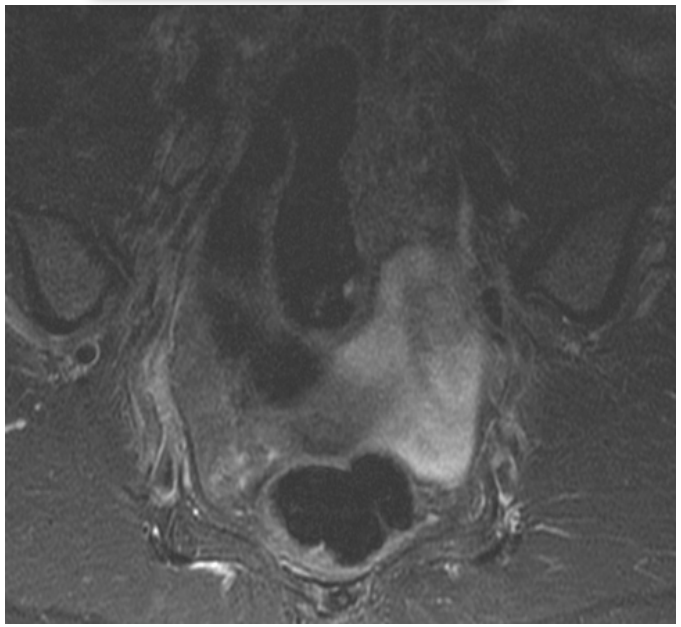
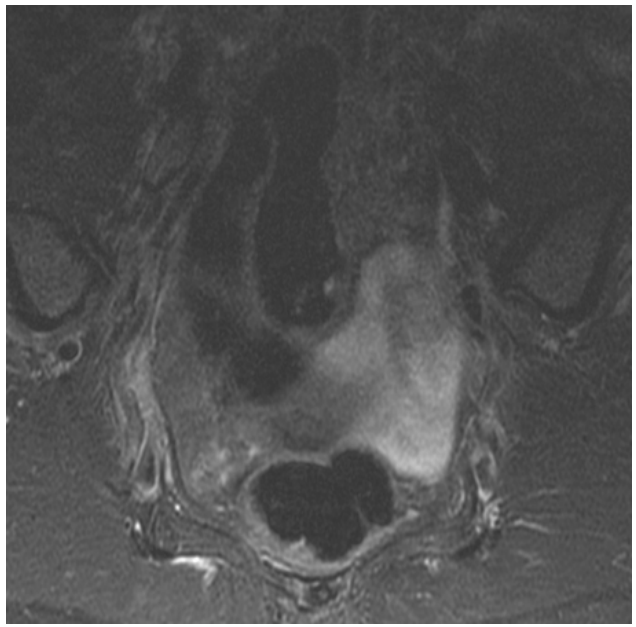
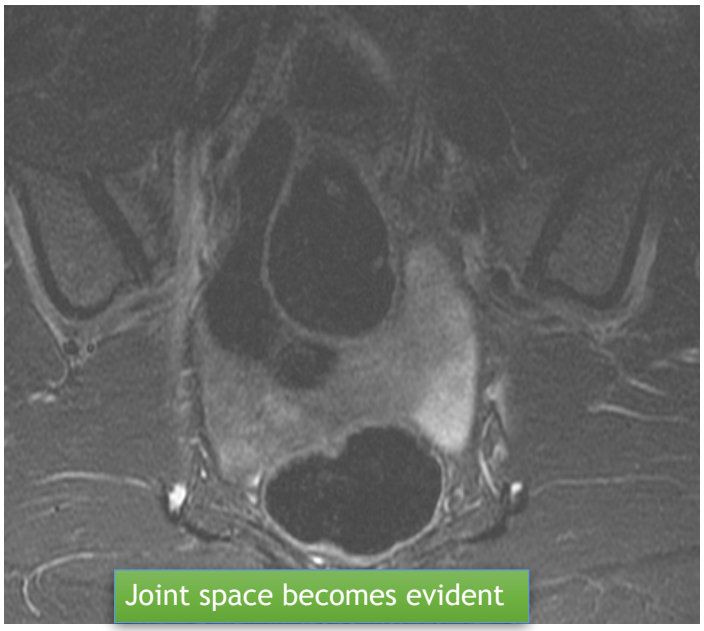
CoronalT2 Fat Saturated Image Mid Articulation

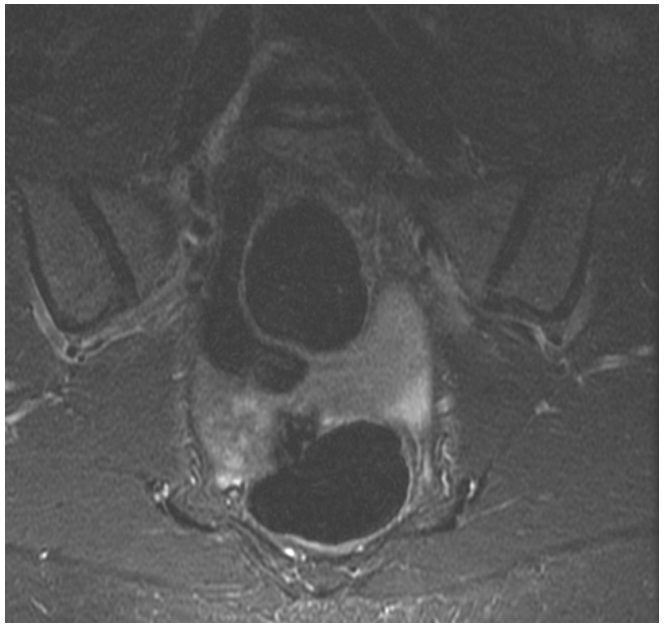
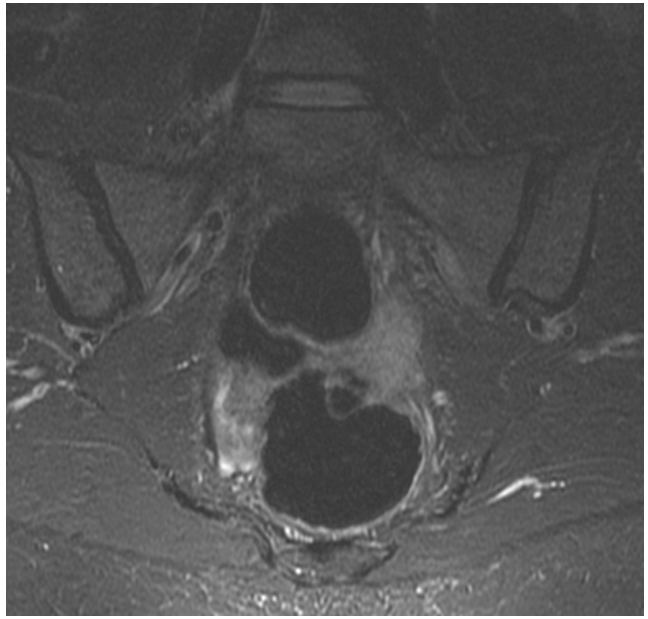
1-1st Sacral body
2-Vestigal disc between S1 and S2
3- Left S1/2 sacral Neural foramina with exiting left S1 nerve root, adjacent vessels and surrounding fat
4 -Right sacroiliac joint cartilage
5-Subchondral bone plate
6-Subchondral normal marrow
7- Anterior most component ligamentous compartment

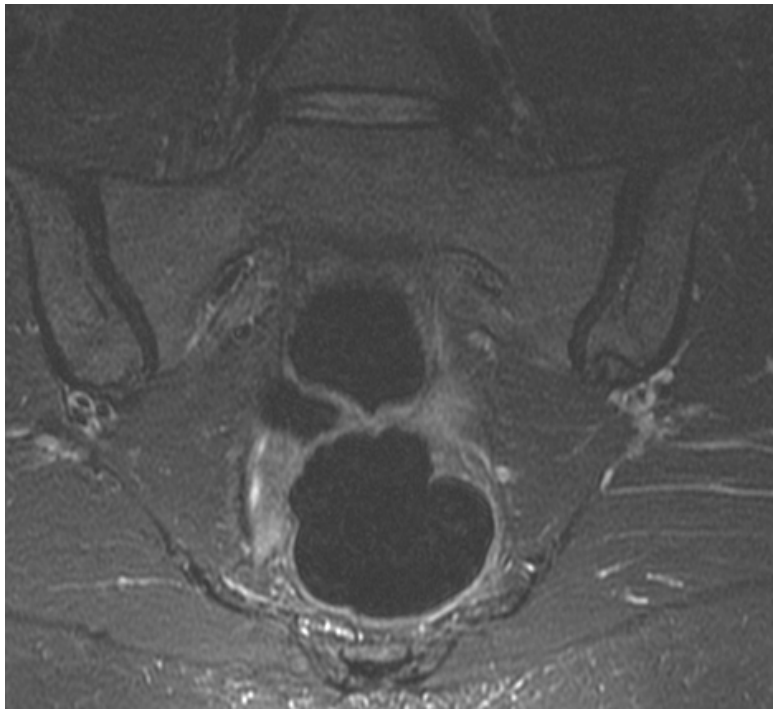


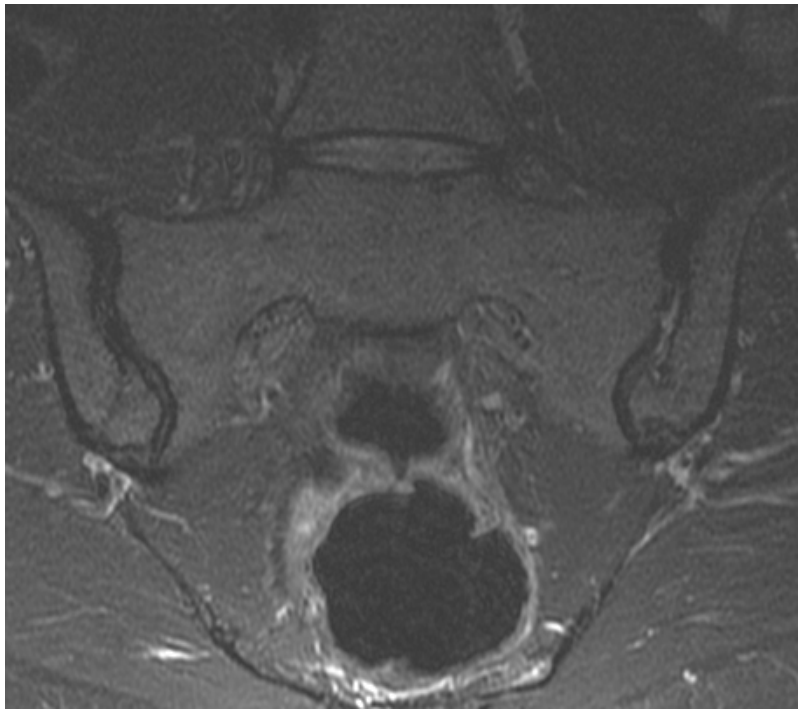
T2FS (T2 Fat Saturated) is the second standard sequence in assessment of the SIJs evaluation of the SIJs. Alternatively a similar sequence, semi-coronal STIR (Short Tau Inversion Recovery) can be performed. Both *suppress fat signal intensity,* therefore any tissue containing fat will decrease in signal intensity proportional to its content of fat. Normal marrow contains a large portion of fat and therefore becomes darker with fat saturation.
Without fat saturation the T2 would look similar to the T1 sequence except for the different appearance of fluid between T1 and T2. On T1 *fluid* is low signal intensity and therefore dark, whereas it is high signal intensity on T2, bright. Looking at the normal CSF signal intensity is a useful way to *differentiate* between these two sequences.
It is important to note that *hemopoietic marrow* is intermediate to high signal intensity on T2 thus making assessment of edema, which is high signal intensity, difficult to differentiate. Suppressing the fat signal will allow clear visualization of fluid/edema.
The *joint space* is low signal intensity unless it contains fluid and then is high signal intensity (bright)
Cartilage is intermediate in signal intensity (gray)
Subchondral bone plate is thin, regular and of low signal intensity (dark).
The *subchondral marrow* is low signal intensity, due to the suppression of the normal fat signal within normal marrow.

Semi-Coronal T2 FS SIJ

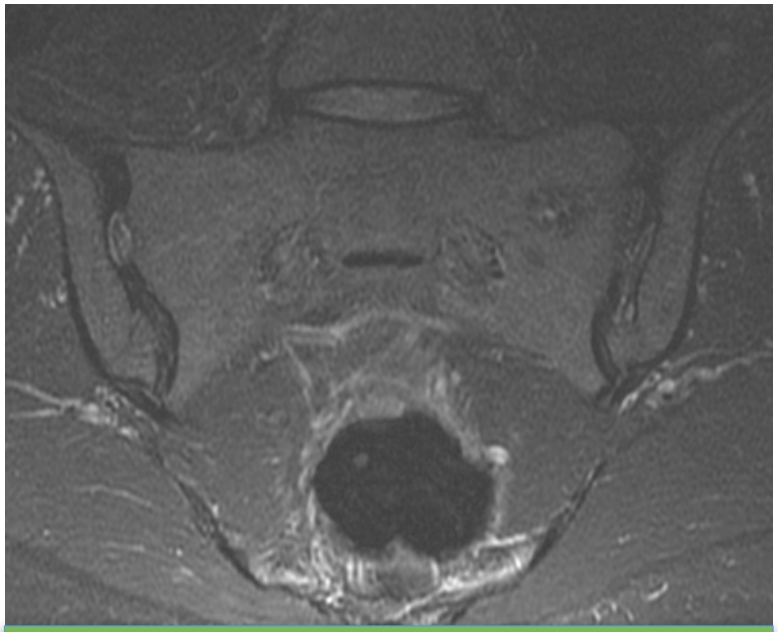





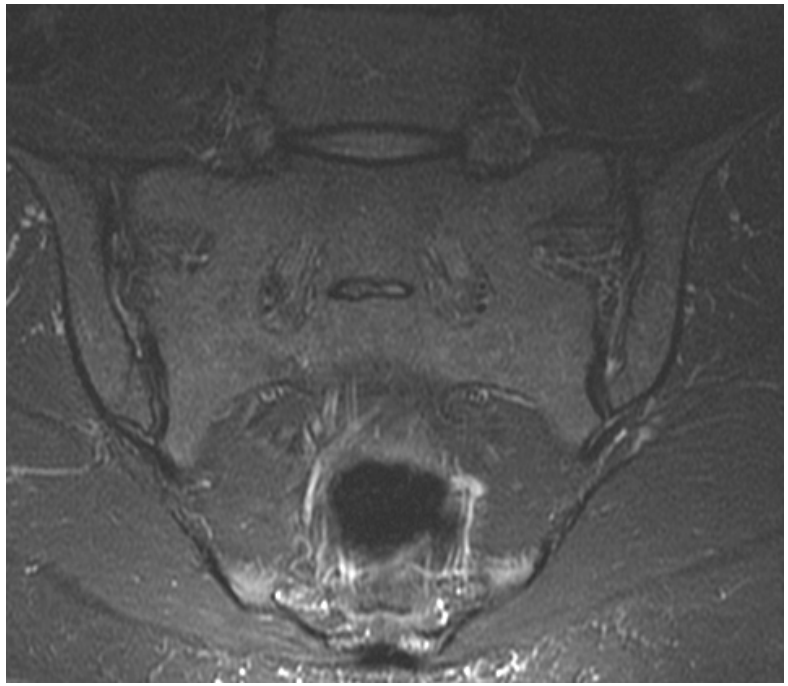


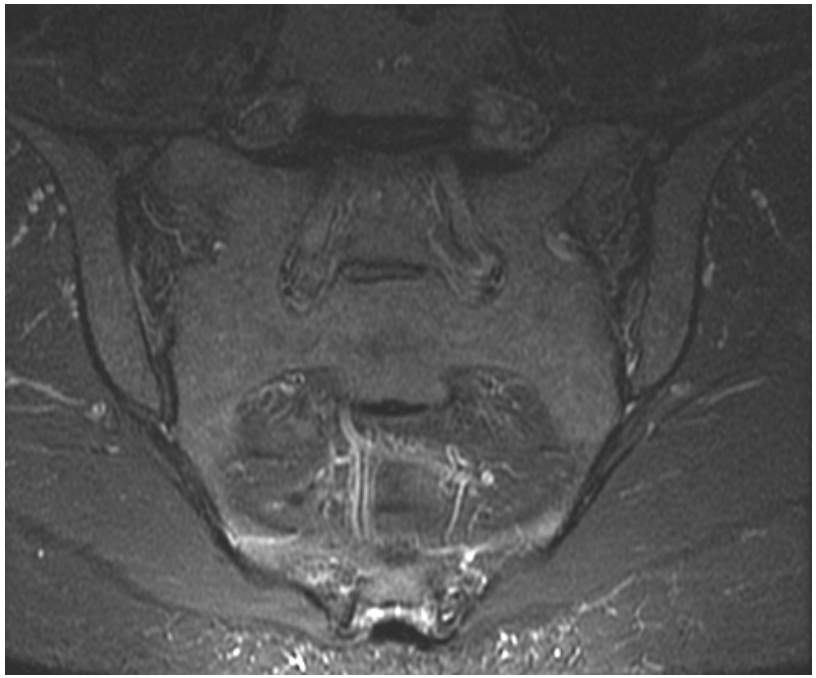


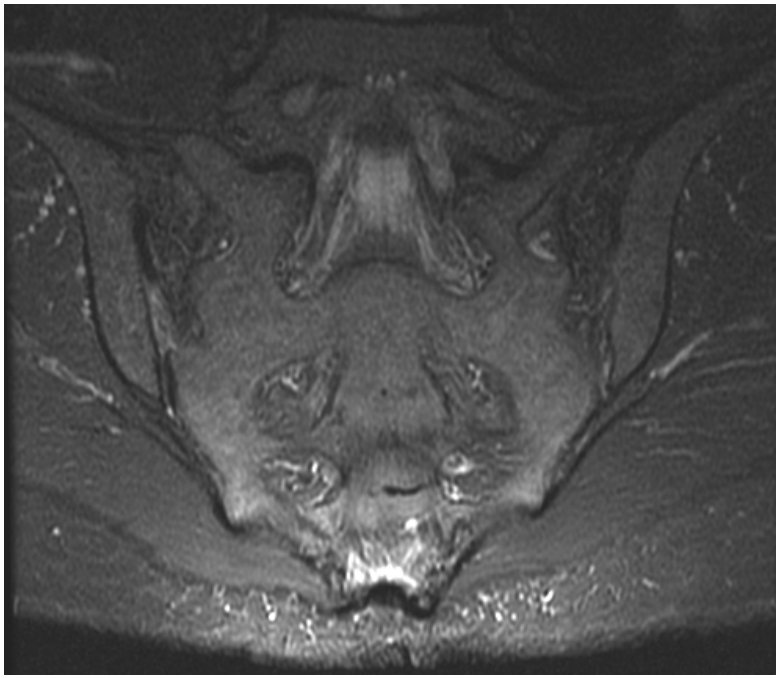
Coronal T2FS (from anterior to posterior) continued



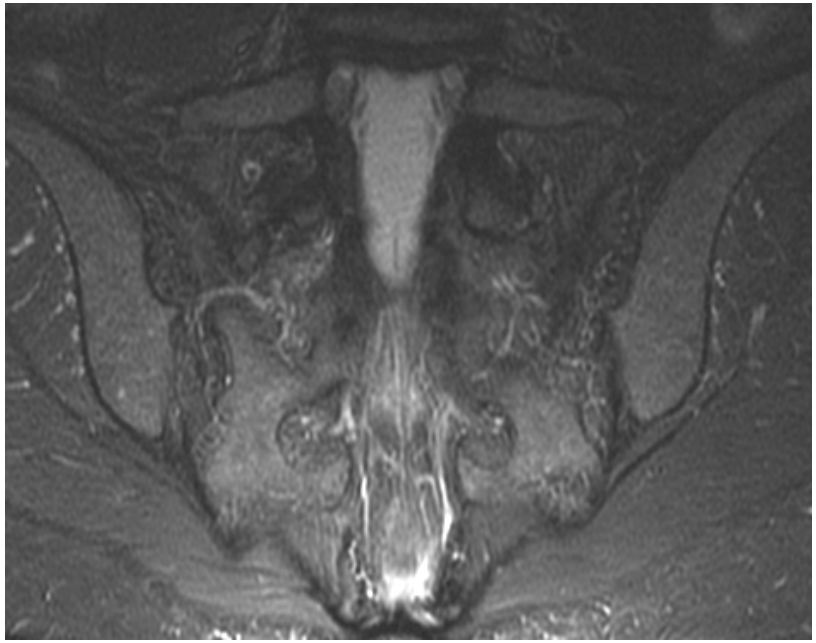
Transition between joint and ligamentous compartments

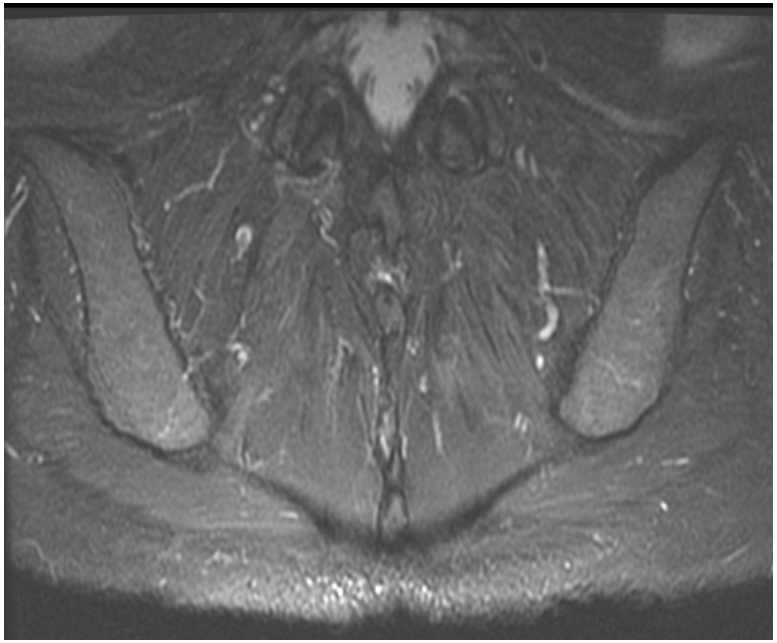




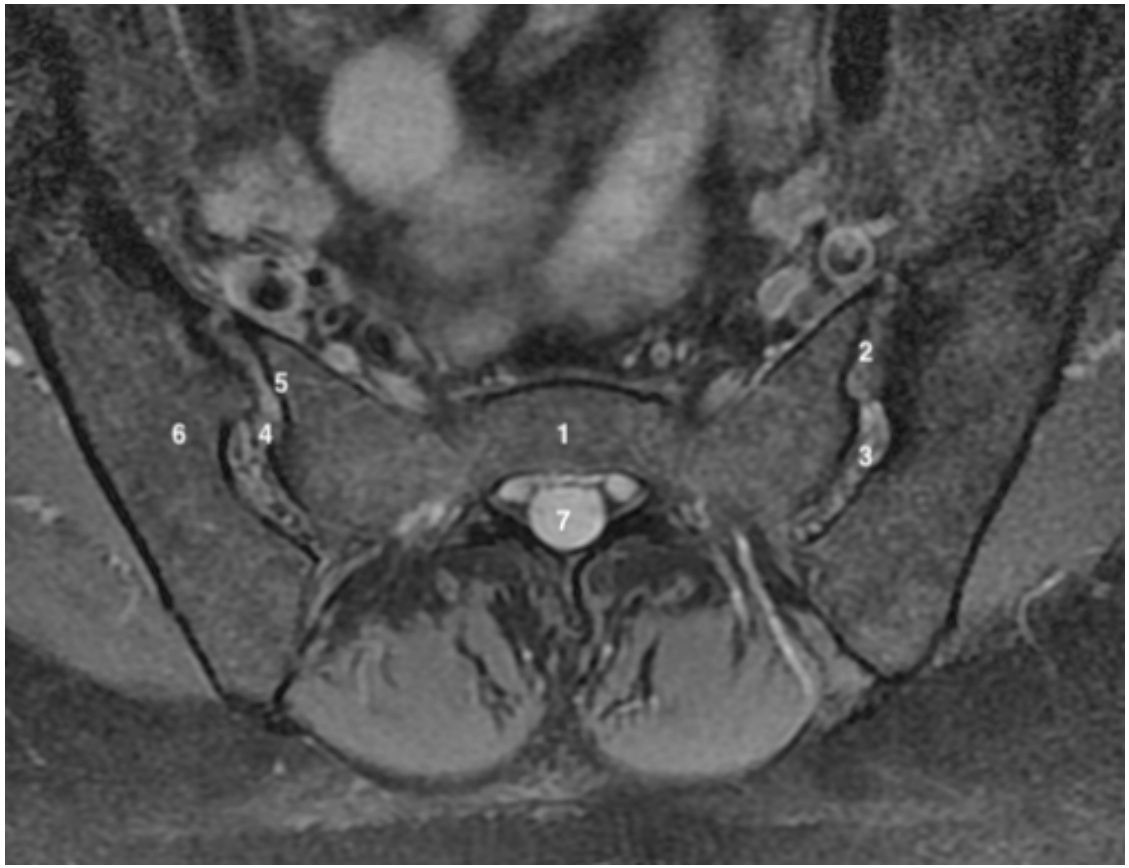


Coronal T2FS (from anterior to posterior) continued





Axial T2 FS SIJ



Axial T2 Fat Saturated Mid Articulation

1-1st Sacral body

2--Lt Sacroiliac joint cartilage

3- Ligamentous compartment

4-Transition between cartilaginous and ligamentous compartments

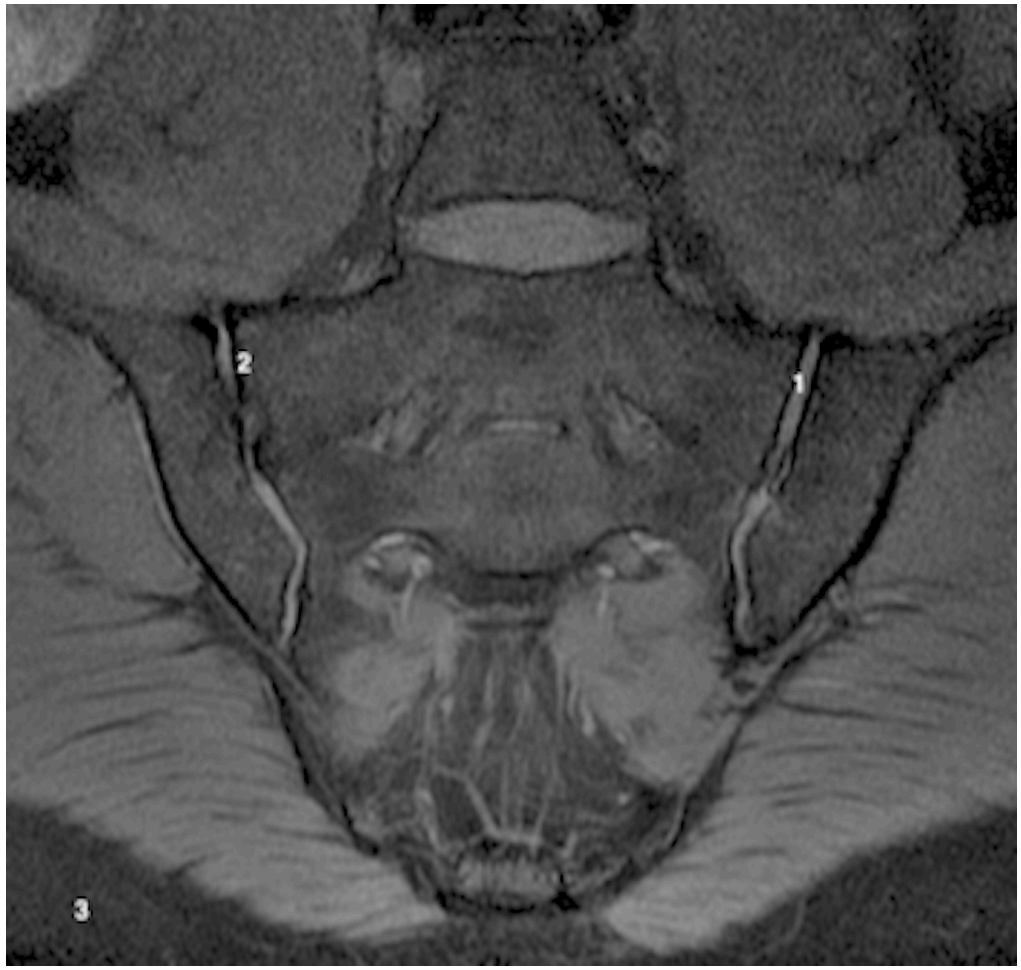
5- Subchondral bone plate

6-Subchondral normal marrow

7- Spinal canal, high signal intensity due to CSF

Axial T2 fat saturated sequence, imaging plane perpendicular to the SIJ, is acquired in studies dedicated to the sacroiliac joints but is excluded in combined studies of the SIJs and spine in the assessment of axial spondyloarthritis. This is because imaging protocols are optimised to create the maximum efficiency between time to scan and the required optimal images for diagnosis. The axial study provides little additional information but does add confidence to assessment findings on coronal T1 and T2FS sequences such as confirming that oblique vessels on Cor T2FS, which may appear like ligamentous edema, are truly vascular in nature.

SemiCoronalT1 FS SIJ



Semicoronal T1FS Saturated Mid Articulation

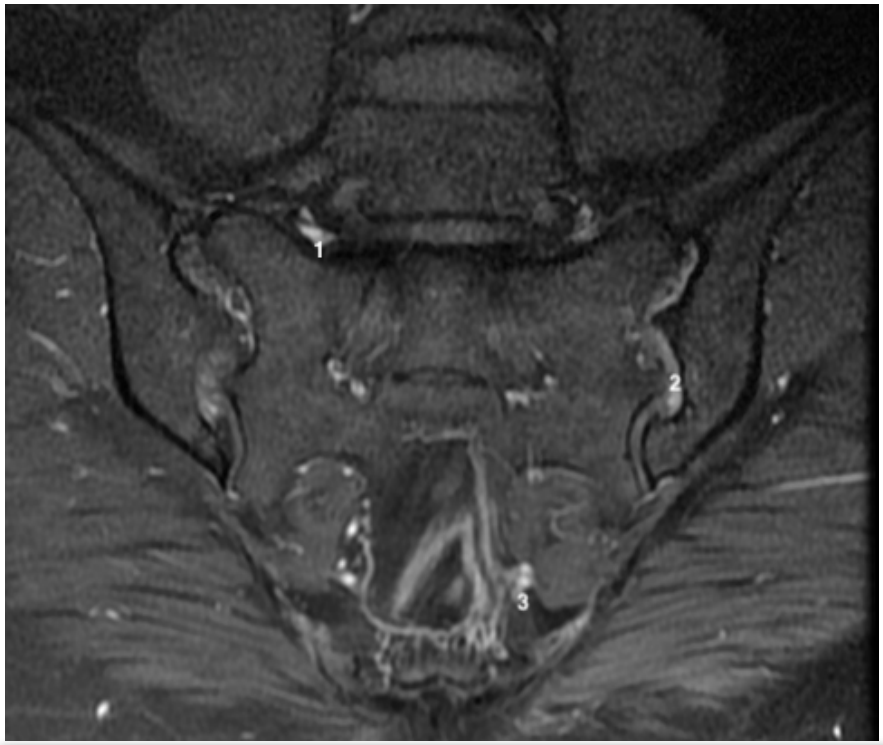
1-Lt sacroiliac joint cartilage

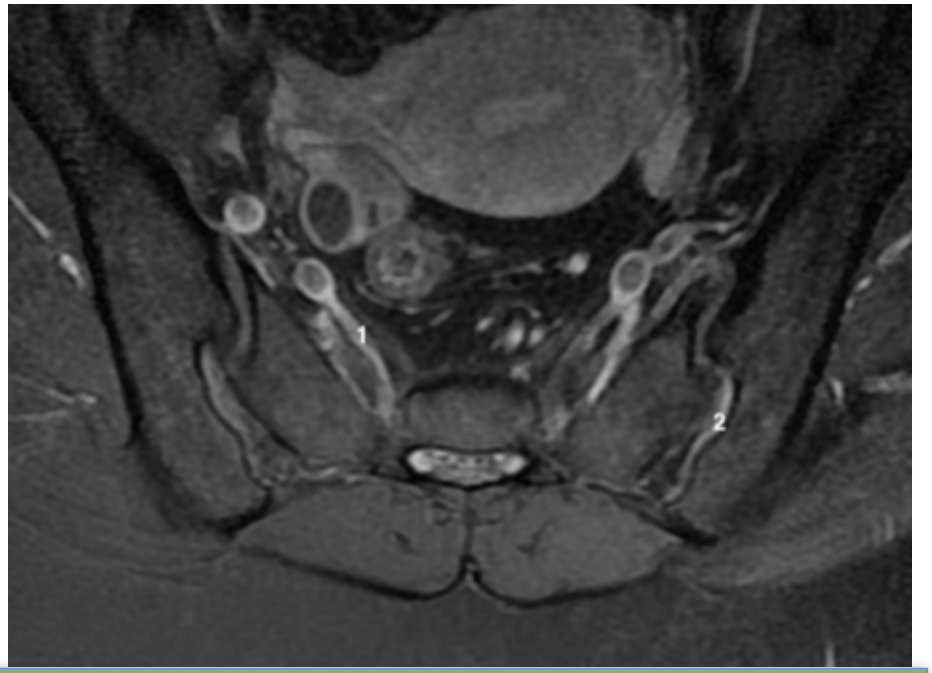
2--Subchondral bone plate

3- Subcutaneous fat

Semicoronal T1FS is acquired in the same plane as the semicoronal T1. Some centres are beginning to use this sequence as part of their standard assessment of the SIJs given its ability to enhance visualization of erosions. It is routinely acquired in cases where contrast is given, such as for the assessment of septic arthritis. The addition of fat saturation has a profound effect with significant diminished signal from marrow which contains abundant fat. Although no direct effect on cartilage with fat saturation the cartilage signal is accentuated by the increased contrast with the low signal intensity marrow thereby increasing the conspicuity of erosions.

SemiCoronal & Axial T1 FS Post Contrast SIJ

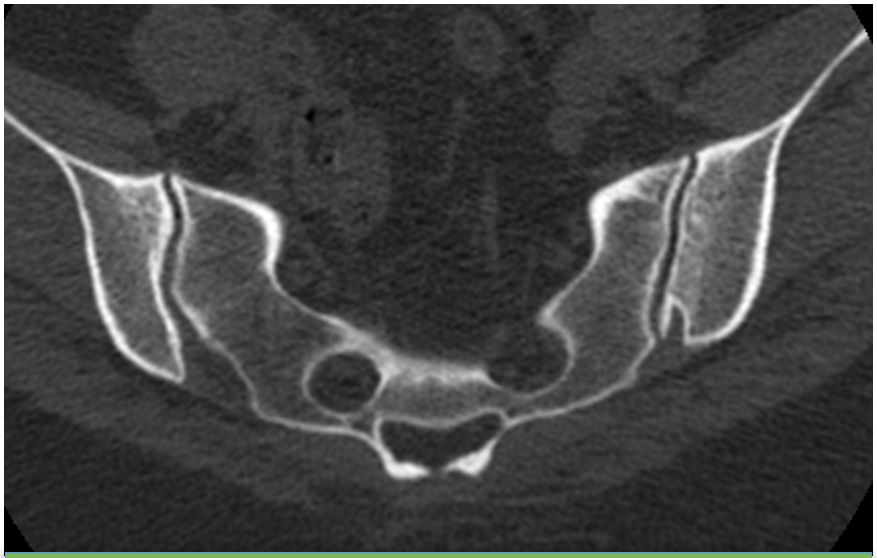




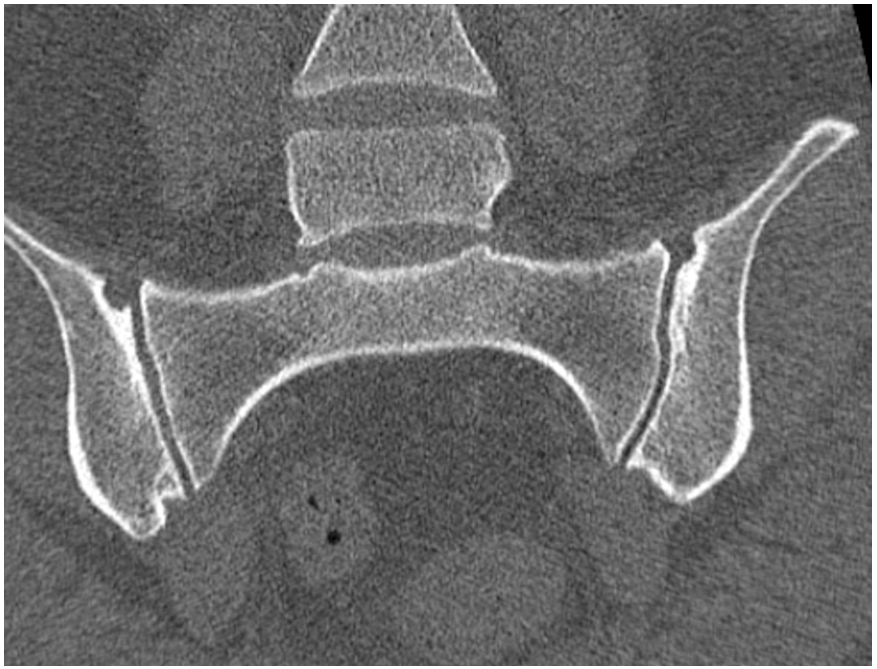
Normal semicoronal & axial T1FS PG, left & right images respectively mid articulation 1, 2 & 3 demonstrating normal vascular enhancement. Note no enhancement within the joint space, ligaments or subchondral bone marrow. Reviewing the pre-contrast and post-contrast studies side by side increases sensitivity for more subtle enhancement .

Semicoronal & Axial T1FS PG (post contrast) are acquired post intravenous gadolinium. Active inflammatory lesions that enhance post contrast including : Osteitis, capsulitis, enthesitis, joint enhancement/osteochondral inflammation. In addition normal vascular structure enhance and can be visualized in the ligamentous compartment and within the neural foramina. Correlation with the pre-contrast study is helpful to confirm pathological enhancement

SACROILIAC JOINT CT



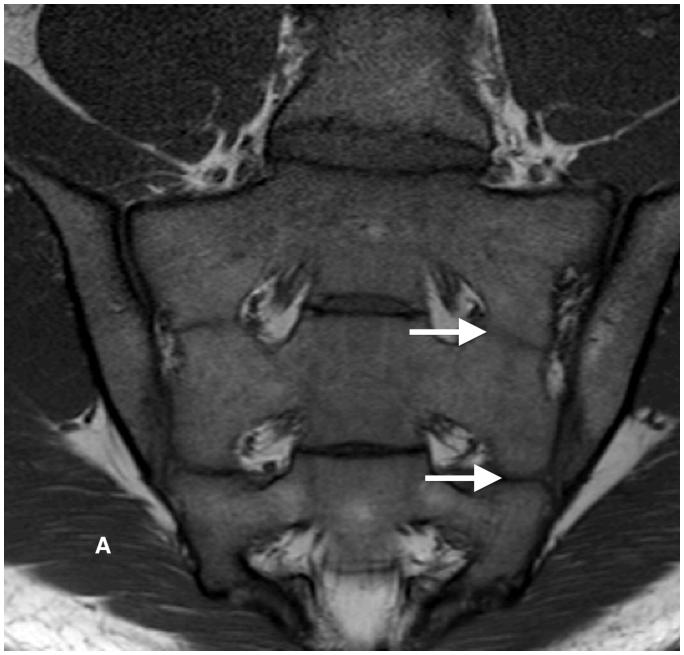
Axial (upper)low dose CT SIJ with semicoronal (right) reconstruction

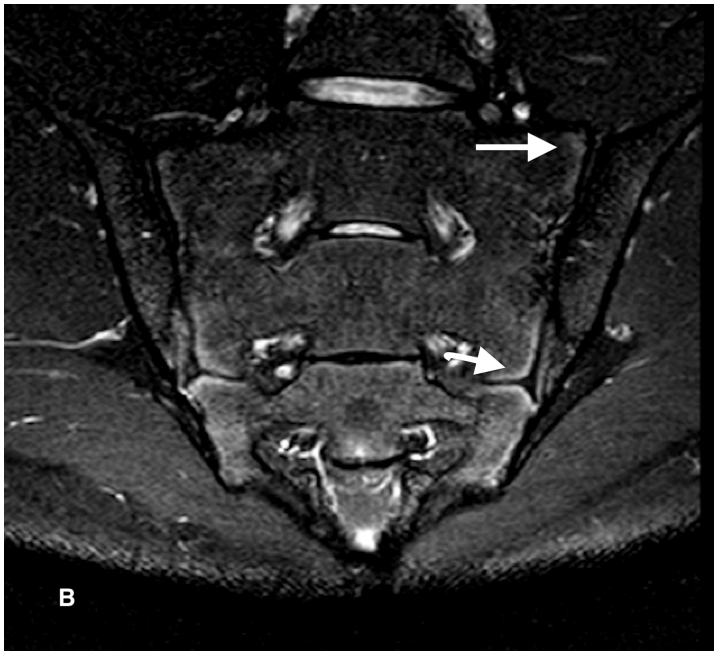


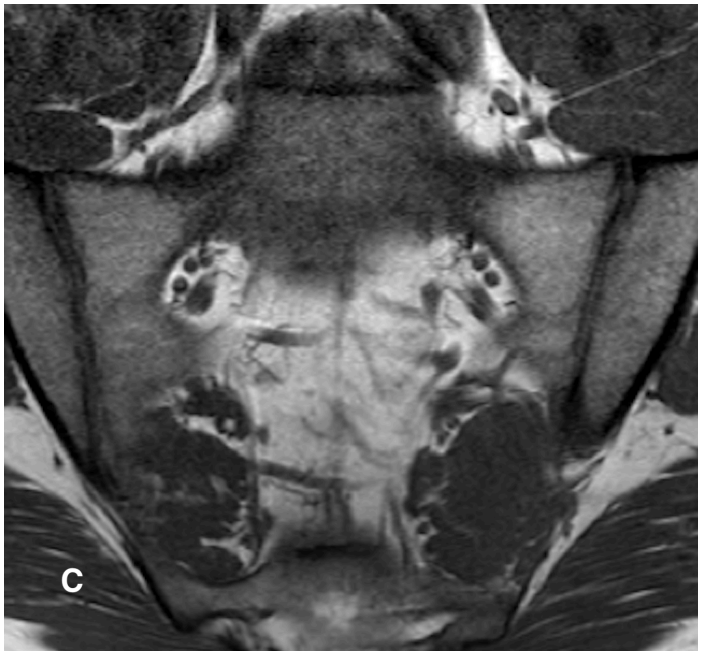
CT is excellent in demonstrating the structural changes related to axial SpA at the sacroiliac joints. Radiation however remains a concern although newer techniques of low dose CT have significantly reduced radiation exposure. Dual energy CT has shown promise in research studies in the assessment of bone marrow edema however is not widely available. MRI remains the gold standard given lack of radiation and ability to image both the inflammatory and structural changes. CT may be considered in patients who have MRI contra-indications.

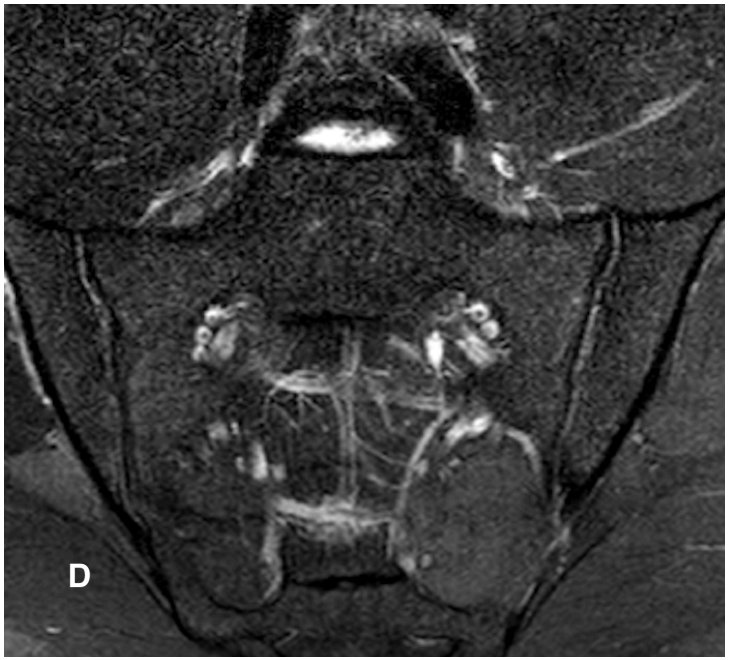
Patients may have had *prior imaging with CT of their pelvis for alternate pathologies and these studies may be helpful when reviewed in conjunction with current imaging with radiographs or MRI.*

Ossification Centres









18 F, IBP, HLA B27+. MRI requested for assessment possible axial SpA.

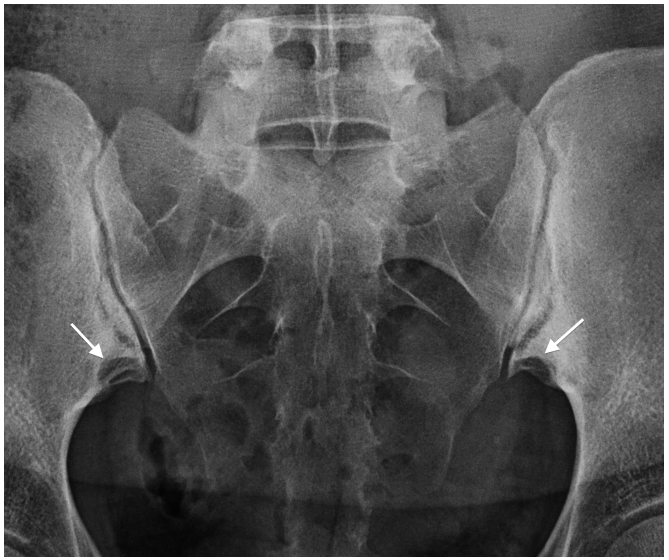
A) Cor T1 demonstrating early fusion (top arrow) and unfused (lower arrow) ossification centres sacrum.

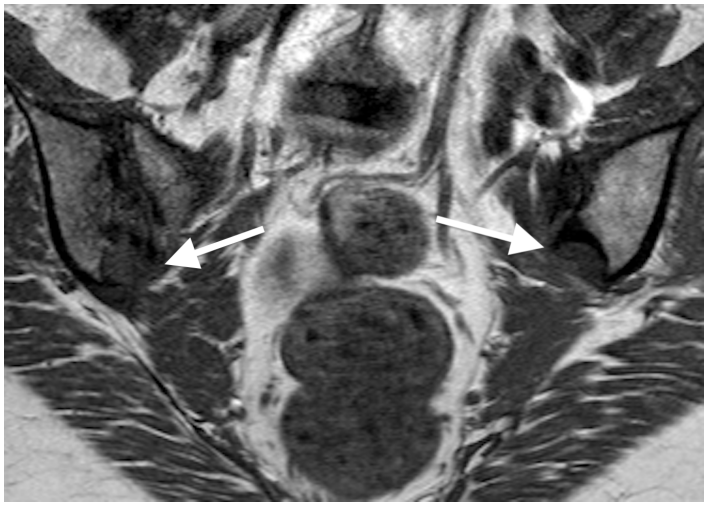
B) Cor STIR images demonstrate bands of high signal suggesting edema of the subchondral regions and paralleling the unfused borders ossification centres. This is a **normal imaging finding.**

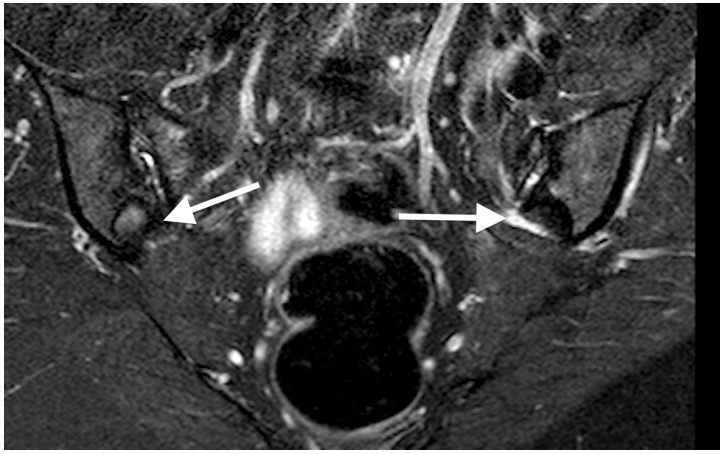
C) & D) Same patient 3 years later with normal MRI study.

Paraglenoid Sulcus

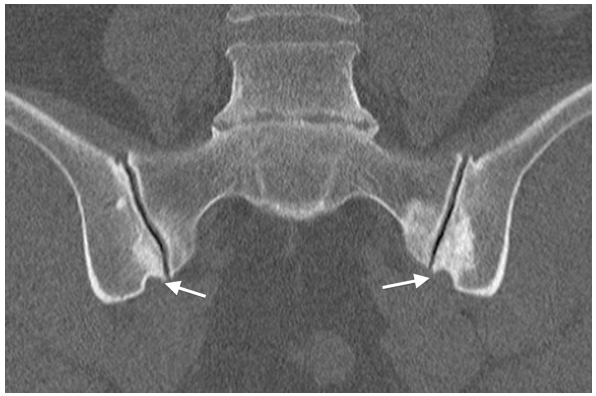
The paraglenoid sulcus is an indentation/groove along the lower ilium adjacent to the sacroiliac joints and may be seen as normal variant. There is a noted increase in incidence in patients with increased stress across the joint such as in OCI and is thought to be related to secondary osseous resorption at the insertion of the anterior sacroiliac ligament. It is important to be aware of its existence as it may simulate pathology on MRI.

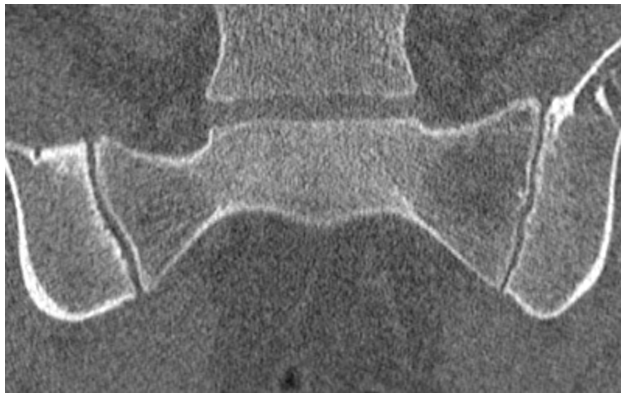






AP pelvis (left image) and Cor T1 and Cor STIR SIJs (right top and bottom images respectively) demonstrating bilateral paraglenoid sulci.



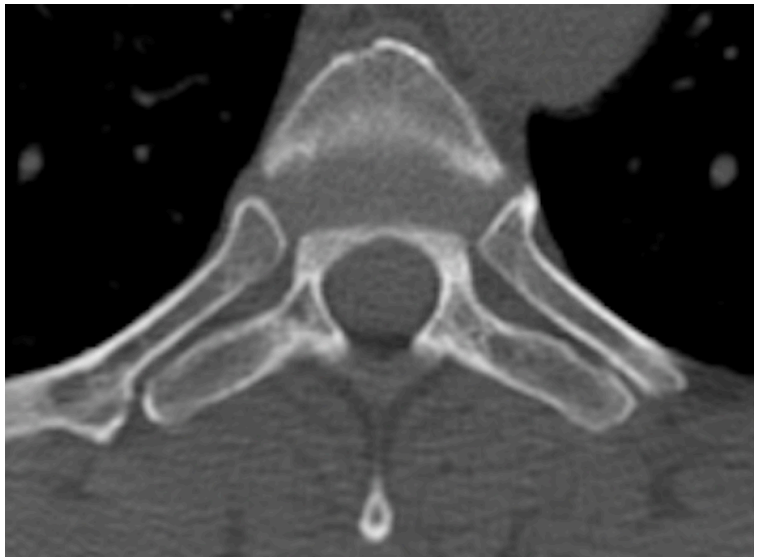


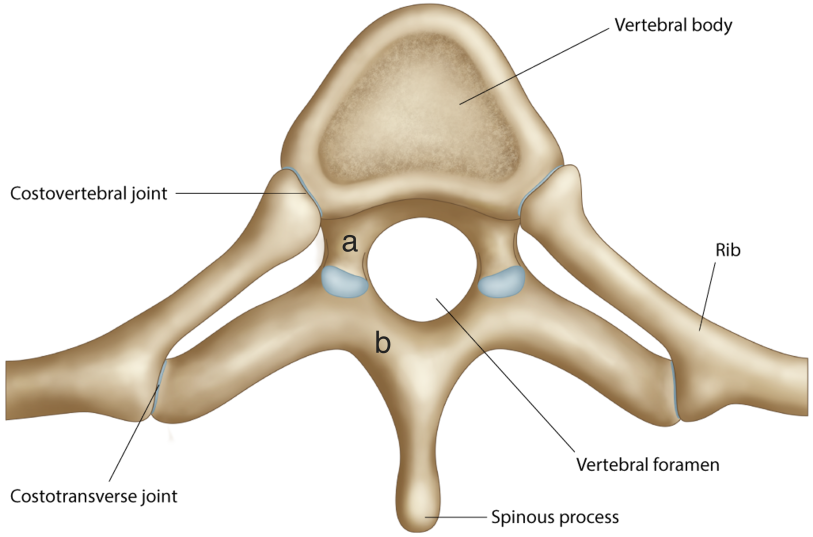
Coronal CT sacrum. Left image in a female patient with OCI demonstrating bilateral triangular subchondral sclerosis more pronounced on iliac aspects with bilateral incidental paraglenoid sulci (arrows). Right image is a corresponding normal CT in a male patient without sulci.

Notes

Anatomy & Imaging Spine

SPINAL ANATOMY





Axial CT (bone windows) & Illustration Thoracic Spine . a-pedicle, b-lamina

The vertebral column extends from the skull base to the inferior coccyx and is composed of 33 vertebrae: 7 cervical, 12 thoracic, 5 lumbar, 5 fused sacral vertebrae forming the sacrum, and 4 coccygeal vertebrae. A typical vertebra is composed of a body anteriorly and a vertebral arch posteriorly. They enclose the vertebral foramen or spinal canal. The latter is composed of bilateral pedicles anteriorly and bilateral laminae posteriorly. The bilateral transverse processes (projecting laterally) arise from the junction of the pedicles and lamina, and the spinous process from junction laminae (projecting posteriorly).

There are four articular processes, bilateral superior and inferior, articulating with the vertebra above and below respectively at synovial joints called the facet joints. The intervertebral foramen passes between the pedicles of adjacent vertebrae and have small notches to help create the foramen. Thoracic vertebrae have costal facets for articulation with head of the ribs. These form the *costovertebral joints*.Similarly the transverse processes of the thoracic vertebrae articulate with the ribs at *costotransverse joints*.

Intervertebral disc are composed of an outer annulus fibrosus. This consists of concentric rings of fibrocartilage. The outermost fibres are attached to the anterior and posterior longitudinal ligaments. Peripheral fibres known as Sharpey's fibres enter the adjacent vertebral bone. The nucleus pulposus is contained centrally by the annulus fibrosus. It is gelatinous with a high water content and desiccates as one ages. It serves as a shock absorber.

In general there are 23 discs: 6 cervical, 12 thoracic and 5 lumbar.

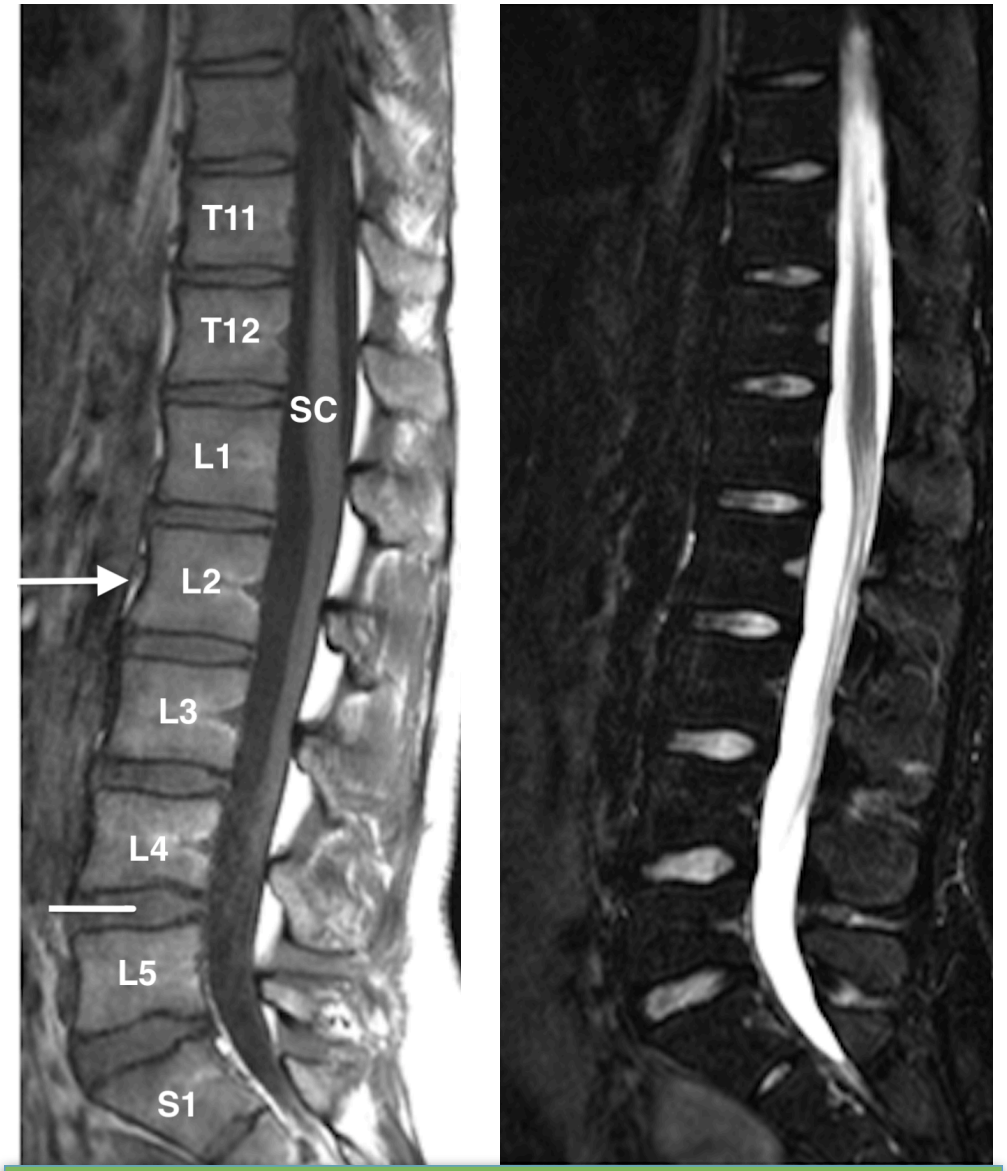
Discs articulate with adjacent vertebra, which have a thin layer of hyaline cartilage, at a fibrocartilaginous joint.

Anterior Longitudinal Ligament - attaches to the anterior vertebral body and discs. Extends inferiorly from the atlas to the superior sacrum.

Posterior longitudinal ligament- firmly attaches to posterior discs and loosely attached to vertebrae. Extends from axis (continued superiorly as tectorial membrane) to the superior sacrum.

Supraspinous ligament extends between tips of spinous processes (becomes ligamentum nuchae in cervical spine).

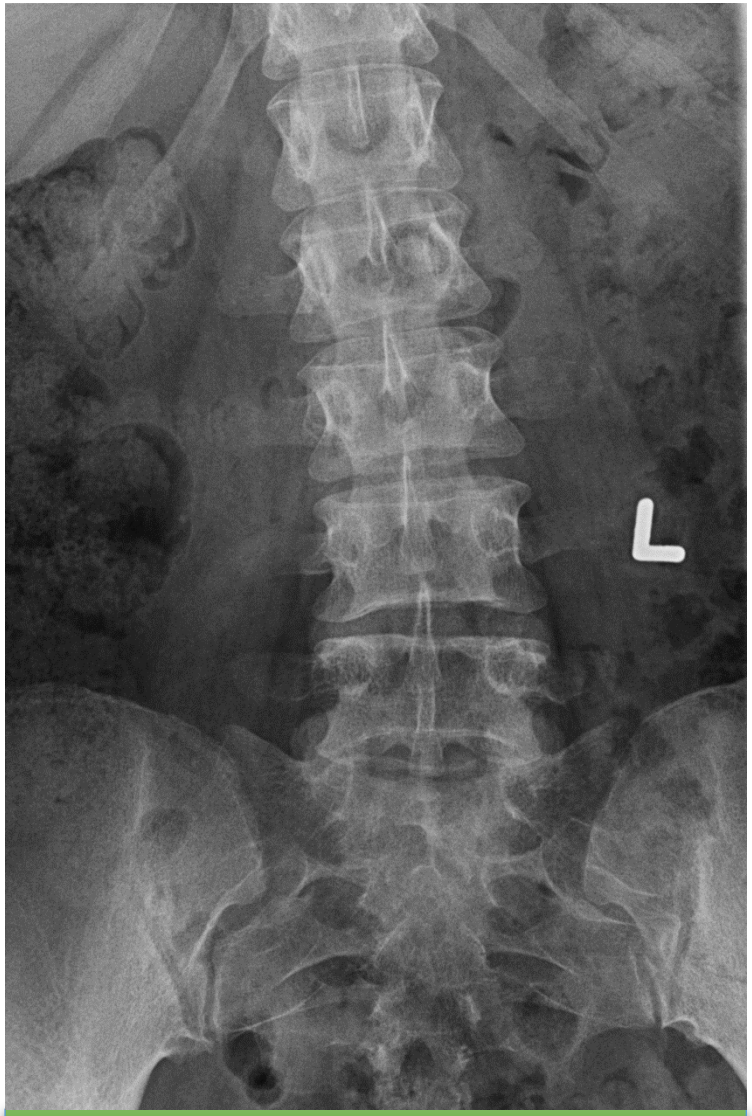
Interspinous ligament runs between adjacent spinous processes



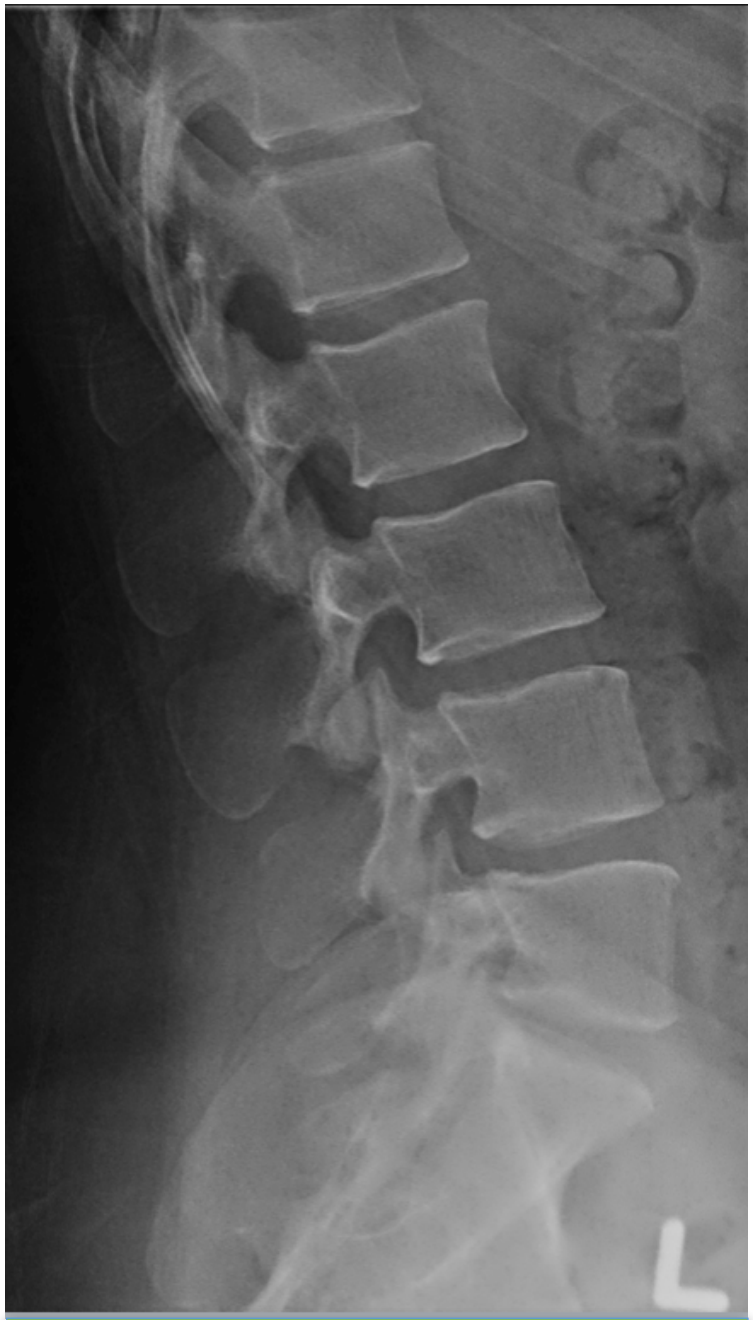
Sagittal T1 (left), Sag T2FS (RIGHT) lower thoracic and lumbar spine with numbered vertebrae. SC-Spinal Cord, Line- Intervertebral disc and Arrow- Anterior longitudinal ligament

Spinal Radiographs

Note that the AP radiograph of the lumbar spine *may* allow for adequate assessment of the sacroiliac joints if *fully included* as shown. If not adequately visualized a Ferguson view of the sacroiliac joints should be acquired

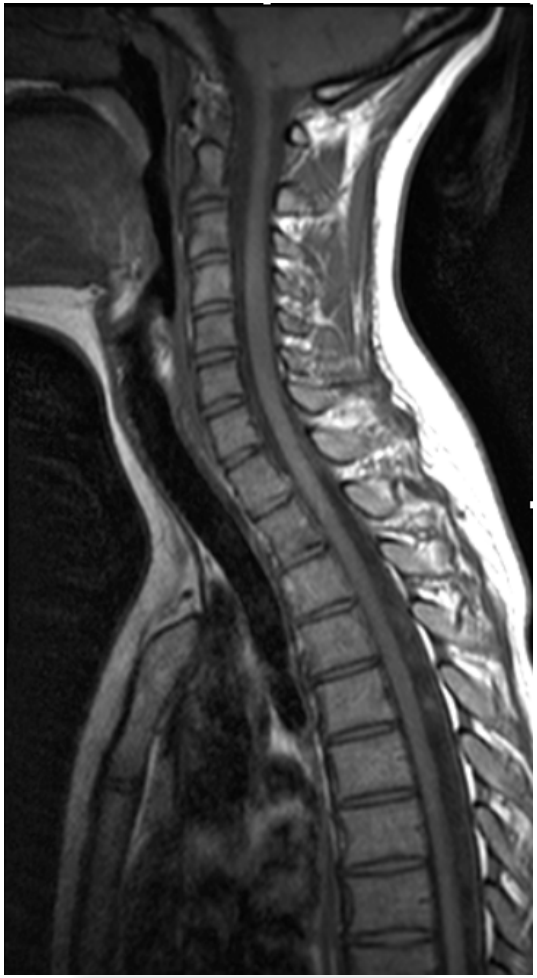


AP Lumbar Spine

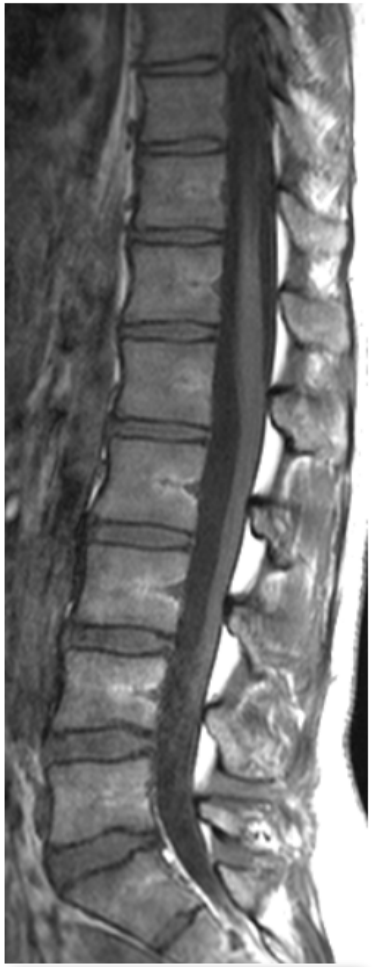


Lateral Lumbar Spine

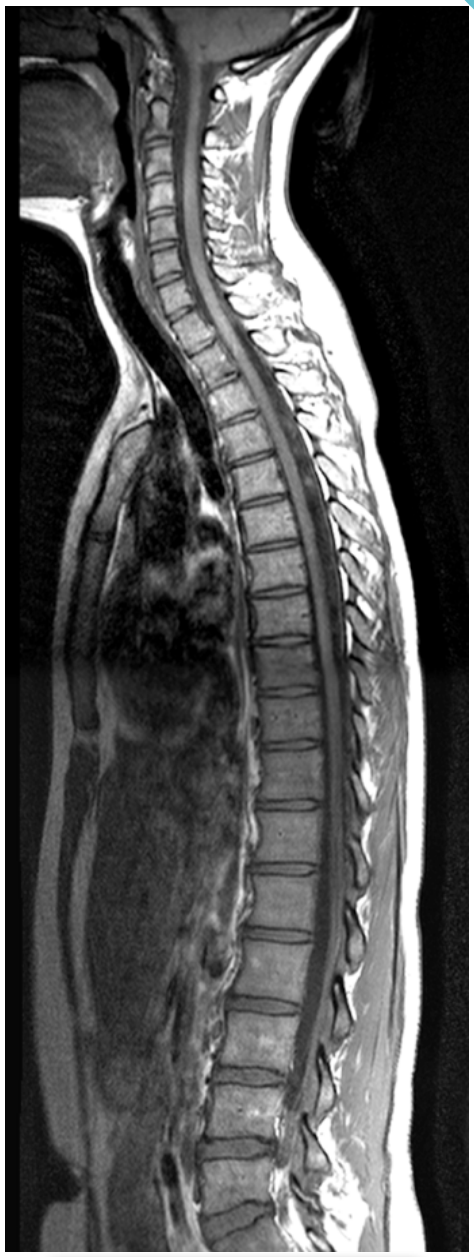
Spinal MRI



Spine Sagittal T1 Upper

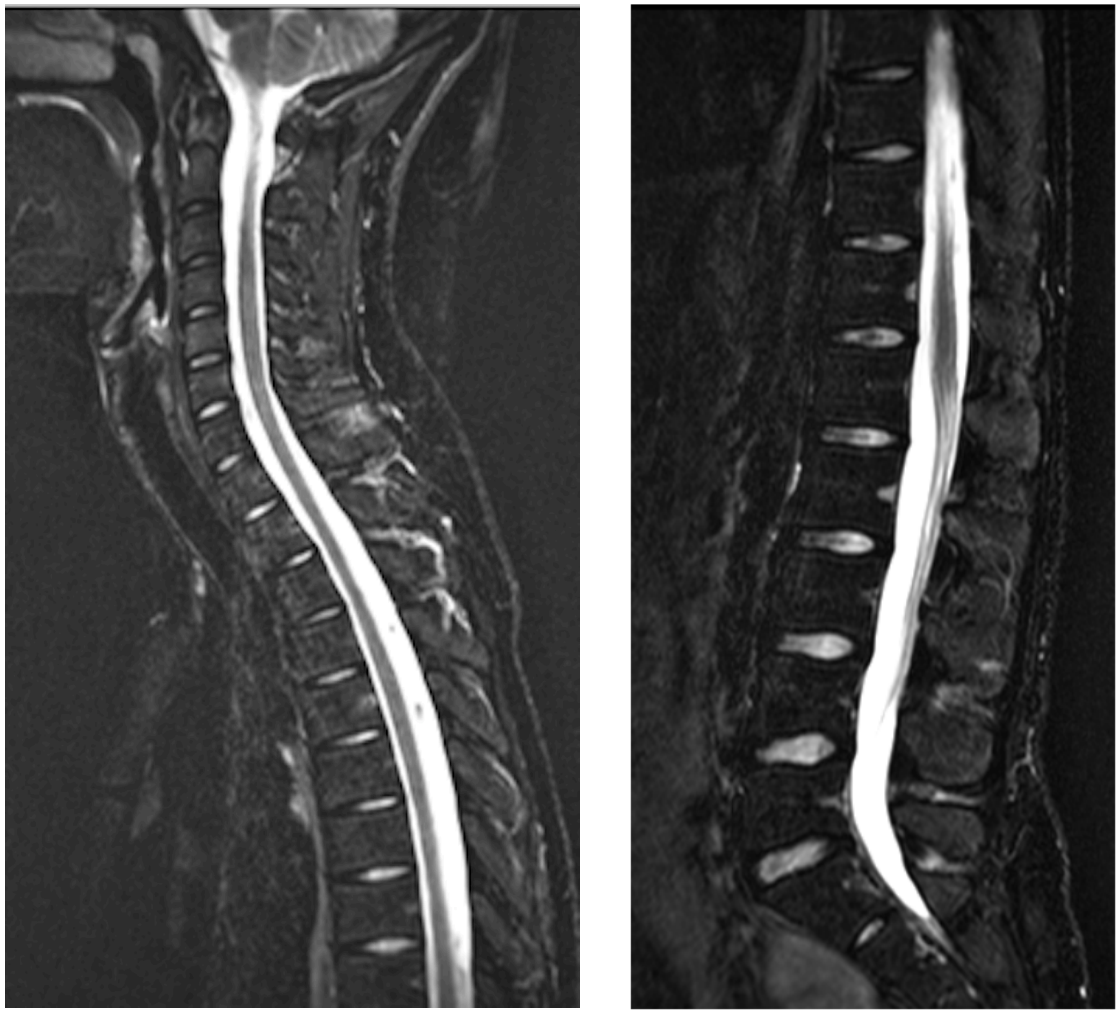


Spine Sagittal T1 Lower



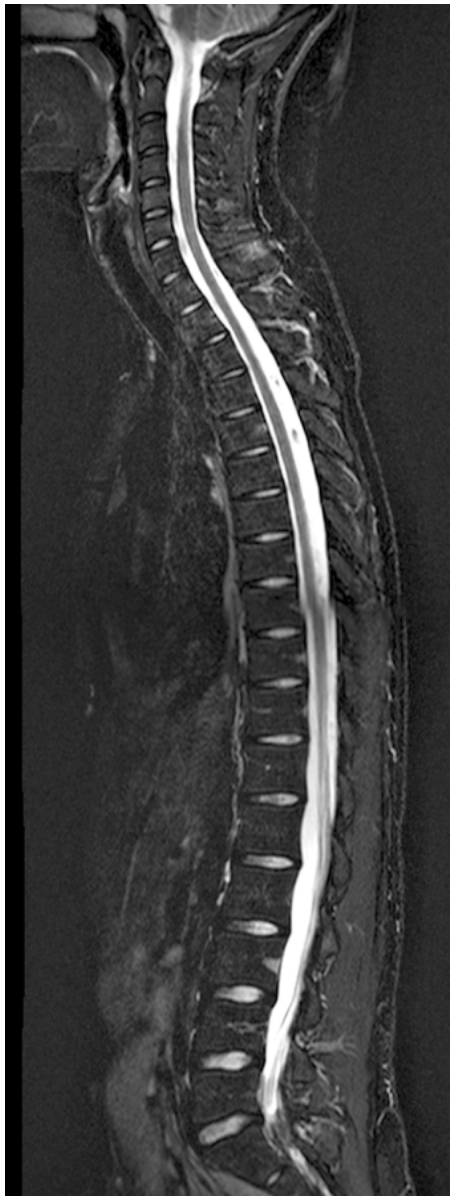
Whole Spine Sagittal T1 (fused images of the upper and lower spine

MRI acquisition of the spine includes Sagittal T1 and STIR or T2FS sequences. The whole spine is imaged at many centres whereas some centres will image mid-thoracic to the lumbosacral junction. Whole spine imaging is divided into 2 separate field of views i.e cervical to mid thoracic spine and mid thoracic to lumbosacral junction. The two images are then attached to provide a full spinal image. Axial imaging is usually not acquired. Assessment of degenerative disc disease is limited in these studies given the larger field of view and lack of axial imaging.

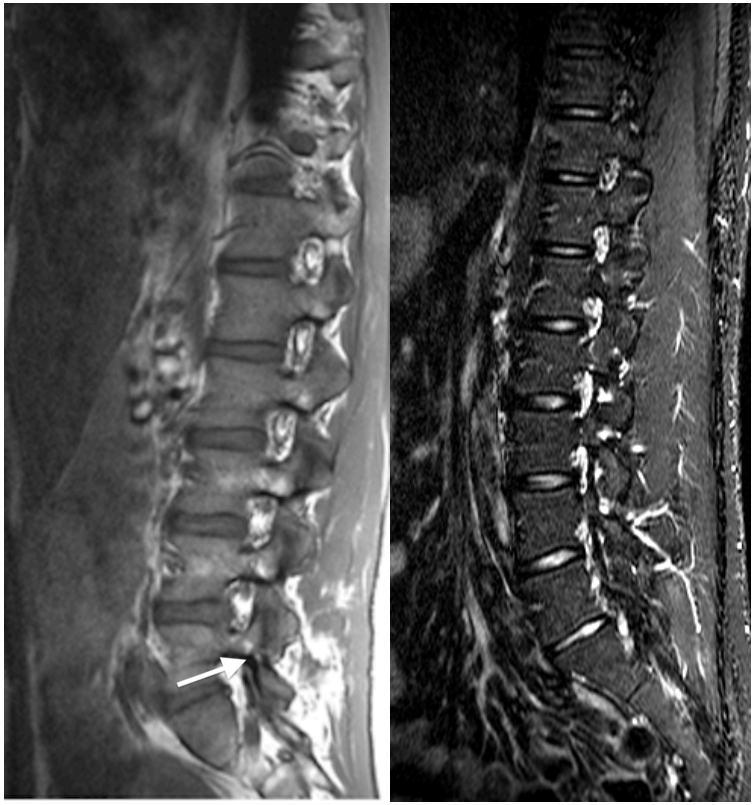


Spine Sagittal T2FS Upper & Lower

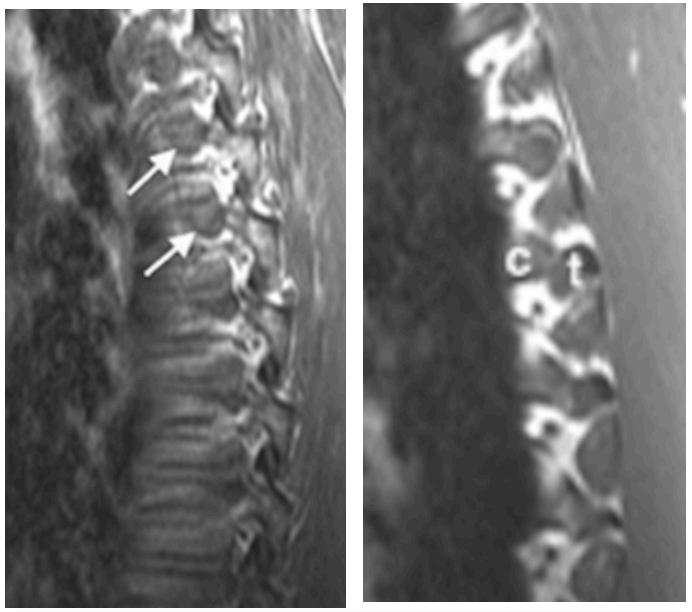
On these T2 fat saturated sequences the marrow fat is uniformly suppressed and is of low signal intensity . The intervertebral discs are hydrated and are intermediate to high signal intensity. The *key to identifying this sequence is to note that fluid, CSF, is high signal (bright) and hence is a T2 weighted sequence and that fat, such as subcutaneous fat, is low in keeping with fat suppression and therefore a T2 fat suppressed sequence.*



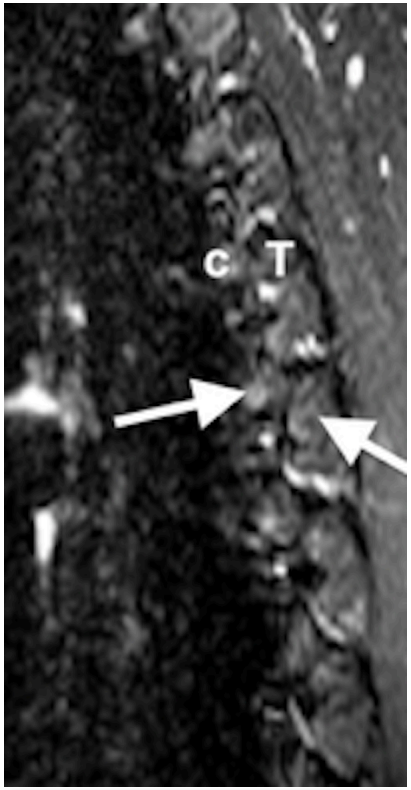
Whole Spine Sagittal T2FS (fused images)



ParaSagittal T1 and T2FS, left and right images respectively, lower spine demonstrating the pars interarticularis (arrow) and neural foramina



ParaSagittal T1 images mid thoracic spine, further lateral than A, demonstrating first the costovertebral (arrows) and far laterally the costotransverse, C & T articulations.

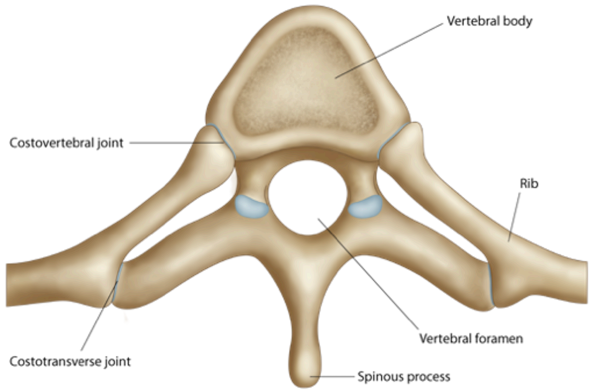


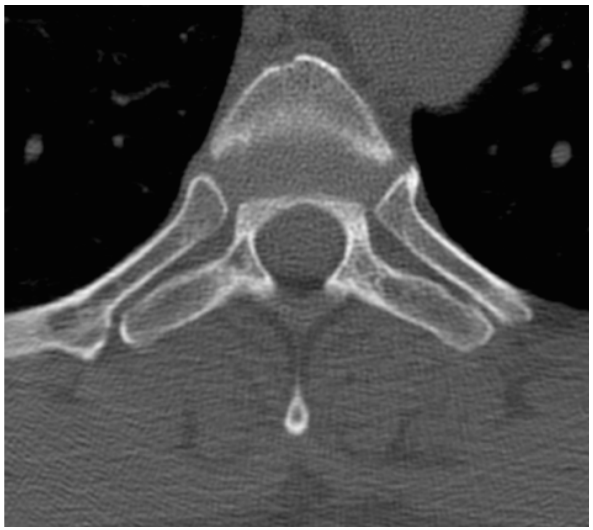
ParaSagittal T2FS far laterally demonstrating consecutive costotransverse articulations (CT, arrows)

MR images of the spine are acquired in the sagittal plan and include not only the vertebral bodies but *must continue laterally on both sides to include the costotransverse articulations*. A standard MRI does not extend as far laterally. Note that the T1 images allow clear identification of anatomy which is very helpful in correctly identifying sites of pathology which in turn are better appreciated on the T2FS sequence

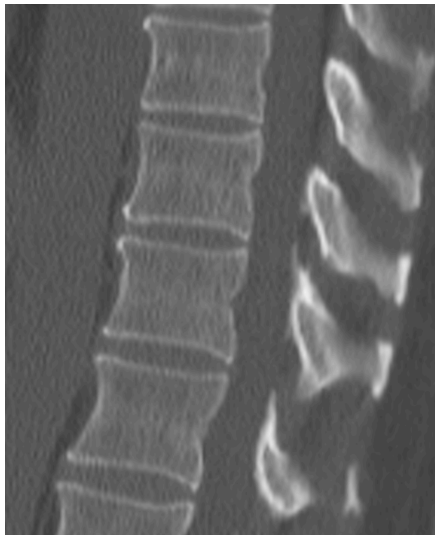
SPINAL CT

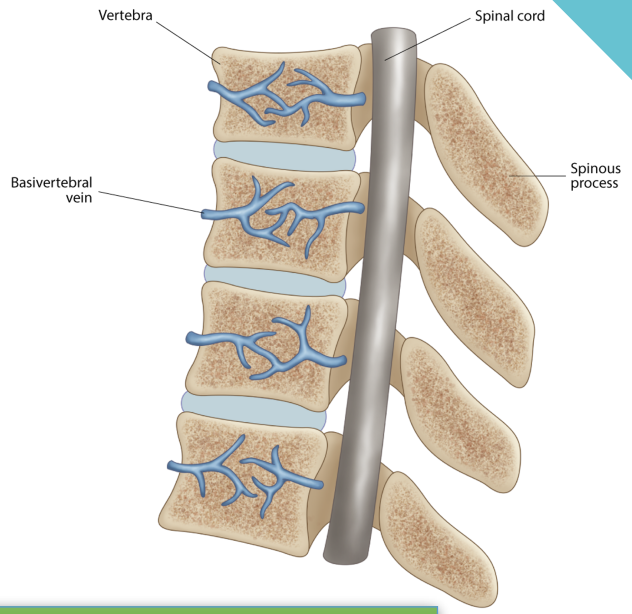
CT of the whole spine is not performed for SpA given the extended field of view and subsequent large radiation exposure. Occasionally localized regions are acquired if MRI is unavailable e.g. assessment of fractures in patient with SpA.
Discussion with your radiologist to determine optimal imaging pathway in complex cases is always encouraged.



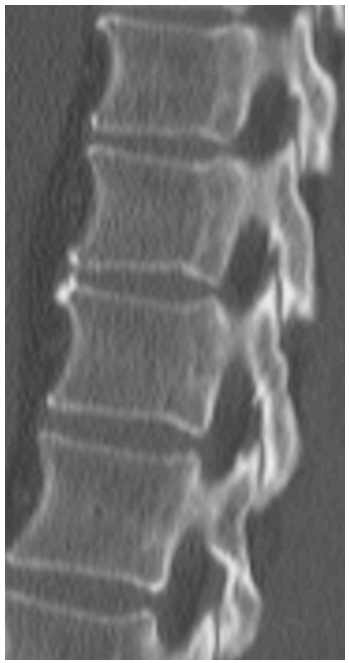


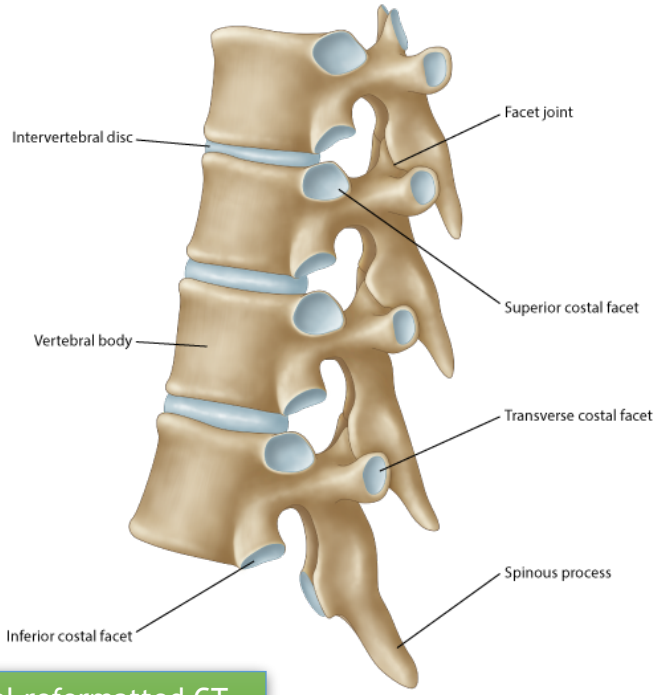
Axial CT & Illustration Thoracic Spine





Sagittal reformatted CT Mid Thoracic Spine & Illustration





ParaSagittal reformatted CT & Illustration Thoracic Spine

Notes

Imaging Findings

SUMMARY IMAGING FINDINGS

TABLE 1: SUMMARY GENERAL MRI IMAGING FINDINGS

	T1	T2 or STIR
Joint space (Normal)	Low SI (signal intensity)	Low but can have a thin band of high SI when normal joint fluid is present
Joint Effusion	Low SI	High SI
Joint Enhancement	Low SI pre-contrast T1FS sequence post contrast high SI	High SI similar to joint fluid. Note: Joint fluid remains low SI on post contrast T1FS sequence
Articular Cartilage (Normal)	Intermediate to low SI	Intermediate SI
Subchondral Bone Plate(Normal)	Low SI	Low SI
Erosion	Focal defect in subchondral bone plate, Low SI	Low SI in chronic inactive disease In active disease the erosion may be filled with fluid or synovitis (depending on location), both high SI on T2, on its articular aspect and have reactive osteitis/edema within the adjacent subchondral marrow
Marrow (Normal)	Intermediate to high (varies with age and the extent of hemopoeitic marrow). The *normal subchondral marrow should be of similar SI to the sacral marrow at the level of the sacral foramina.*	Low SI due to suppression of fat within normal marrow
Edema	Low SI	High SI
Fat Metaplasia/Post Inflammatory Fat	High SI	Low SI
Enthesities	Low SI	High SI (at tendon/ligament/capsular insertion onto bone)
Capsulitis	Poorly appreciated on T1,Low SI thickened	High SI, thickened

TABLE 2: SUMMARY PATHOLOGY IN SACROILIITIS

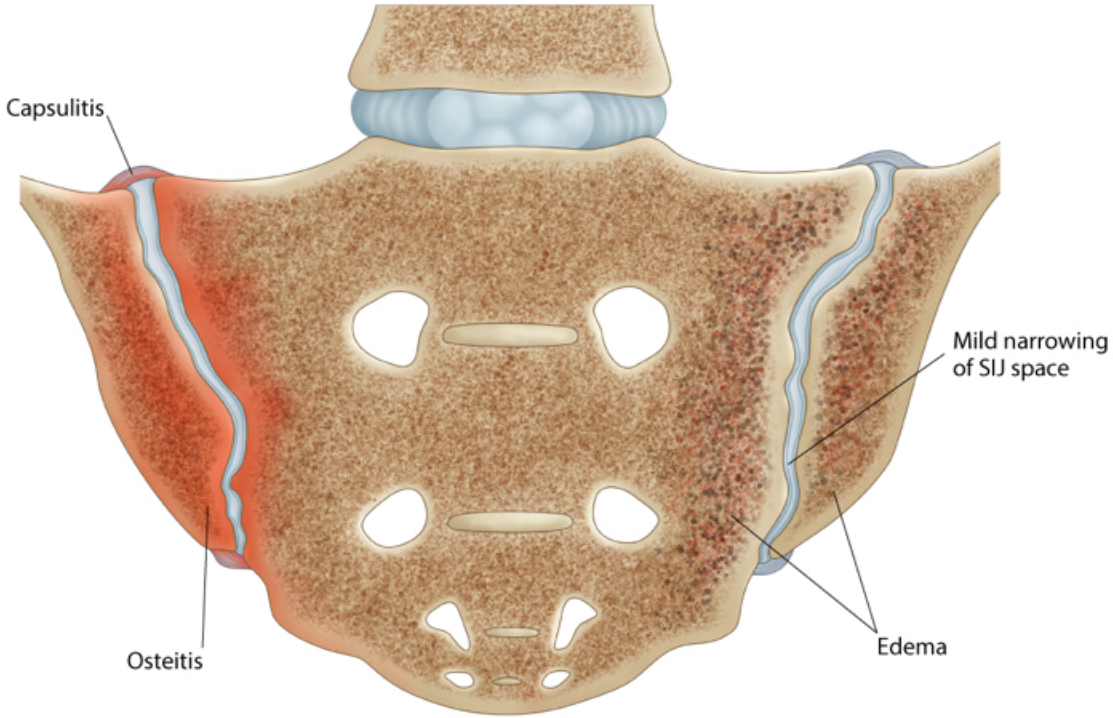
Sacroiliac Pathology	Radiograph	MRI
Edema (Osteitis)	ND	Periarticular high signal intensity on STIR or contrast enhanced T1FS
Enthesitis	ND	High signal intensity on STIR or contrast enhanced T1FS at site ligament or tendon attachment to bone
Joint Enhancement	ND, may be associated with joint space widening (combination synovitis and osteochondral inflammation)	Hgh signal intensity on contrast enhanced T1FS in the cartilaginous portion sacroiliac joint space
Effusion	ND, may be associated with joint space widening	Intra-articular high signal intensity on STIR, no enhancement on contrast enhanced T1FS
Capsulitis	ND	Capsular high signal intensity on STIR or contrast enhanced T1FS. May extend medially or laterally into periosteum as an enthesitis
Erosions	Focal defects subcentral bone plate	Cortical defect within cartilaginous compartment joint. Inactive-Low signal intensity on all imaging sequences. In active erosions high signal intensity on T2 within (active synovitis/joint fluid), or deep to erosion (osteitis). Confluence of erosions may result in *extended erosions* involving a large portion of the articulating surface
Fat Metaplasia	ND	Periarticular high SI on T1, low SI T1FS and STIR, with defined margin
Sclerosis	Subchondral area of high attenuation, appears “white”	Periarticular low signal intensity on T1, low signal intensity T1FS and STIR, extending to a depth of at least 5mm
Ankylosis	Partial or complete bony fusion across joint. Discernible joint space is lost	Partial or complete bony fusion across joint. Discernible joint space is lost. Follows bone marrow signal intensity on all imaging sequences
Backfill	ND	T1 High SI within site erosion, low on T2FS, represents repair tissue. Prelude to ankylosis

TABLE 3: SUMMARY PATHOLOGY IN SPONDYLITIS

Spinal Pathology	Radiograph	MRI
Corner Inflammatory Lesion	Anterior vertebral body corner erosion. May heal with sclerosis, the shiny corner.	Focal osteitis, high SI on STIR, low T1, anterior or posterior corners vertebral body. Chronic lesions are depicted as foci of fat signal intensity, high on T1 and T2. When inflammatory change is extensive termed massive inflammatory lesion
Anderson lesion/ Spondylodiscitis	Types 1,2 and 3. Localised or generalized discovertebral destruction with surrounding ill-defined sclerosis. Fractured posterior elements in type 3.	Irregularity to frank erosion of cortical endplate, adjacent osteitis of increased SI on STIR vertebral body, low SI disc and sclerosis deep to osteitis. Assess for posterior element fracture in type 3
Facet joint arthritis	Erosions, subchondral sclerosis and eventually joint ankylosis.	Erosions facets, osteitis adjacent pedicles, subchondral sclerosis. May eventually lead to joint ankylosis.
Costovertebral and costotransverse osteitis and structural change	N/A	Osteitis at articulation between head rib and vertebral body, T1-T12, (costovertebral) and between rib and transverse process (costotransverse), T1-T10, with low SI on T1, high on T2. Fat metaplasia occurs post resolution acute inflammation with new bone formation/sclerosis and may eventually fuse at costovertebral articulation.
Enthesitis	Poorly assessed. May be normal or erosion and osteopenia, reactive sclerosis	High SI within ligament and osteitis at bony attachment, may develop erosion and sclerosis, commonly seen in posterior element involvement.
Syndesmophytes	New bone formation within the outer fibres of the annulus fibrosis of the intervertebral disc commencing at the juncture with the vertebral body, eventually bridging between vertebral bodies	May be difficult to identify on MRI, radiographs more sensitive. Non/bridging bone following marrow SI on all imaging sequences
Ankylosis	Bony fusion, partial or complete, across a joint space	Bony fusion, partial or complete, across a joint space. May have bone marrow SI (easier to identify on MRI) or be sclerotic and low SI on all sequences,

Sacroiliac Joint Pathology

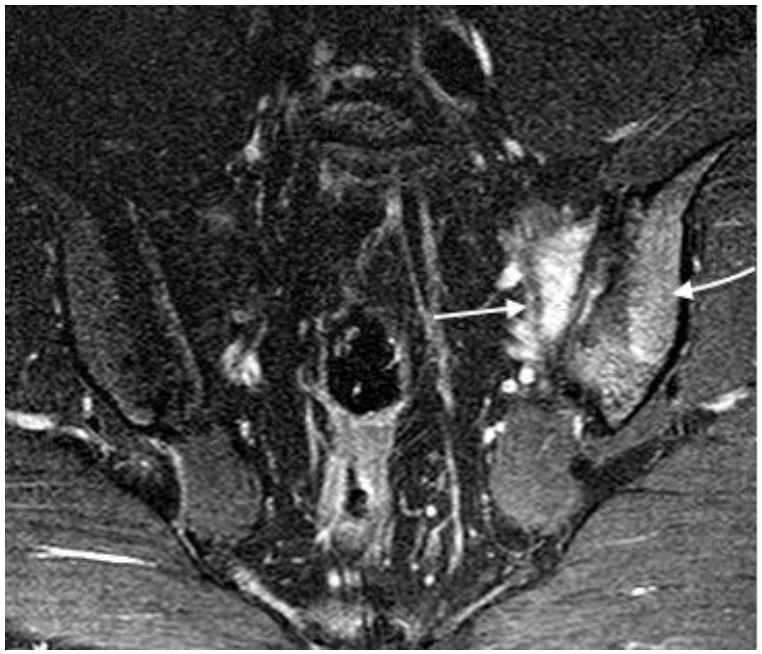
Osteitis



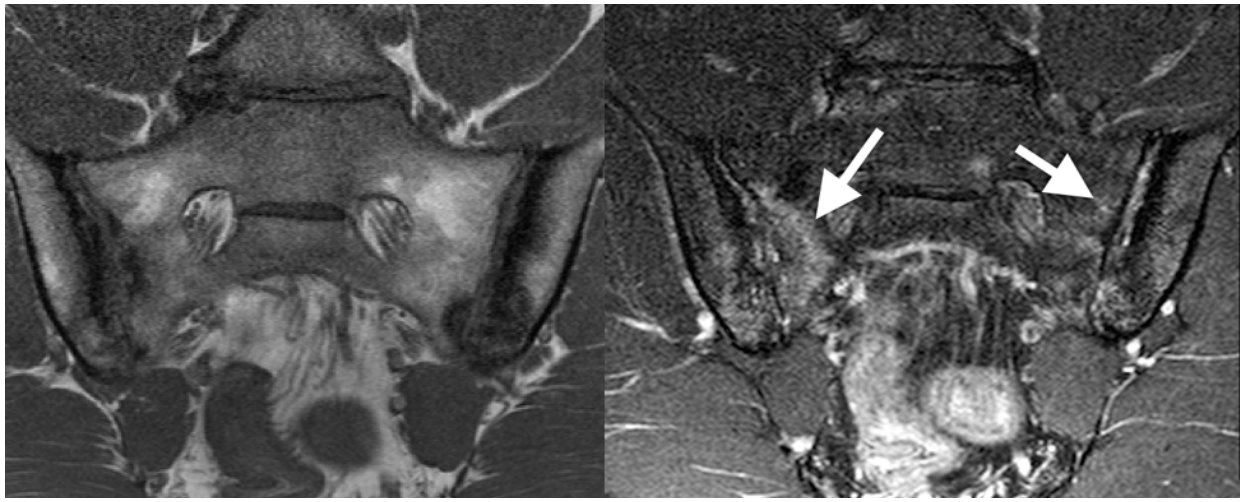
Coronal illustration of acute inflammatory changes right sacroiliac joint with capsulitis and osteitis. Subacute to chronic changes on the left with less pronounced edema, increased joint space loss. Note the irregular subchondral bone plate irregularity in keeping with early erosive disease.

Edema is an excess accumulation of fluid in the bodies tissue and can occur from multiple causes. With respect to axial SpA we will focus on edema related to inflammation. In the case of bone this inflammatory change is termed osteitis.

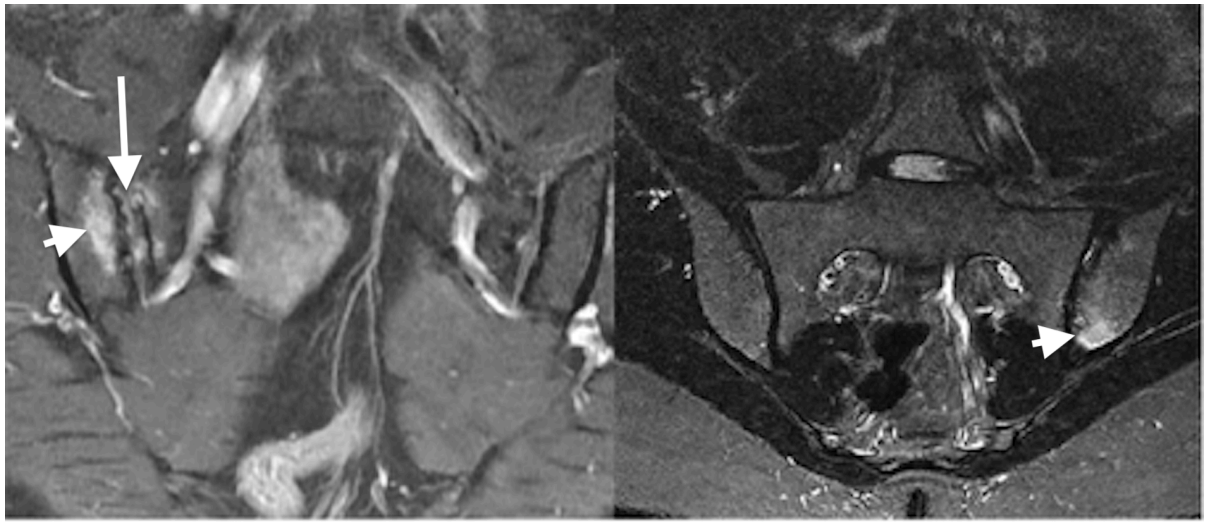
When depicted in MR imaging, edema presents with periarticular high signal intensity on STIR or T2FS sequences and contrast enhanced T1FS. Usually occurs first on the iliac aspect joint, thought to be related in part to thinner cartilage on this side and transversing channels through the subchondral plate.Osteitis is difficult to appreciate on T2 without fat saturation as edema and marrow signal intensity are similar. On T1 edema is of intermediate to low signal intensity.



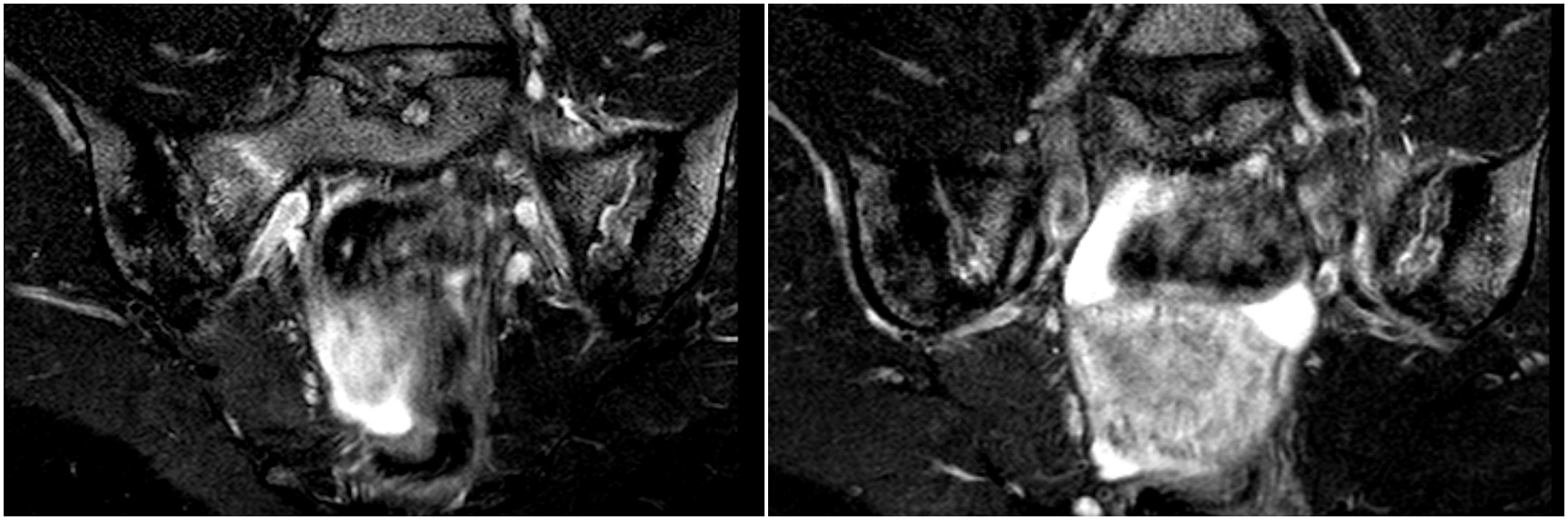
Coronal T2FS, left acute sacroiliitis with extensive subchondral bone marrow edema (arrows) and increased signal intensity reflecting effusion/synovitis left SIJ. Structural changes right SIJ



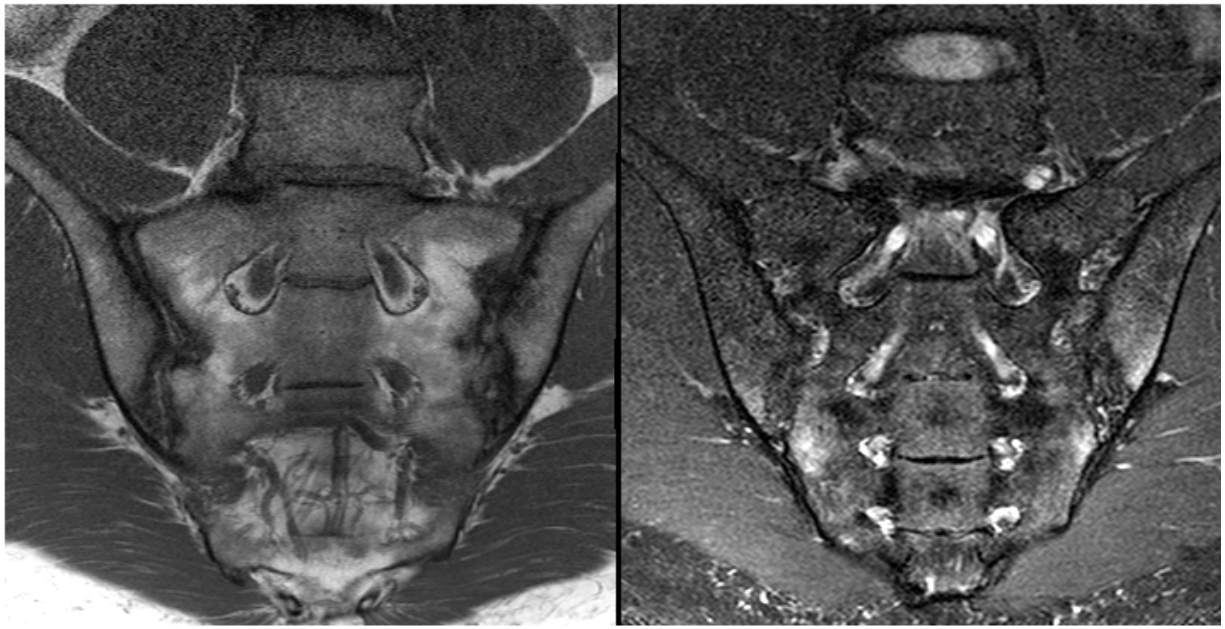
39y M patient on initial presentation with 20yr history low grade inflammatory back pain, Cor T1, left image, demonstrates bilateral erosions, iliac subchondral sclerosis and joint space loss. Cor STIR, right image, demonstrates active osteitis (arrows).



Cor T1FS post contrast, left image, with enhancing right SIJ osteitis (arrowhead) and joint enhancement (arrow). Cor STIR (right image) demonstrates unilateral osteitis (arrowhead) iliac aspect left sacroiliac joint

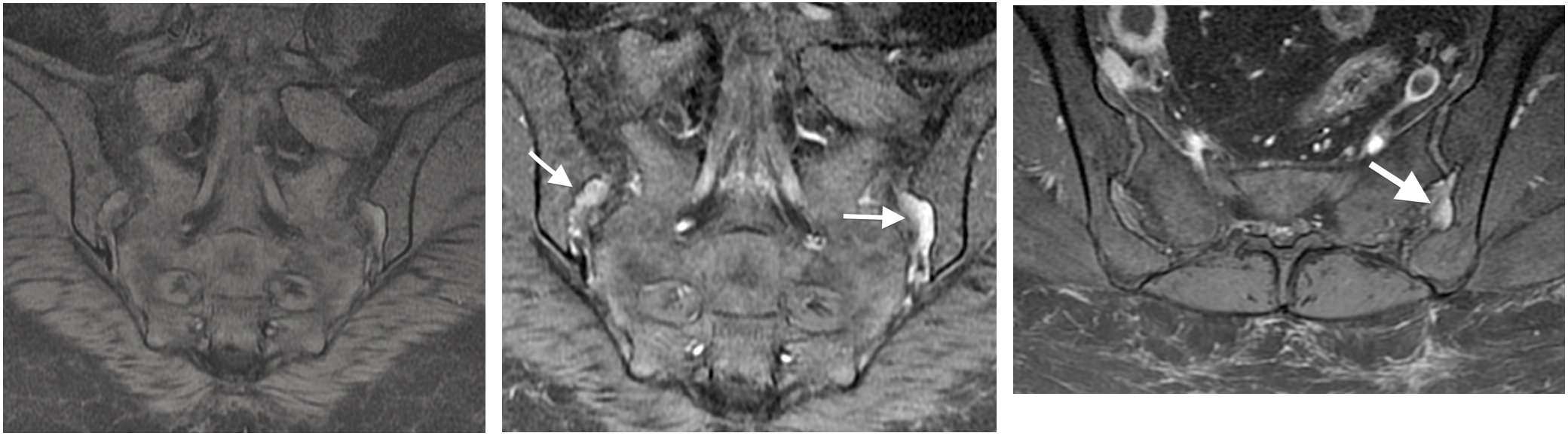


Cor STIR in acute on chronic SIl with bilateral extensive subchondral high SI in keeping with osteitis. Widening joint space with multiple erosions. Bilateral iliac low SI was also low on T1, not shown, in keeping with subchondral sclerosis



Cor T1 (left image) and STIR in acute on chronic SIl. On STIR there is bilateral subchondral high signal intensity, low on T1, in keeping with osteitis. Note also early joint space loss, mild subchondral sclerosis and erosions.

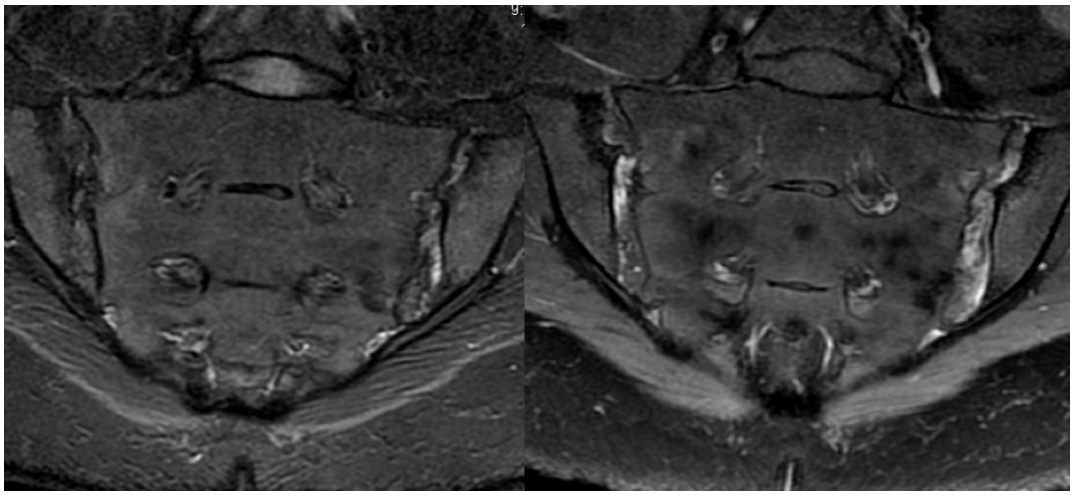
Enthesitis



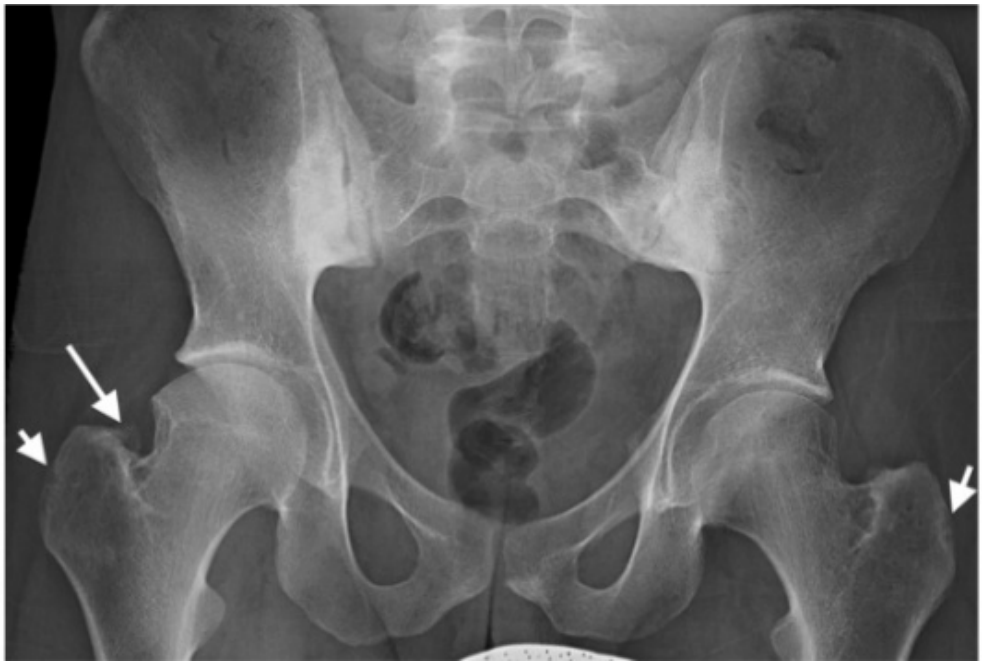
Enthesitis: Cor T1 FS pre (left) and Cor & Axial T1FS post gadolinium (right image) with enhancing ligaments at insertion bilaterally (arrows). In addition note the early cortical erosions iliac aspect right SIJ (arrow, center image). No related enhancing osteitis.

Enthesitis is the inflammation of the enthesis, site of insertion of tendon, ligament or joint capsule to bone. There are 2 types of entheses, fibrous and fibrocartilaginous. Enthesitis is common in SpA. It may be subclinical and detected only on imaging. On MRI enthesitis is identified as high signal intensity on STIR or contrast enhanced T1FS at the site of ligament, tendon or capsular attachment to bone.

CT is excellent at demonstrating enthesophytes but is unable to assess enthesitis. Nuclear studies with bone scan may demonstrate increase uptake at sites of osteitis but is non-discriminatory, is not as sensitive as MRI and incurs a significant radiation dose. With respect to the SIJs it is best visualized in the ligamentous compartment, posterior to the cartilaginous joint, posteriorly at gluteal tendon attachment, superiorly and anteriorly at capsular attachment.

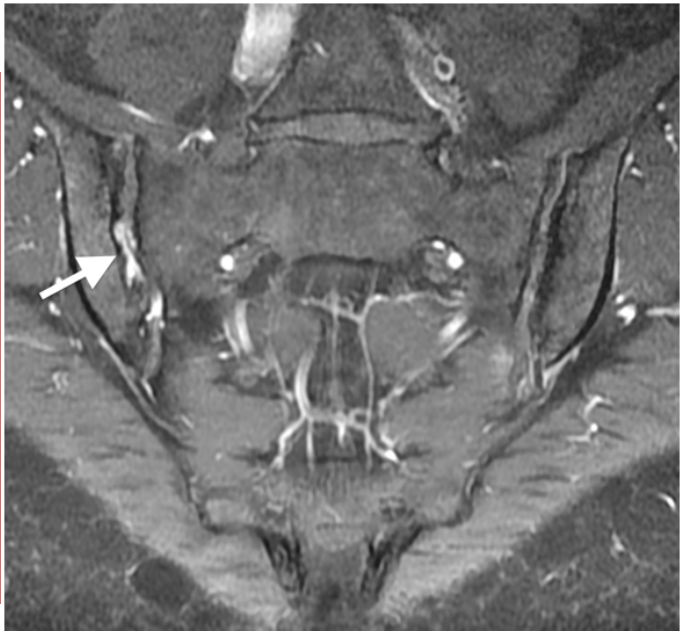


Enthesitis: Cor T1 FS pre (left) and post gadolinium (right image) with enhancing ligaments at insertion bi laterally . Cor STIR, not shown, demonstrated corresponding high SI in keeping with edema.



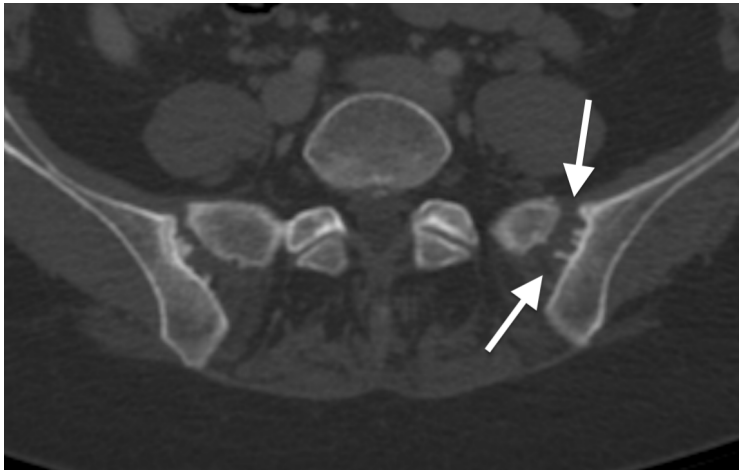
35y M with AS with bilateral grade 2 sacroiliitis, joint space loss, erosions and prominent subchondral sclerosis without ankylosis.Early cortical erosions (small arrows) greater trochanters (at gluteal entheses) and enthesophyte formation (large arrow). Erosions right femoral head-neck junction.

Cor T1FS post gadolinium demonstrating enhancement in the right ligamentous compartment. One should be careful that apparent ligamentous enhancement is not vascular, axial images may be helpful in this regard.

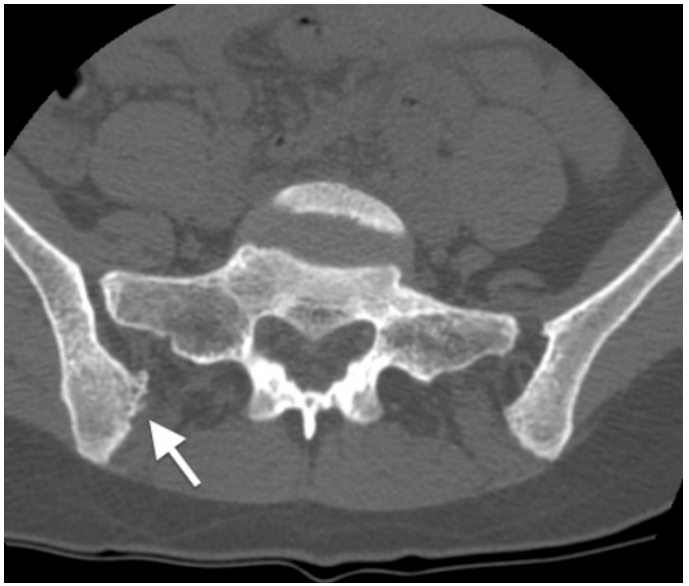


Enthesophytes

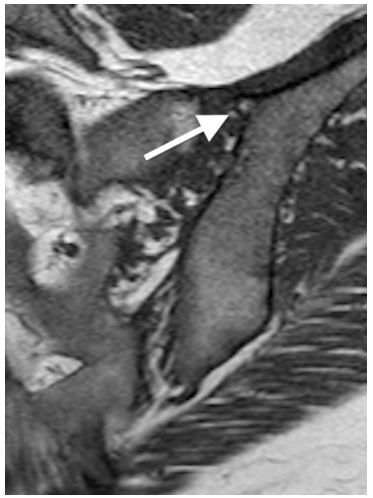
An enthesophyte is new bone formation at an enthesis secondary to chronic stress or inflammation at the enthesis. In axial disease it is usually best appreciated in the entheseal/ligamentous compartment of the SIJ. CT is the most sensitive imaging study in identifying an enthesophyte as small spikes of new bone at ligamentous insertion.

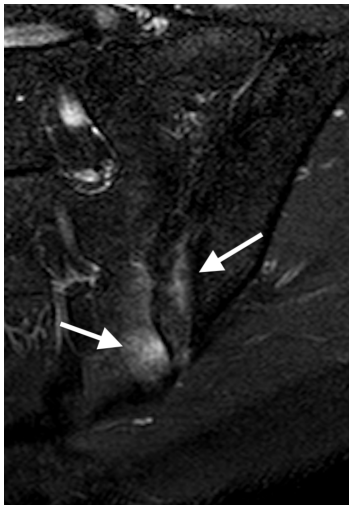


Patient with chronic IBD, cropped axial CT, bone window (top image), from CT abdomen/pelvis demonstrating bilateral enthesophyte formation along superior entheseal compartments (arrows).
Corresponding followup MR SIJ, below, same patient with enthesophte superior left SIJ (left). Cor STIR left SIJ (right) demonstrating enthesitis (arrows)



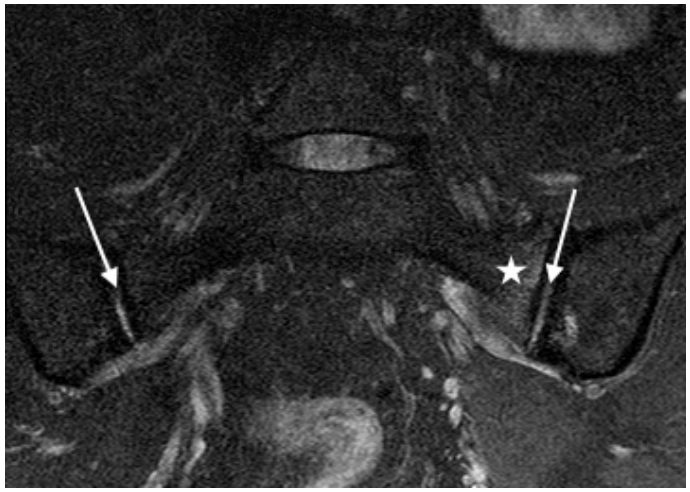
Early enthesophyte formation (arrow) right posterosuperior SIJ ligamentous compartment on axial CT in patient with chronic AS



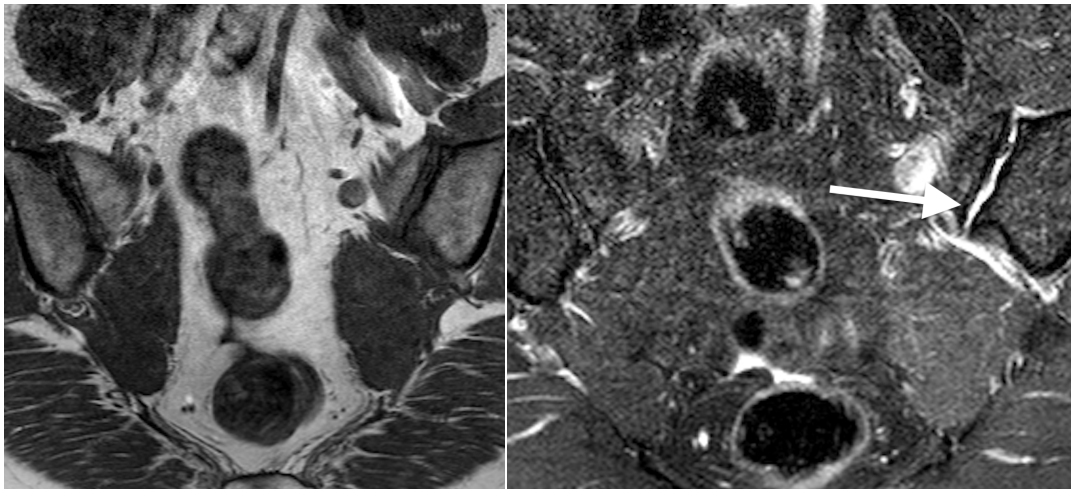


Joint Effusion

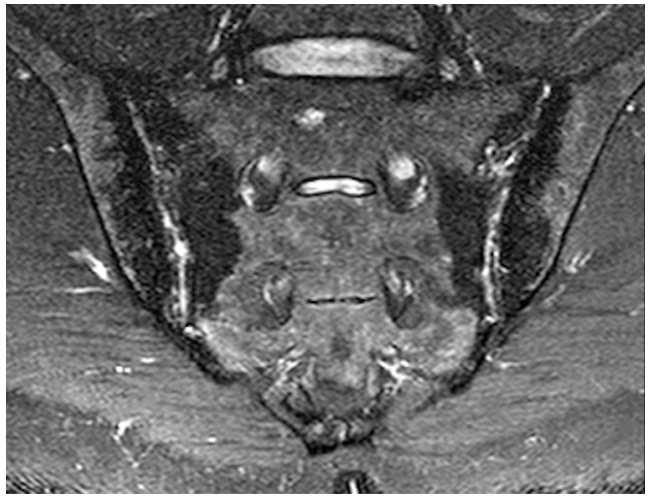
An abnormal collection of fluid in a joint space. On MRI appears as intra-articular high signal intensity on STIR, low on T1, with no enhancement on contrast enhanced T1FS MRI. Joint effusion occurs at the sacroiliac joints and spinal facet joints.



Cor T2FS through anterior sacroiliac joints with linear high signal intensity within the joint spaces representing effusion and left subchondral bone marrow edema (star).



Cor T1 (left) and T2FS (right) through anterior sacroiliac joints with linear high signal intensity within the joint spaces on T2FS, low T1, without post contrast enhancement (not shown) representing left effusion in a patient with mild degenerative disease SIJs



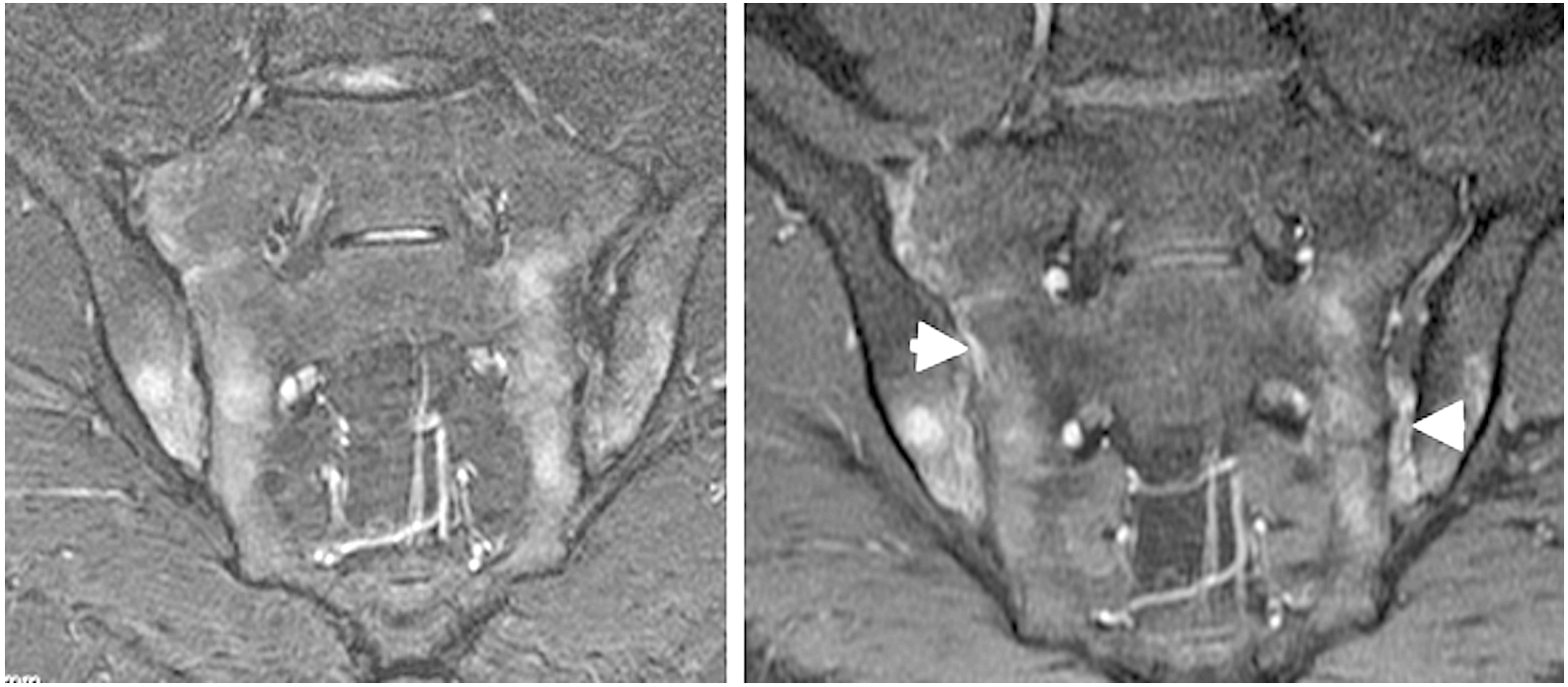
Coronal STIR with bilateral high Sl within both SIJ, effusion, and subchondral low Sl which was high Sl on T1 (not shown) in keeping with fat suppression and fat metaplasia

Joint Enhancement/Osteochondral Inflammation

Synovial tissue lines a synovial joint and is not visible on imaging in the absence of synovitis. In synovitis the synovium proliferates, becomes inflamed and edematous and can appear identical to fluid on MRI i.e. low SI on T1 and high SI on T2FS and STIR. Synovitis may occur in the sacroiliac joints, facet joints and sternoclavicular joints on spondylitis imaging.

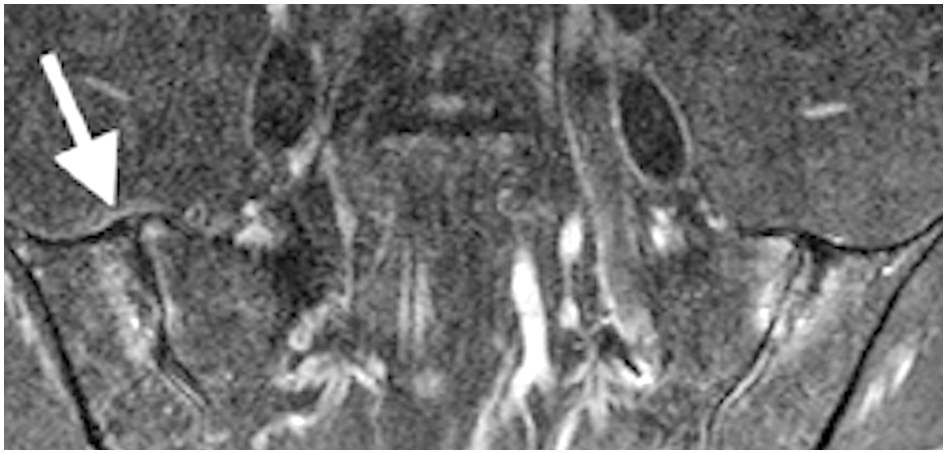
Joint enhancement post contrast may to be secondary to inflammation at the osteochondral interface and this is the likely dominant pathology when inferior peripheral enhancement (synovitis) is absent.

Note: Assessment joint enhancement SIJs is usually not required in the clinical setting. If acquired post contrast images should be fully acquired not longer than 10 minutes post injection as contrast may diffuse into a joint effusion and hence simulate joint enhancement

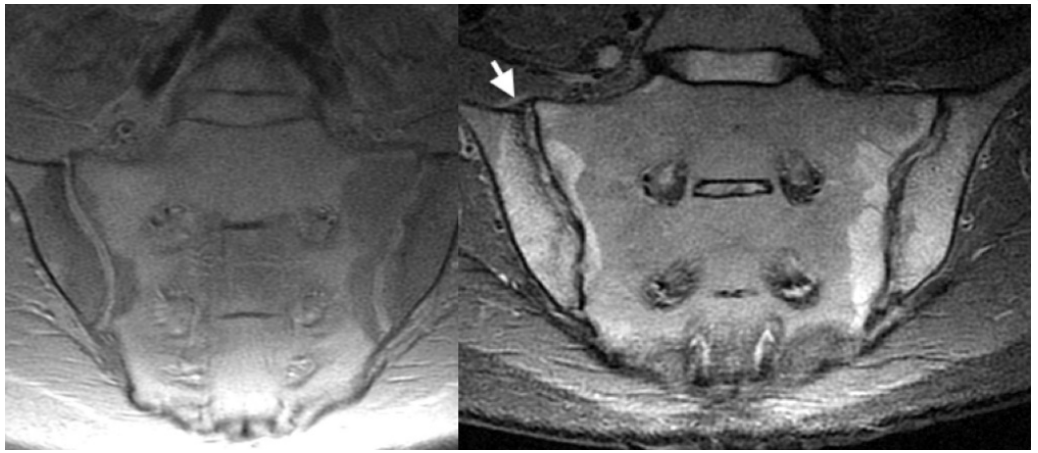


24-M with IBP. Coronal STIR MRI (left image) demonstrates bilateral symmetrical osteitis, bilateral loss of joint space with small erosions and subtle increased signal intensity in the left sacroiliac joint. Cor T1 FS post-gadolinium (right image) demonstrates in addition right SIJ enhancement, left entheseal enhancement (arrowhead) and confirmed as ligamentous enhancement on Ax T1FS image (not shown) and bilateral enhancing osteitis.

Capsulitis

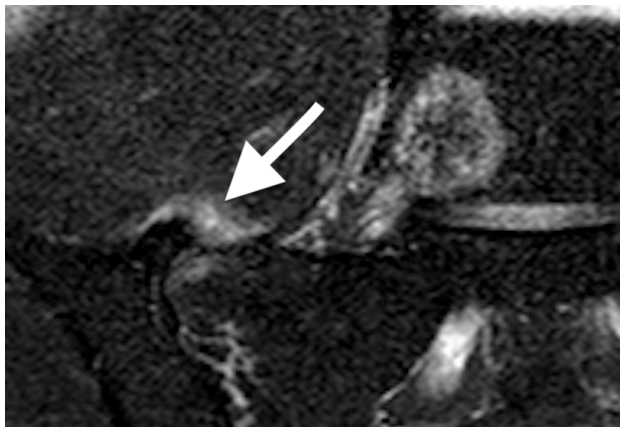


Cor STIR high right capsular Sl in keeping with capsulitis (arrow) on a background of acute on chronic sacroillitis with joint space loss, small erosions and periarticular osteitis

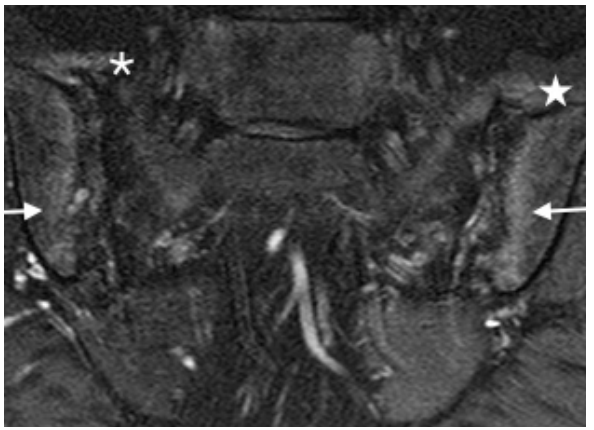


Pre (left) and post-contrast (right) Cor T1 FS SIJ demonstrating post contrast enhancement on both sides SIJs in keeping with osteitis and capsulitis Rt superior SIJ (arrow) and mild bilateral enhancing joints

Capsulitis refers to the inflammation of the capsule, a fibrous coating surrounding the joint, and is only identifiable on MRI. Capsular high signal intensity is noted on STIR or contrast enhanced T1FS. May extend medially or laterally into the periosteum as an enthesitis. Capsulitis is often seen in conjunction with other acute inflammatory changes

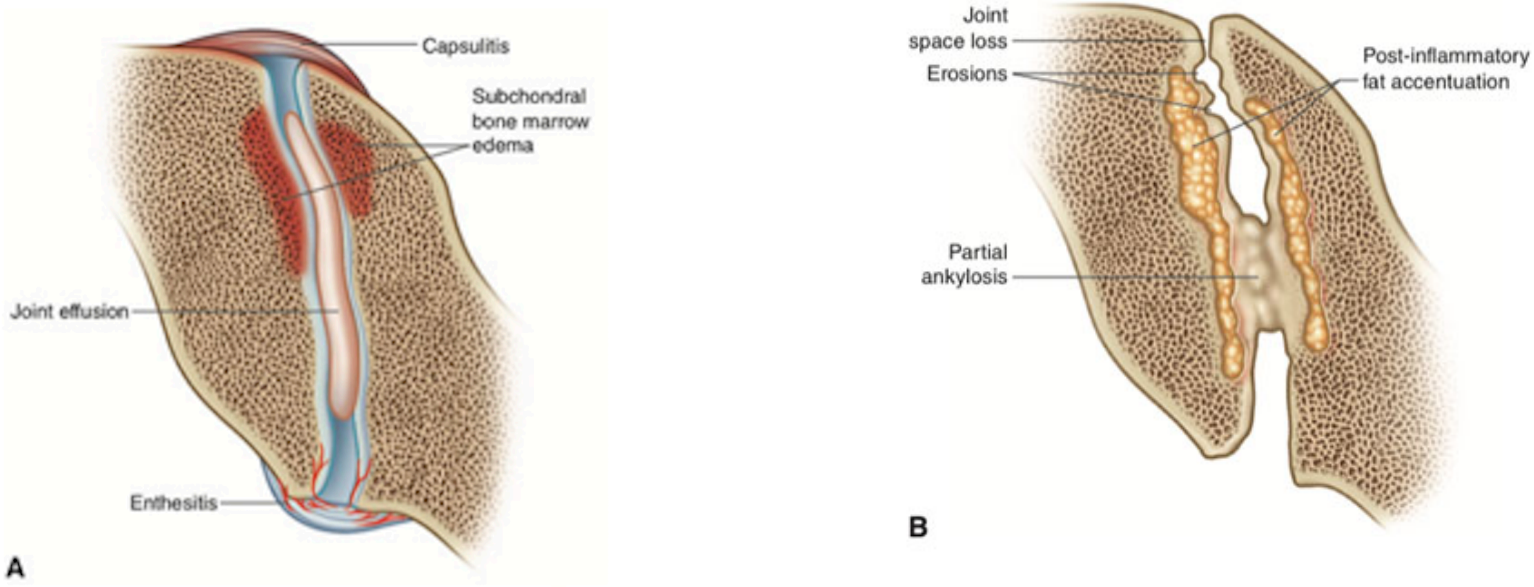


Coronal T1FS post contrast, magnified image, demonstrating enhancing thickened right SIJ capsule, (arrow), acute capsulitis



Coronal T2FS, bilateral acute sacroiliitis with osteitis (arrows) and bilateral superior capsulitis (stars)

Erosions

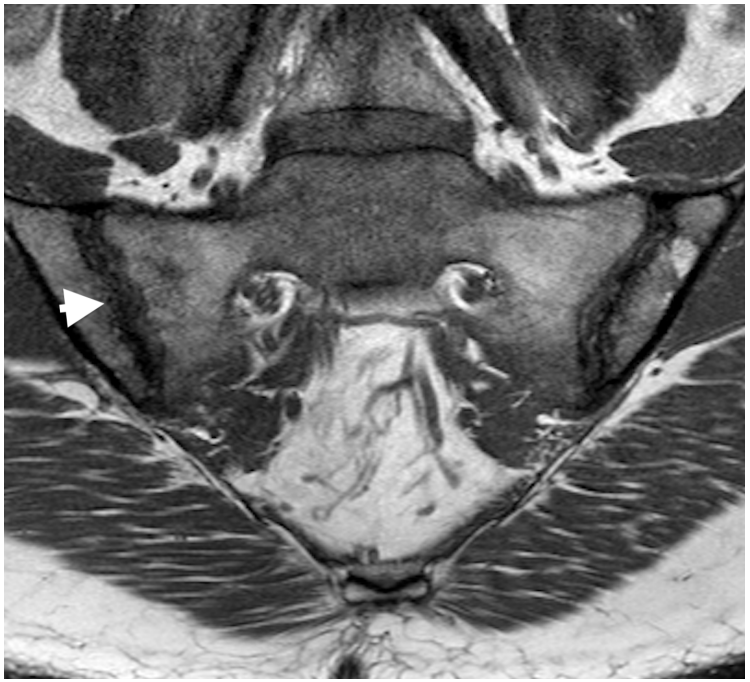


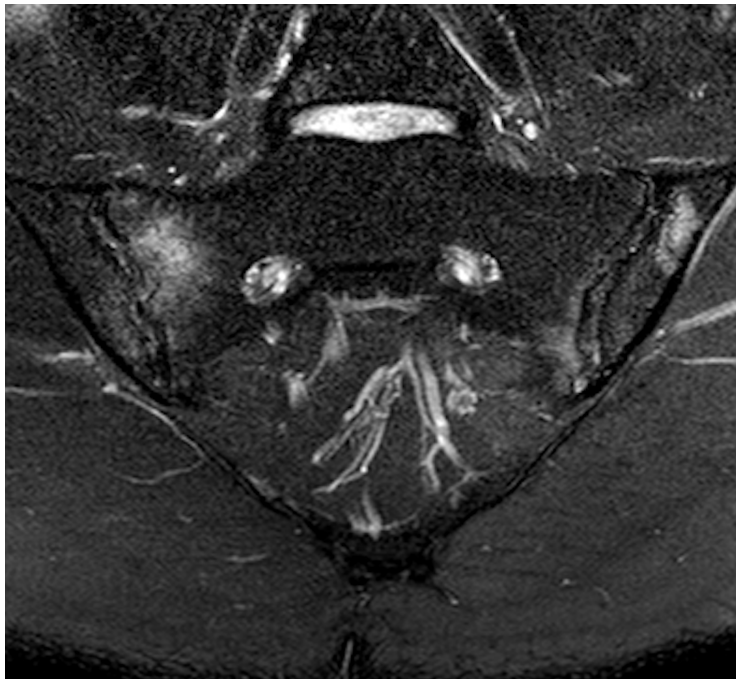
Illustrations of a) acute and b) structural changes in sacroillitis

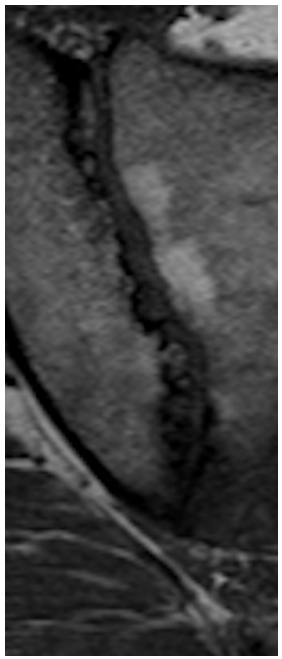
An erosion on MRI is defined as a defect in subchondral bone associated with full thickness loss of the dark appearance of the subchondral cortex at its expected location, with loss of signal on a T1W non-fat-suppressed sequence compared to the normal bright appearance of adjacent bone marrow. Erosions in axial SpA predominantly occur in the sacroiliac joints, the sternoclavicular joints and in the facet joints. CT is the gold imaging standard for erosions due to its high resolution and exquisite detail of bone architecture but is rarely required as MRI can also demonstrate acute inflammatory changes not visible on CT and incurs no radiation dose.

Structural changes are in general better appreciated on T1 weighted sequences in comparison to STIR or T2FS. In the SIJs coronal oblique T1FS images is more sensitive than T1 for early erosions with good discrimination between the cartilage and the low SI subchondral bone plate. However this sequence is not routinely used in clinical practice.

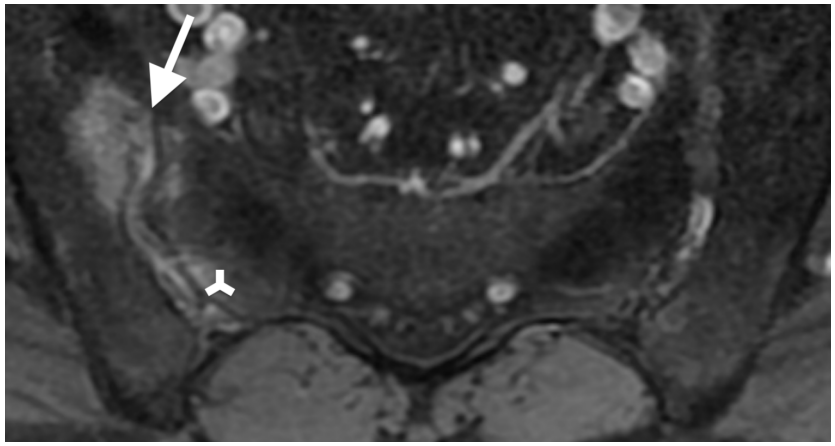
Inactive erosions are low signal intensity on all imaging sequences. In active disease the erosion may be filled with fluid or joint enhancement, both high SI on T2, on its articular aspect and have reactive osteitis/edema within the adjacent subchondral marrow. Cor T1FS is sensitive for erosions but will not demonstrate related osteitis or joint enhancement unless study is performed post contrast.



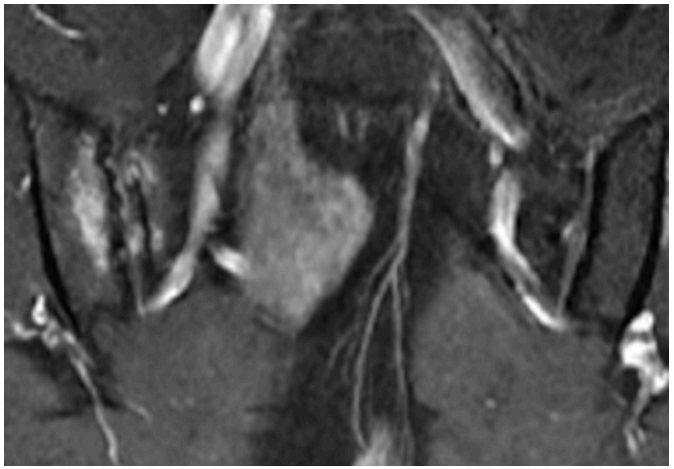




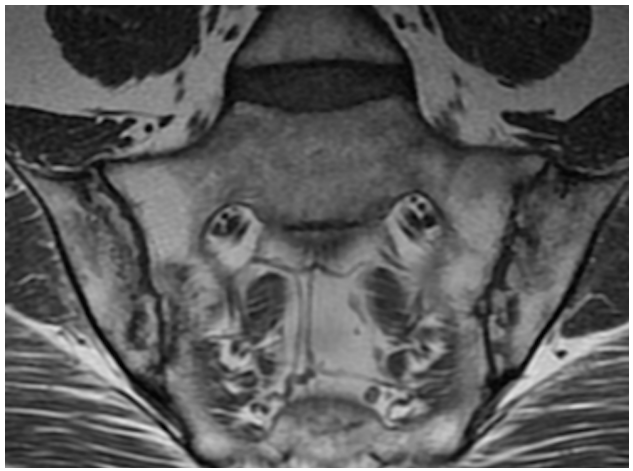
Cor T1 (top left image), or T2FS (top right), magnified image of the right SIJ and normal SIJ for comparison (bottom left and right respectively). **Extended erosions** are seen, predominantly on the iliac aspect right SIJ with loss of the normal smooth low signal intensity sunchondral bone plate best appreciated on T1. The related osteitis is high signal intensity on the T2FS image extending to the right sacral erosions in keeping with active erosions

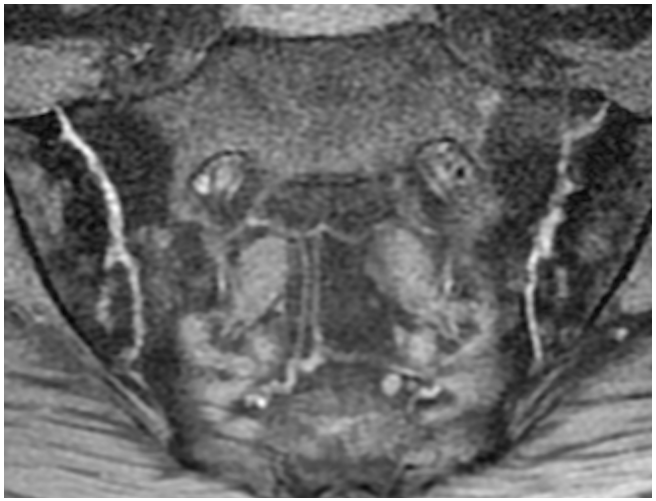


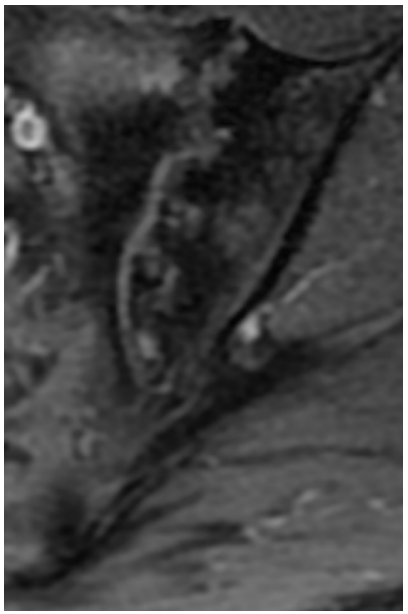
Axial T1 FS post contrast demonstrating active erosions right iliac aspect SIJ with focal defect subchondral bone place, joint enhancement on the articular side and adjacent enhancing osteitis. Y-enhancing enthesitis



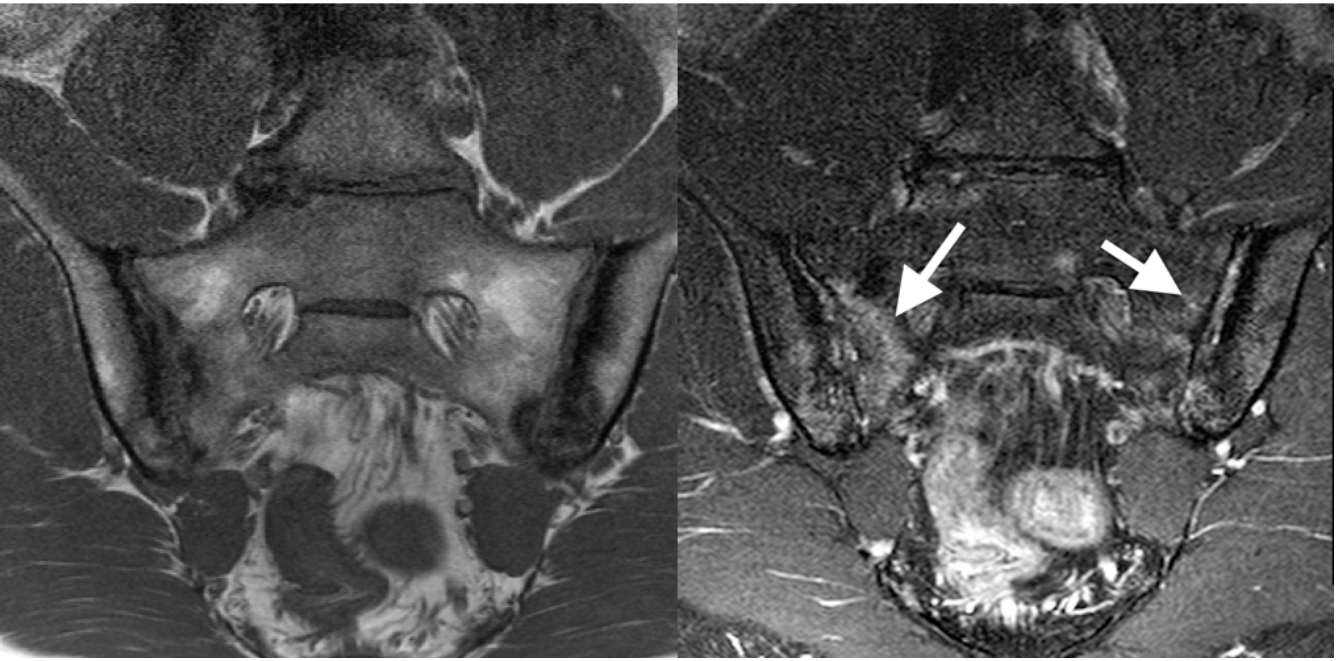
Cor T1 FS post contrast with enhancing right SIJ erosions, osteitis and joint enhancement. Normal left SIJ



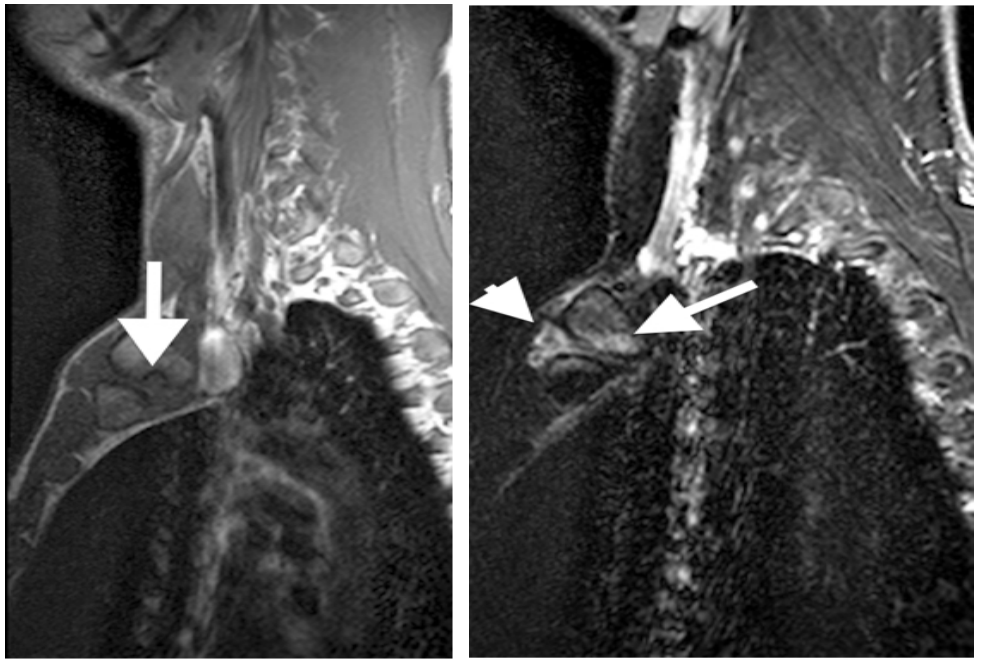




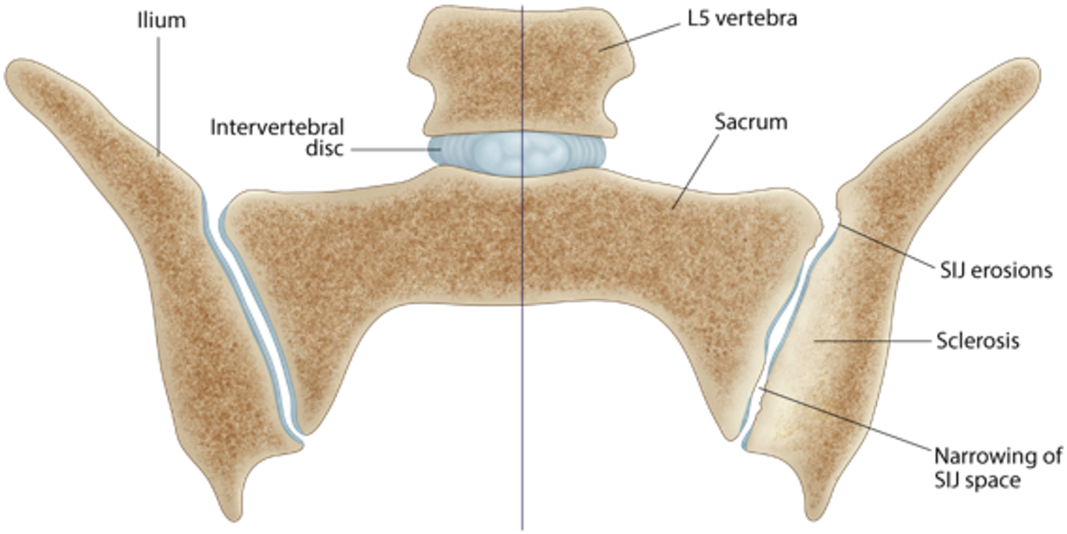
Cor T1 (left image), T1FS (centre) and magnified left SIJ T1FS PG (right) demonstrating multiple erosions without significant enhancement



39y M patient on initial presentation with 20yr history low grade inflammatory back pain. Cor T1, left image, demonstrates bilateral erosions, iliac subchondral sclerosis. Cor STIR, right image, demonstrates active osteitis (arrows), joint space loss and erosions. Note areas of osteitis/edema are low on Sl T1 although not as low as sclerosis (low Sl on both sequences)



30y M with known AS, Sag T1 (left image) and STIR (right image)cervical and upper thoracic spine demonstrate erosion (arrow) and joint distension (can be either effusion or synovitis on this unenhanced study) left sternoclavicular joint.



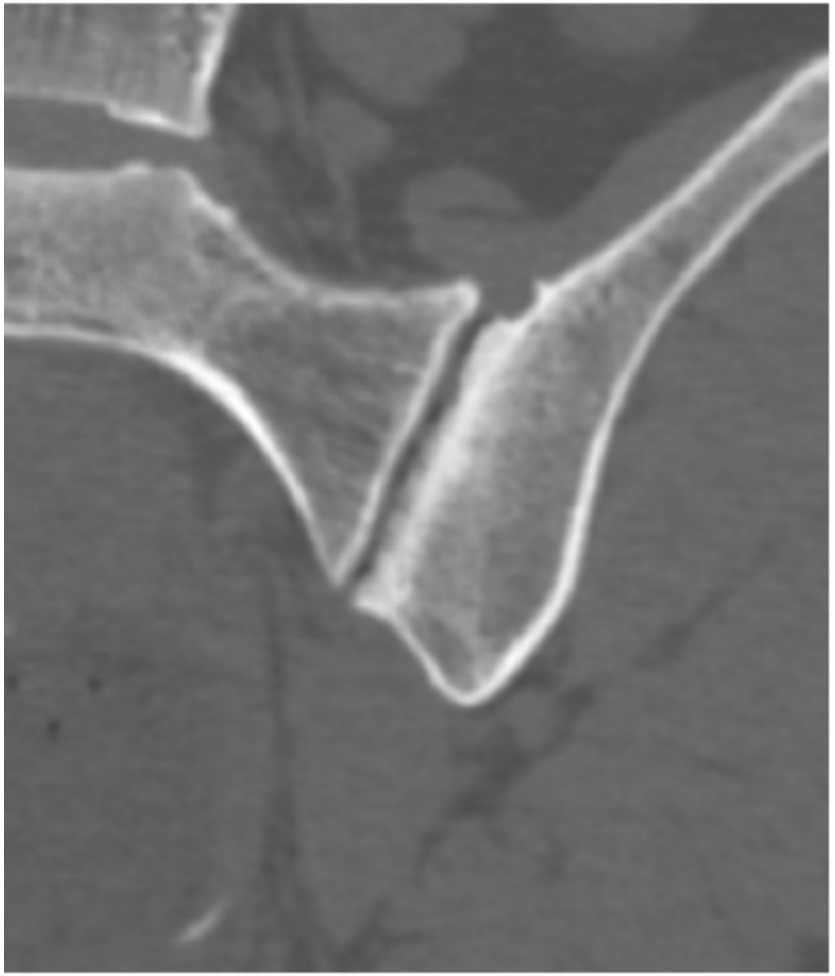
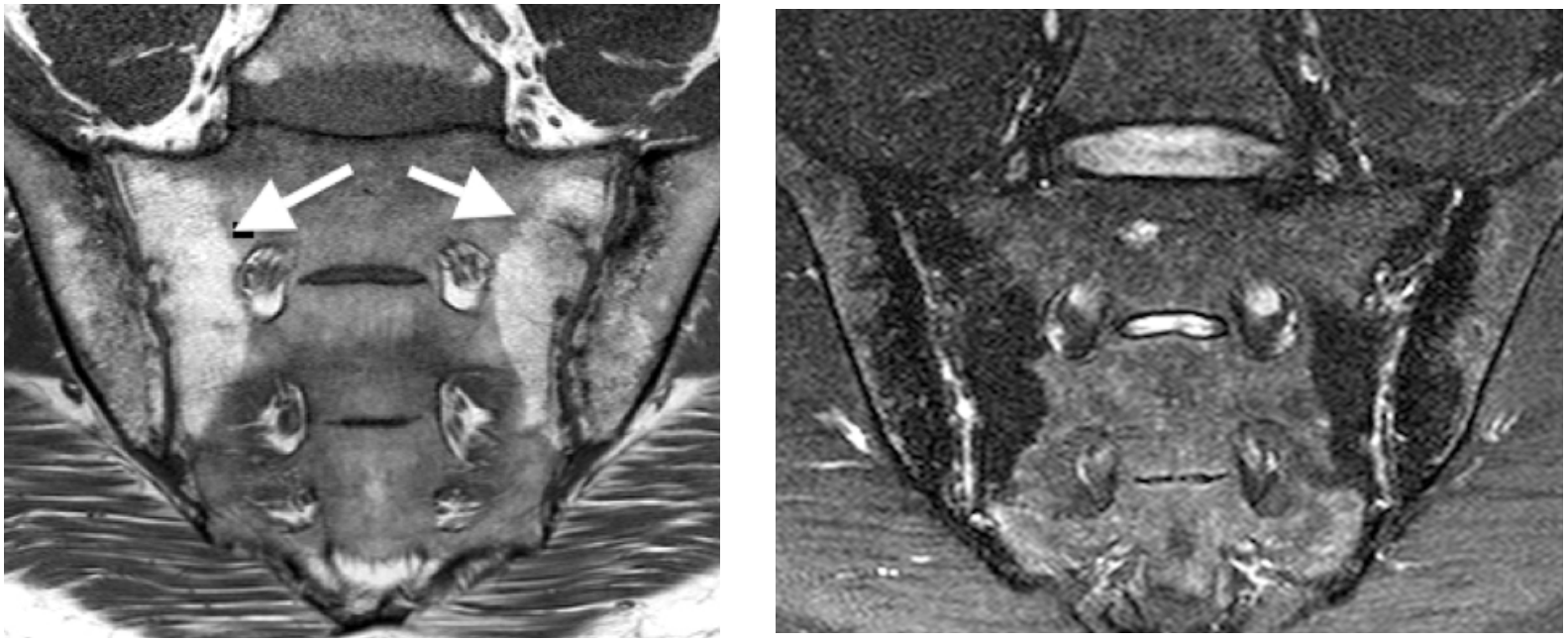


Illustration SIJs (above) with normal right and chronic changes left SIJ. Magnified Cor CT left SIJ with matching changes with joint space loss, erosions and iliac subchondral sclerosis

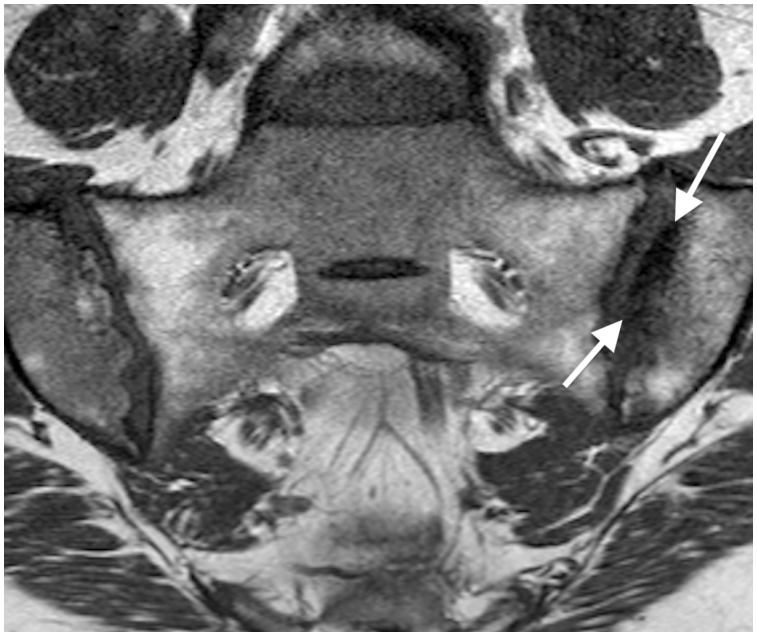
Fat Metaplasia

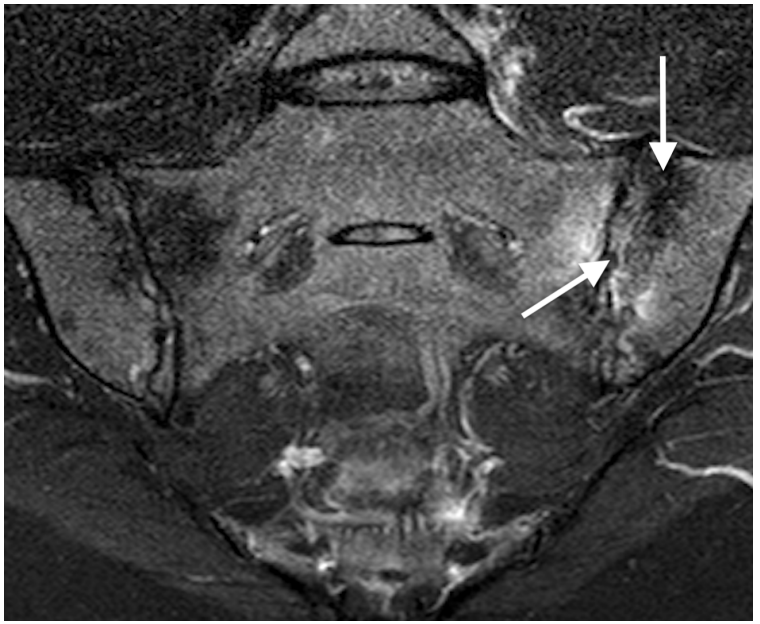


MRI SIJ 24y F, HLA B27 positive, Cor T1 (left image) and Cor T2FS (right image) demonstrate bilateral periarticular fat, more pronounced on the sacral aspect, with defined margins. Note the normal marrow SI at the level sacral foramina. Note the *fat is high signal on T1 and becomes low signal on T2FS*. Note also bilateral erosions and small bilateral SIJ effusion on the Cor STIR

Fat metaplasia or post inflammatory fat accentuation (PIFA) is the fatty conversion/esterification of bone marrow at sites of prior inflammation. Since SIJ osteitis in SpA is periarticular so too is the fat metaplasia. PIFA is identified as periarticular high signal intensity on T1 and low signal intensity T1FS and STIR (both have fat suppression) with *defined irregular marginal band of low signal intensity reflecting sclerosis*. Bone marrow constituent changes with age with increased fat deposition with centralization of hemopoietic cells as one ages, therefore when assessing for PIFA one needs to assess what is the normal marrow signal intensity for that patient. Normal bone marrow signal intensity is assessed at the level of the sacral neural foramina and serves as a reference when assessing the periarticular region.

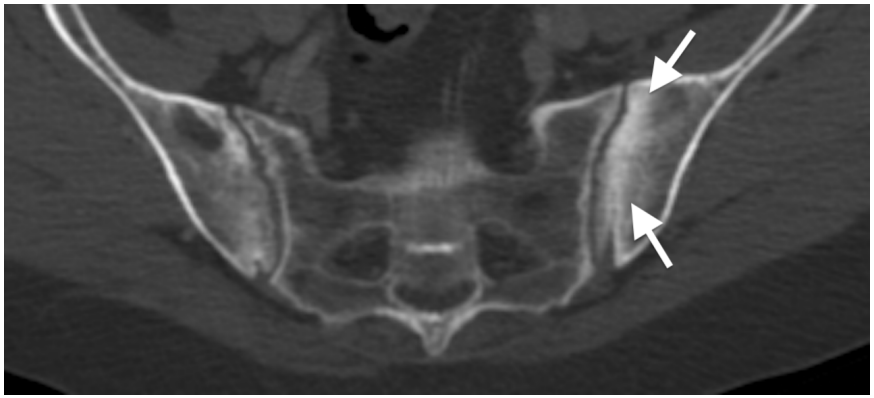
Subchondral Sclerosis





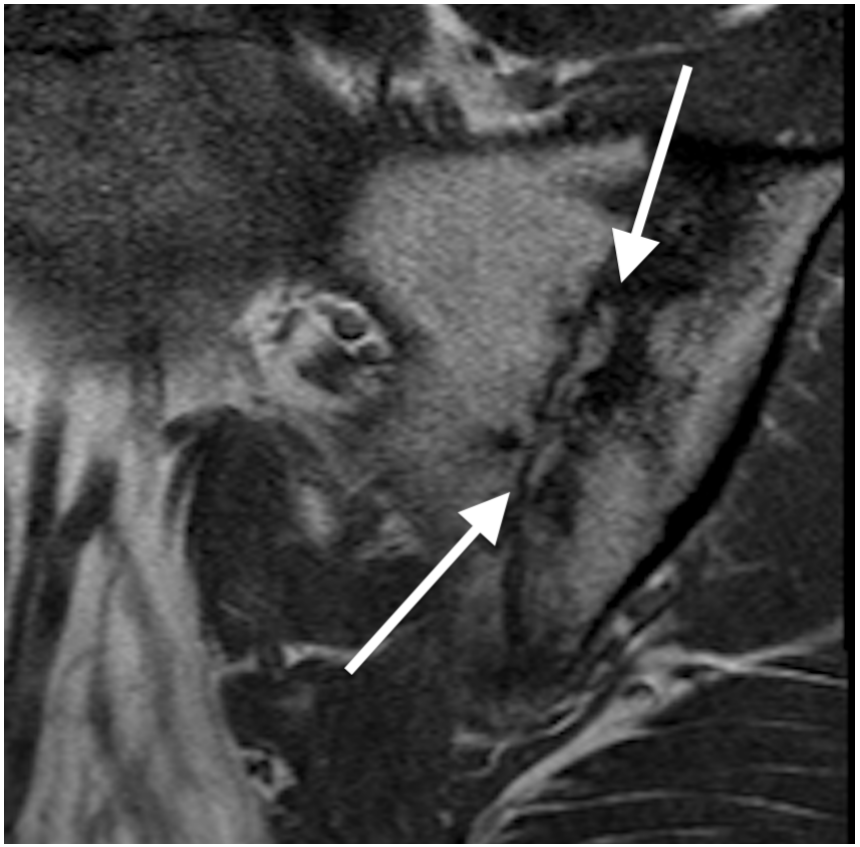
MRI demonstrating subchondral sclerosis, arrows, as low subchondral signal intensity on T1, left image, and STIR, right image

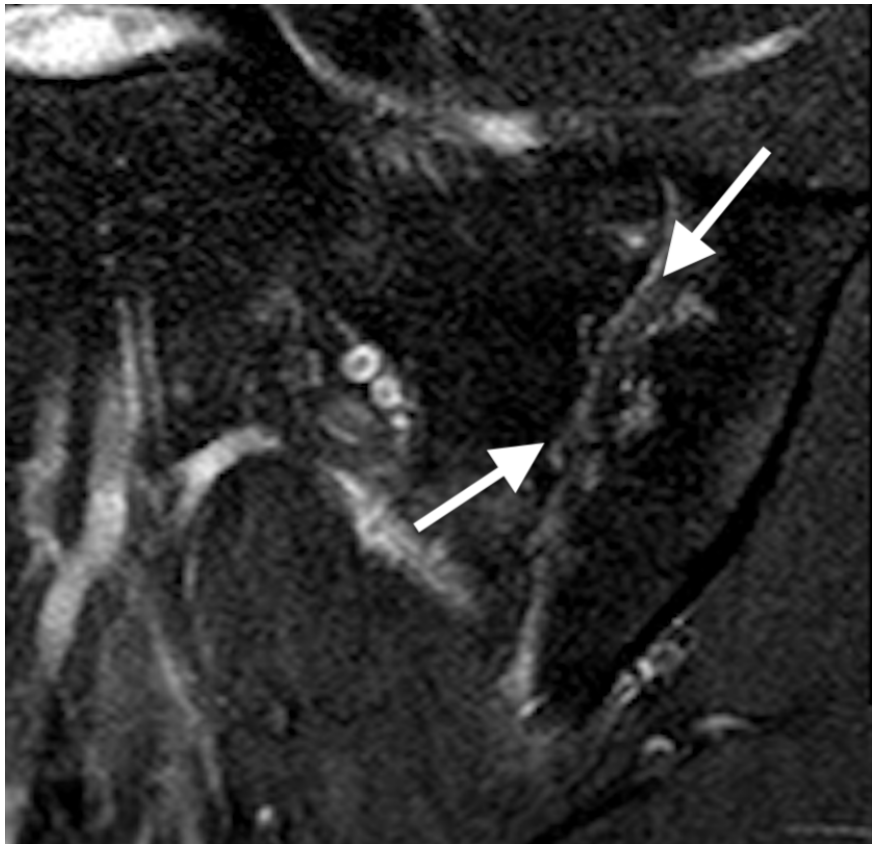
With loss of the overlying articular cartilage the subchondral bone is exposed to increased stress across the joint. The bone responds with increasing trabecular collapse and flattening with subsequent increased attenuation of bone on radiographs and CT.
Subchondral sclerosis on MRI is low signal intensity on T1 and STIR deep to the subchondral bone plate with a combined depth of > 5mm. Most often evident at the SIJs but also evident at facet joints. Sclerosis is denser closer to the joint surface.



Axial CT demonstrating subchondral sclerosis, arrows, left ilium. Note the normal subchondral bone on the sacral aspect and bilateral SIJ erosions

Backfill





Chronic sacroillitis with joint space loss, erosions, fat metaplasia and left iliac aspect backfill, arrows, high SI on T1 and corresponding low SI T2 and following marrow signal intensity.

Backfill is the presence of high signal intensity on T1 at a site of prior erosion/s representing repair tissue along the evolutionary pathway to ankylosis in patient with chronic sacroiliitis. It is hypothesized that it represents new bone formation but has not been confirmed histologically to date. It has corresponding low signal intensity on T2FS sequence. It is associated with complete loss of the dark appearance of the subchondral bone plate at its expected location and is clearly demarcated from adjacent bone marrow by an irregular band of dark signal reflecting sclerosis at the border of the original erosion

Ankylosis

Ankylosis is the proliferation of bone across a joint space with secondary loss of the joint space. Ankylosis may be partial or complete. Partial ankylosis can be further divided into the percentage of joint space involved. On radiographs joint space is lost, the subchondral bone plate becomes indistinct and is eventually lost and bone trabeculae can be seen transversing the previous joint space. CT is excellent in demonstrating bone detail and ankylosis. MRI demonstrates continuation of bone marrow signal intensity across the previous joint space with loss of the subchondral bone plate. In partial ankylosis regions of backfill may also be seen.

A **bone bud** may also be seen as part of the early ankylosis spectrum, defined as abnormal bright signal on a T1W non-fat-suppressed sequence with similar signal intensity to bone marrow, which is in the expected location of the sacroiliac joint space but does not bridge the joint so that it is continuous with the subchondral bone of either the ilium or the sacrum but not both. It is associated with full thickness loss of the dark appearance of the subchondral cortex on the corresponding side of the joint, at its expected location.

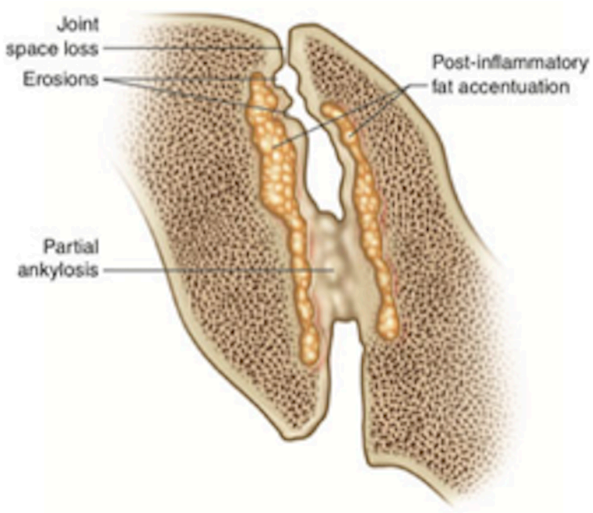
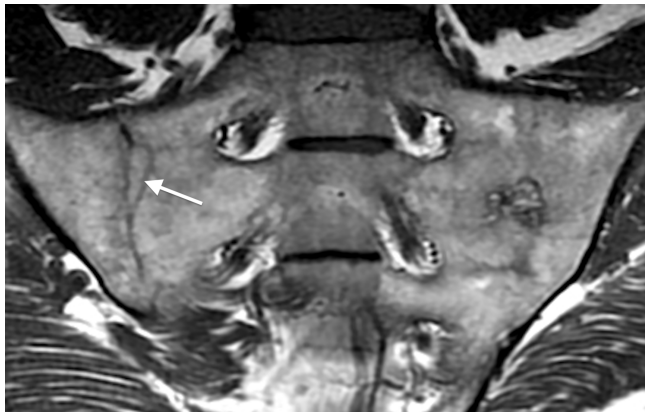
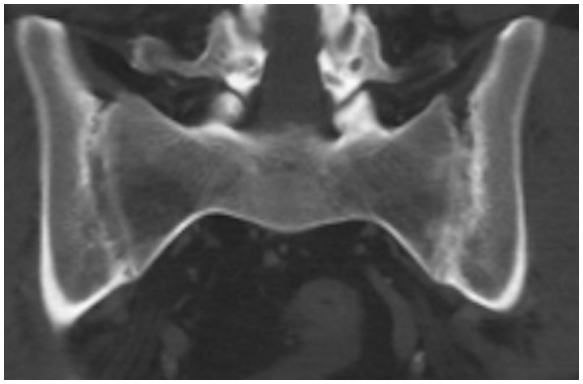
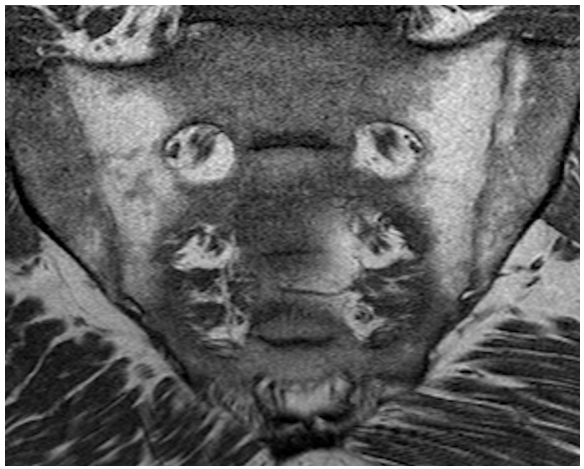


Illustration right SIJ demonstrating partial ankylosis

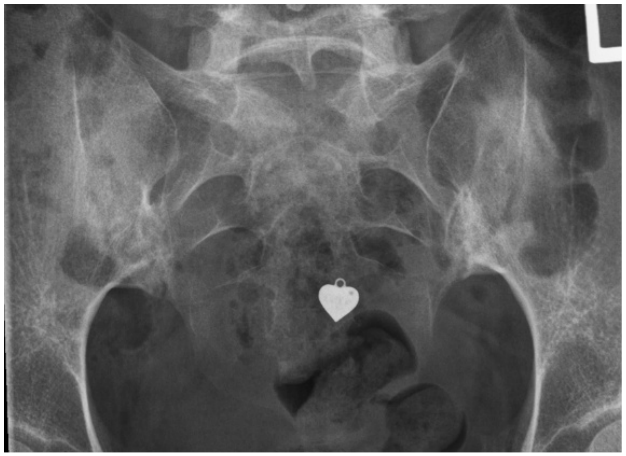


Cor T1 SIJs with bilateral ankylosis, partial right and complete on the left. The subchrondral bone plate remains partially evident on the right with interposed backfill (arrow)

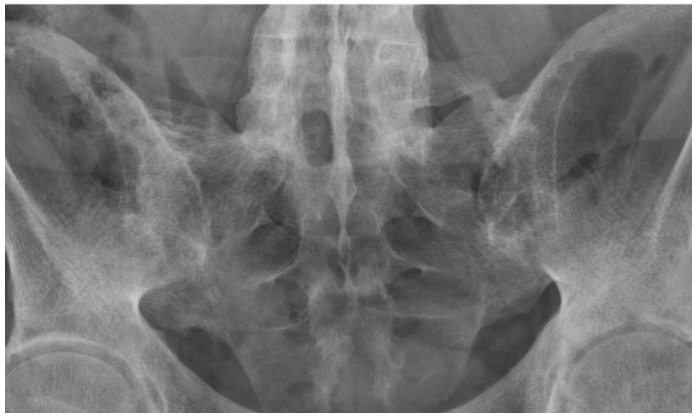




Cor T1 SIJs with bilateral developing ankylosis, joint space remains partially evident filled with backfill with partially evident subchondral bone plate. Corresponding reformatted coronal CT a CT of the abdomen same patient.



Grade 3 18F with bilateral erosions, joint space loss and partial ankylosis



Grade 4 Bilateral SIJ ankylosis

Notes

Spondylitis

Osteitis

Edema is an excess accumulation of fluid in the bodies tissue and can occur from multiple causes. With respect to SpA we will focus on edema related to inflammation, osteitis. MRI can demonstrate focal osteitis, high SI on STIR, low on T1, at the anterior corners vertebral body in the acute stage. This is also termed a corner inflammatory lesion. These may occur anteriorly or posteriorly.

Non-corner inflammatory lesions are identified as osteitis parallel to the endplate centrally. When osteitis involves the more lateral margins of the vertebral body, at the level pedicles and beyond, it is termed a lateral inflammatory lesion. Osteitis at the costovertebral and costotransverse articulations may occur and are thought to be more specific for SpA. Inflammation may also involve the posterior elements of the vertebrae including the facet joints (including capsule and perifacet soft tissues) and posterior ligaments (entheses).

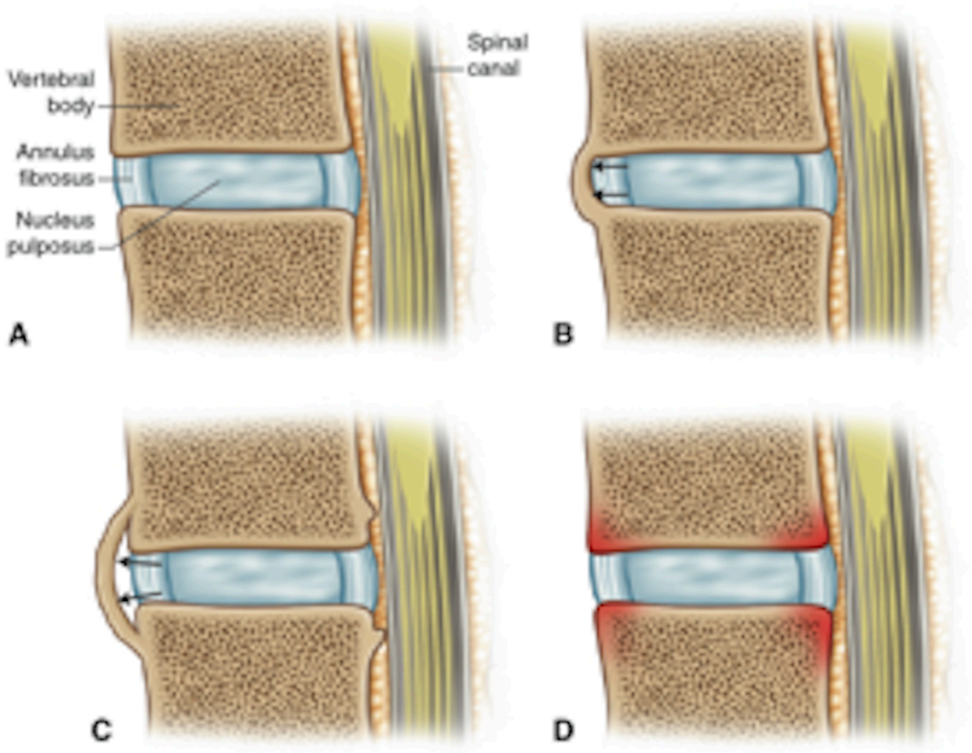
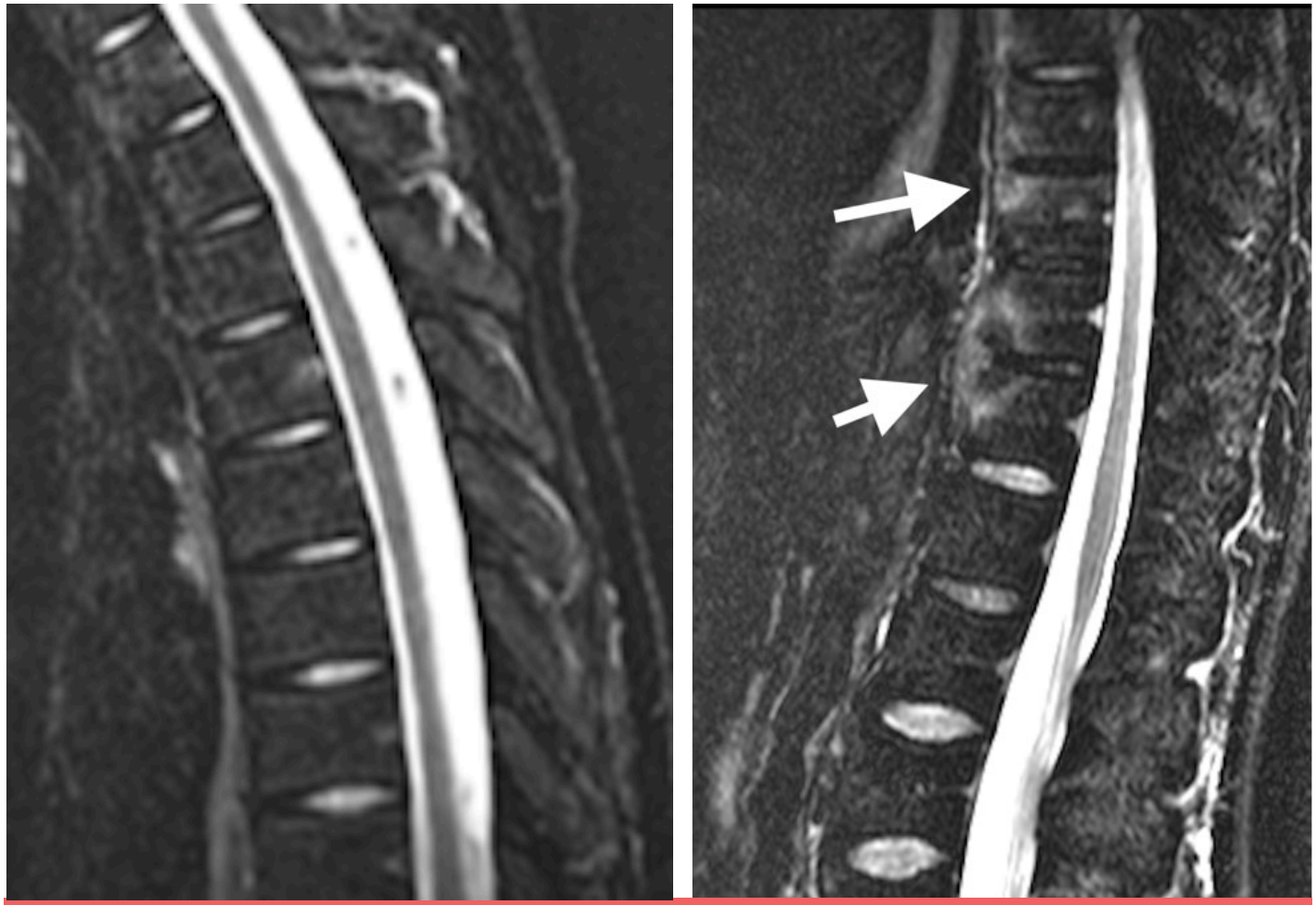
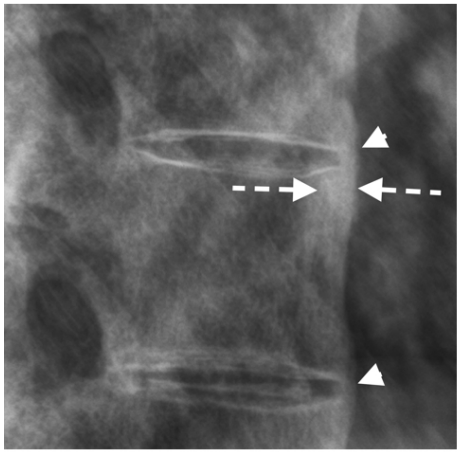


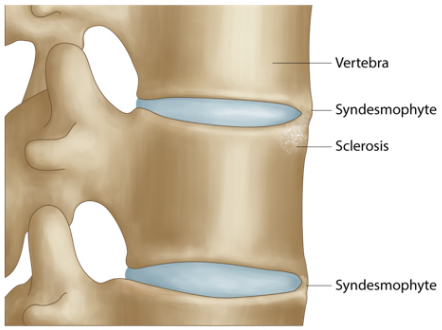
Illustration spinal changes in SpA, a) normal, b) syndesmophyte formation (arrows) in ankylosing spondylitis, c) versus syndesmophyte in psoriasis and Reactive arthritis, d) vertebral anterior and posterior corner osteitis (outlined in red)



Sag T2FS thoracic spine, magnified images, normal left for comparison, right image demonstrating extensive corner osteitis (arrows) with osteitis extending across a large syndesmophyte (lowermost arrow)

Romanus Lesion

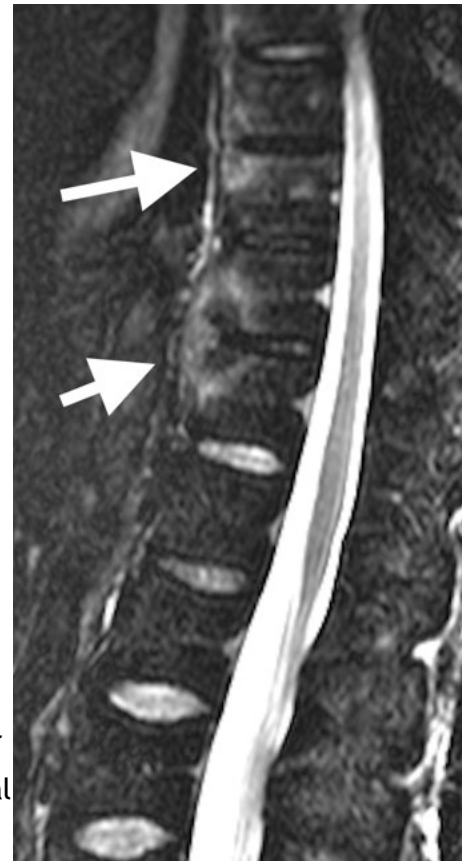




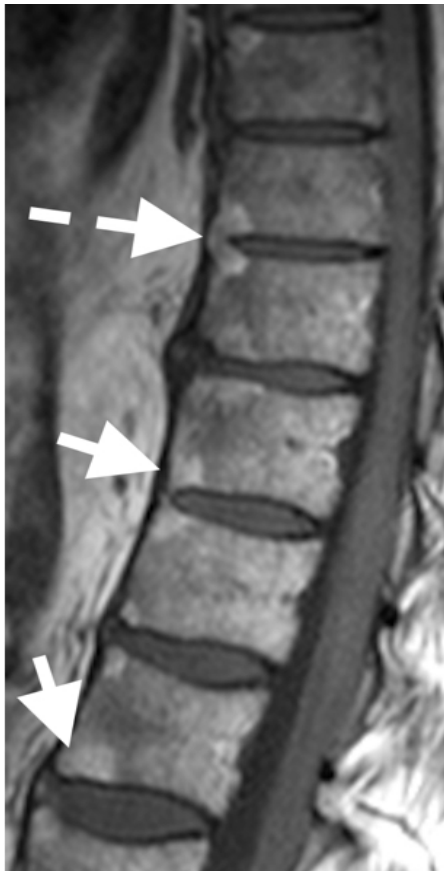
Thoracic sydesmophyes (arrowheads) and adjacent corner sclerosis (Romanus lesion), early squaring, with corresponding illustration

A Romanus lesion, initially described on radiographs as an early spinal structural change in AS, represents small erosions at the superior and inferior vertebral corners with surrounding reactive sclerosis. Eventually the vertebral bodies become squared. On a radiograph an anterior vertebral body corner erosion is seen which may heal with sclerosis, known as a “shiny corner”.

On MRI, focal osteitis is noted as high SI on STIR, and low SI onT1, in the anterior corners vertebral body and termed anterior corner osteitis (this is not a Romanus lesion).True focal erosions of the vertebral corner may however become evident at a later date. Chronic lesions are depicted as foci of fat signal intensity, high on T1 and T2, i.e fat metaplasia.

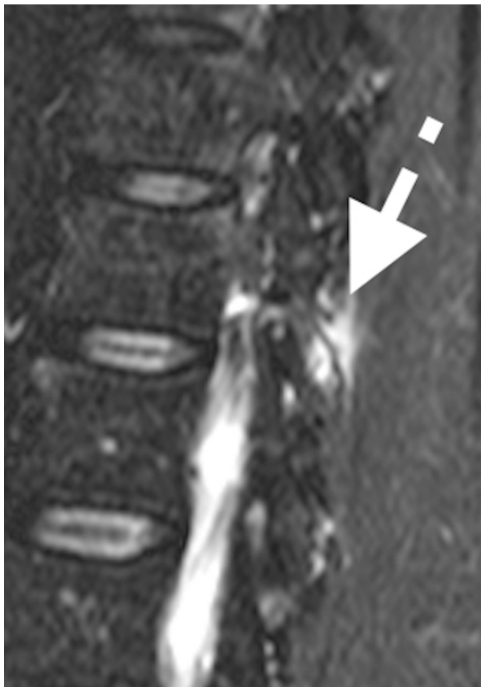


Sag T2FS lower thoracic spine, magnified image, with extensive corner osteitis (arrows) with osteitis extending across a large syndesmophyte (lowermost arrow)

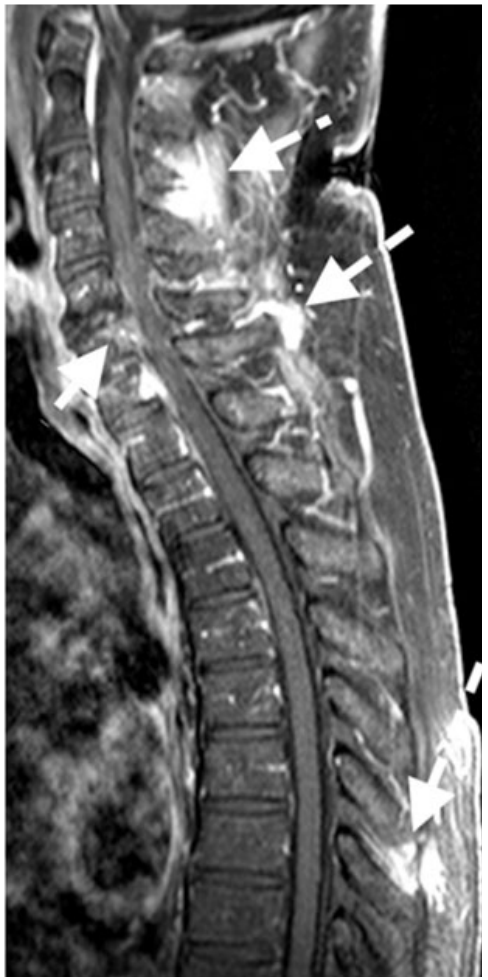


Sag MRI T1 thoracic spine, magnified image, with syndesmophyte (dashed arrow) and anterior corner PIFA (arrows)

Enthesitis



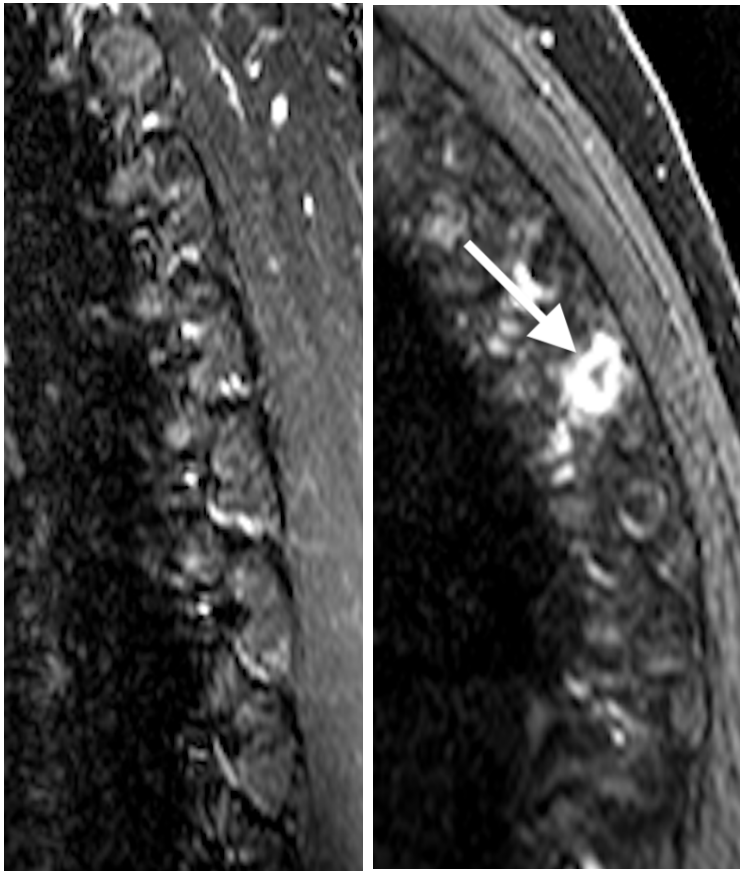
Sag T2FS facet joint capsulitis/ enthesitis (dashed arrow) and osteitis



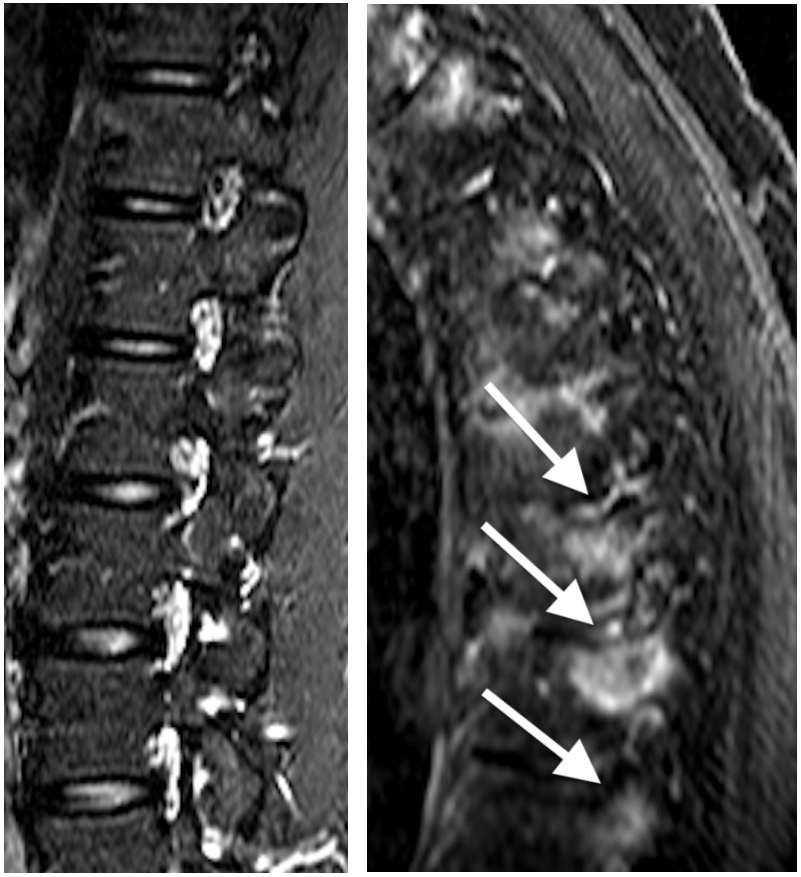
Sag T1 FS PG, multifocal posterior ligamentous enhancement at ligamentous attachment, dashed arrows. Note also posterior corner enhancing osteitis (arrow). Contrast was provided for assessment possible infectious discitis and is not required for standard imaging SpA

Enthesitis is the inflammation of the enthesis, site of insertion of tendon, ligament or joint capsule to bone. Enthesitis is common in SpA. It may be subclinical and detected only on imaging. On MRI enthesitis is identified as high signal intensity on STIR or contrast enhanced T1FS at the site of ligament, tendon or capsular attachment to bone. Enthesitis is more common posteriorly at the supraspinous and interspinous ligamentous insertion, facet joint capsule and paravertebral muscle tendinous insertions.

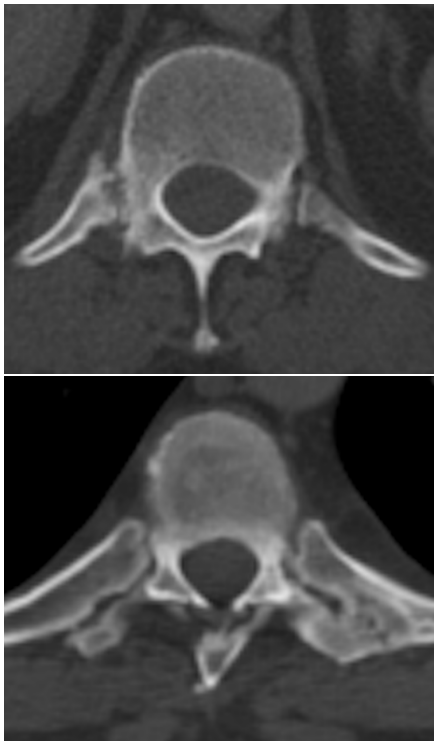
Costovertebral & Costotransverse Osteitis



Normal left and right mid thoracic costotrasverse osteitis (arrow)



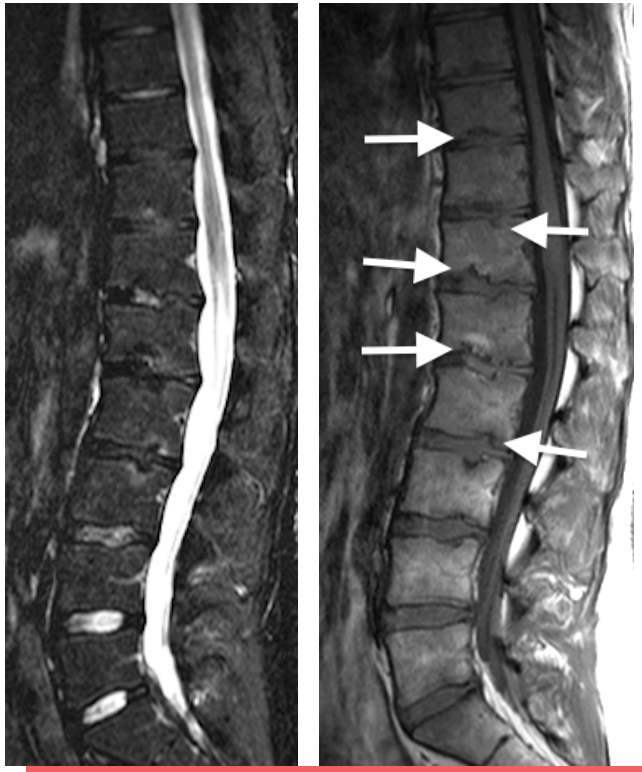
Normal left and right mid thoracic extensive costovertebral osteitis (arrows)

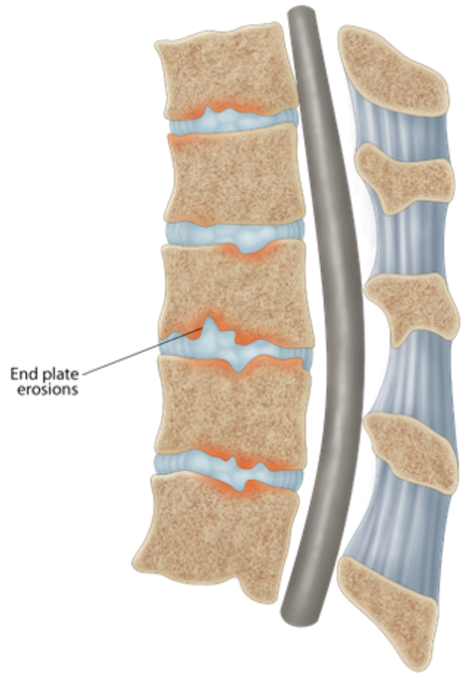


Axial CT magnified images from CT of the chest. Top image demonstrates erosions at head of right rib with new bone formation and joint space loss. Joint space loss with early fusion at left costotransverse joint (lower image)

Inflammatory changes at the costotransverse and costovertebral articulations have high specificity and lower sensitivity in axial SpA (articulation between rib/transverse process vertebra and rib /vertebral body respectively). Acute inflammatory changes are delineated by osteitis (high signal intensity T2FS or STIR) and corresponding low signal on T1. Chronic changes include fat metaplasia, new bone formation and occasionally ankylosis (better appreciated on CT)

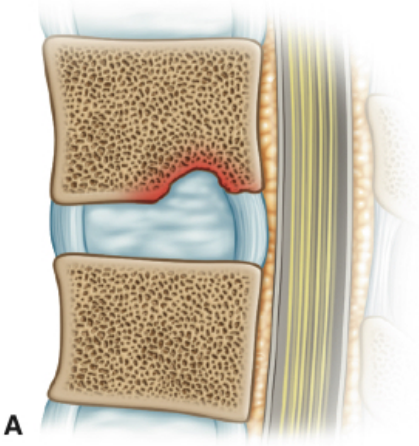
Andersson Lesion

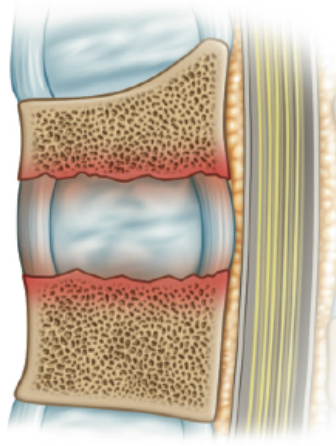




Sag T2FS , T1 and illustration with multilevel end plate erosions (arrows)

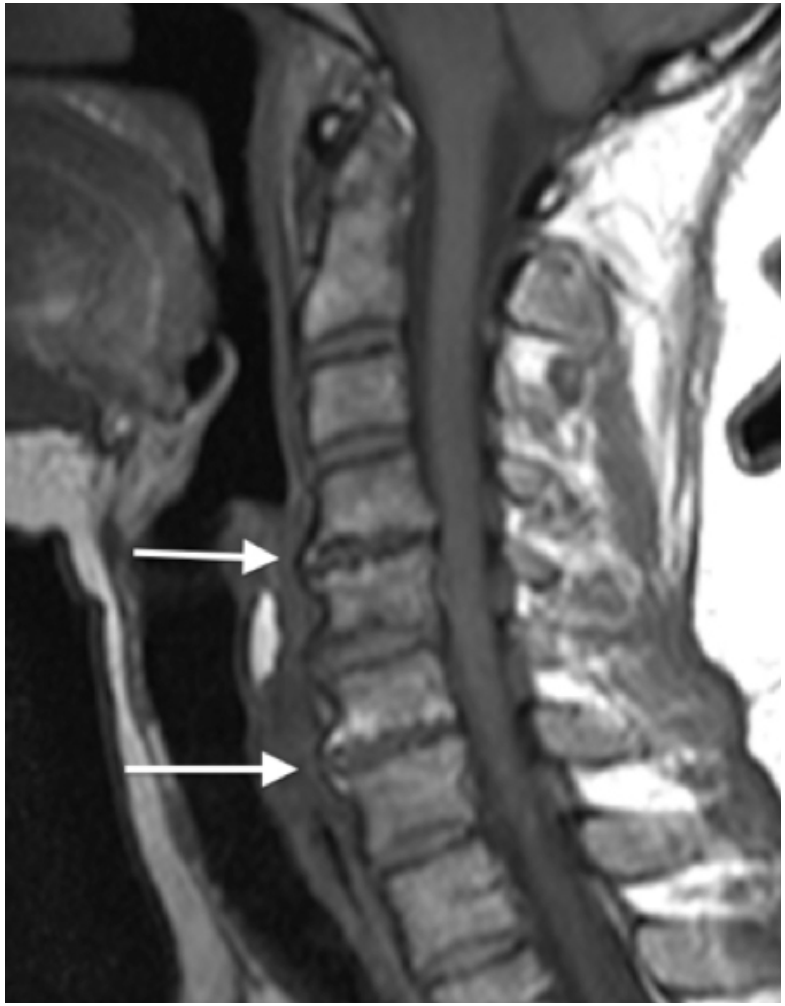
Illustration Anderson lesions, a) localized with endplate erosion, b) post traumatic with endplate erosions, anterior vertebral body loss of height (compression fracture) and secondary kyphosis



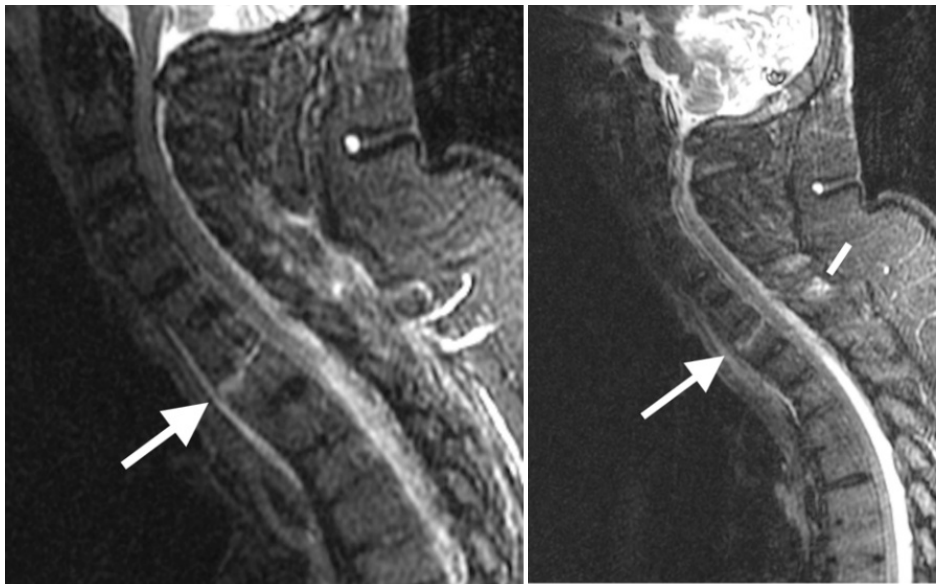


Spondylodiscitis, or Andersson lesion, is the occurrence of discovertebral erosions in patients with SpA. It is a non-infected heterogeneous entity that has two major etiologies, inflammatory and traumatic. Lesions may be localized or diffuse. The localized lesion may be central or peripheral. The diffuse or generalized involves the whole discovertebral junction and can be subdivided into those with and without fractured posterior elements.

Localised lesions occur more commonly in the non-ankylosed spine and may relate to inflammation, secondary osteoporosis and herniation of the disc contents through the weakened endplate. Radiographs demonstrate localised destruction or erosion of the vertebral endplate with radiolucent foci and surrounding sclerosis. MRI demonstrates irregularity to frank erosion of the cortical endplate, adjacent osteitis of increased SI on STIR within the vertebral body, low SI disc and sclerosis deep to osteitis. The posterior elements should be closely evaluated for fracture.

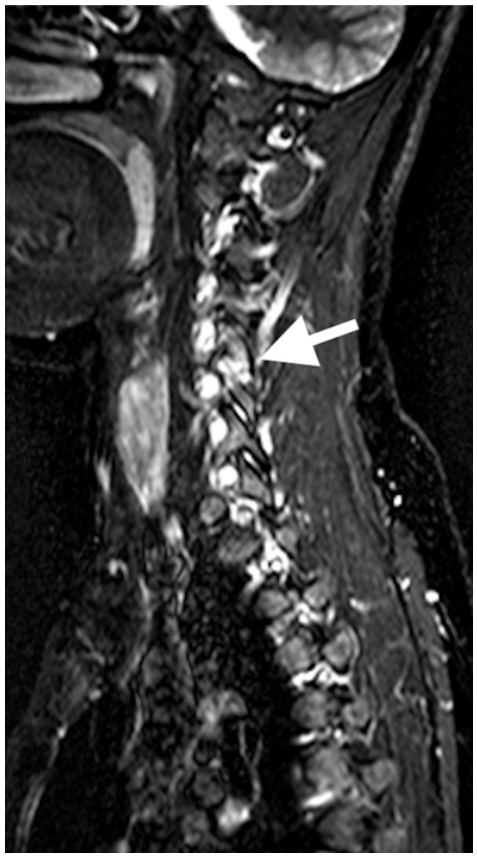


Sag T1 upper cervical spine with C4/5, C6/7 endplate diffuse erosions, Anderson lesions, in longstanding AS

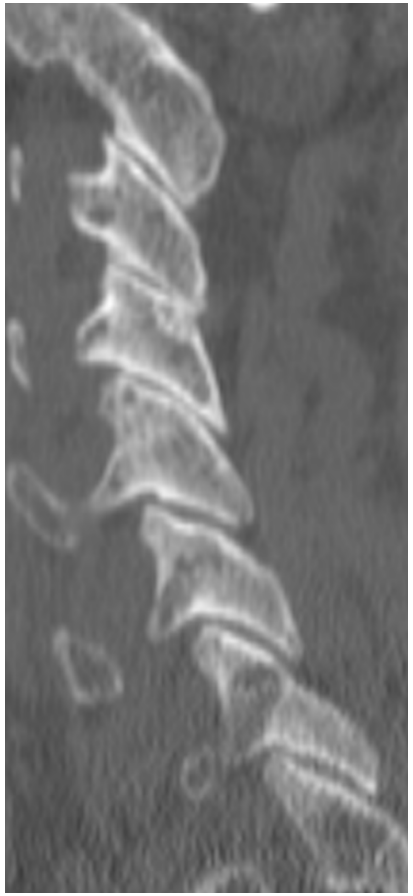


Sag T2FS with acute fracture T1 (arrow) extending posteriorly (bar) to involve interspinous ligaments in a patient with longstanding AS. Image degradation due to motion

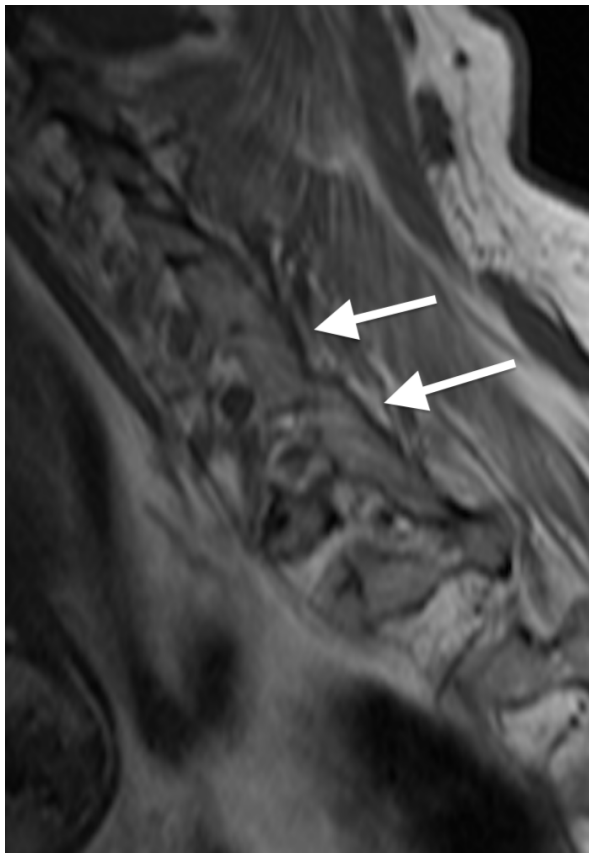
Joint Space Loss



Sag T2FS cervical spine with joint space loss, small facet effusion/ synovitis, osteitis. Note small effusions at the adjacent 2 inferior facets



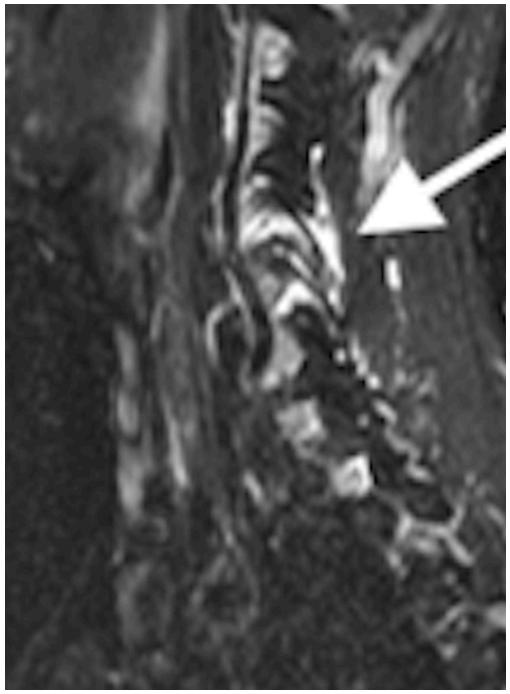
Reformatted sagittal CT cervical spine with diffuse facet joint space loss



Sag T1 cervical spine with multilevel cervical facet fusion in patient with chronic axial SpA facets

Joint space loss refers to the narrowing of the width of a joint. In axial SpA this is a chronic finding related to repeated episodes of inflammation with eventual joint cartilage loss and subsequent narrowing. Occurs prior to ankylosis. May be seen on X-ray, CT and MRI.

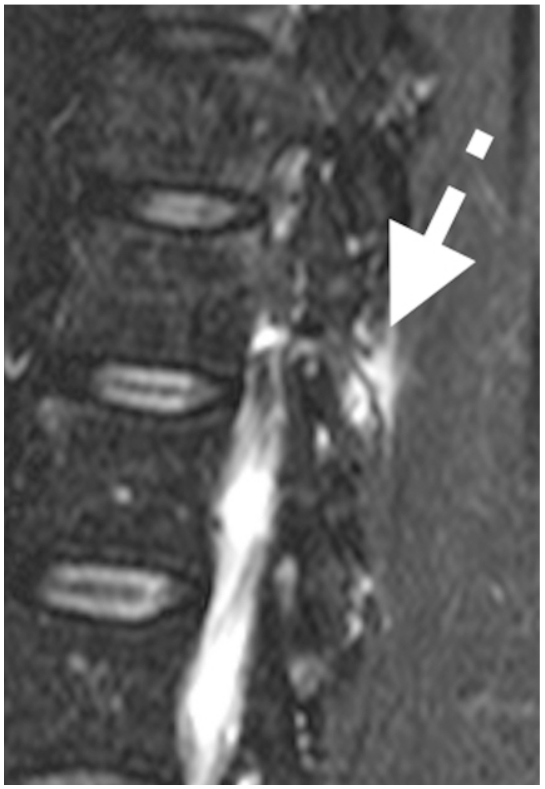
Synovitis



Sag T2FS in a 52y F with psoriatic spondyloarthropathy demonstrating facet joint distension, capsulitis and extensive osteitis (arrow)

Synovial tissue lines a synovial joint and is usually not visible on imaging. In synovitis the synovium proliferates, is inflamed and edematous and can appear like fluid on MRI i.e. low SI on T1 and high SI on T2FS and STIR. Synovitis may occur in the facet joints and sternoclavicular joints on spondylitis imaging. With intravenous contrast synovium enhances whereas joint effusion does not.

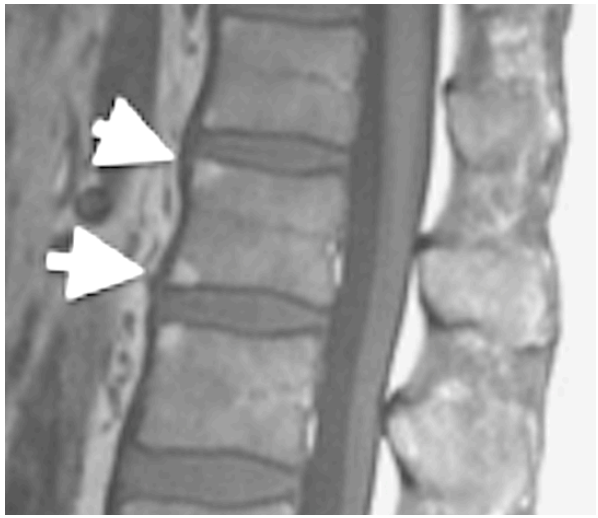
Capsulitis



Sag T2FS facet joint capsulitis/ enthesitis (dashed arrow) and osteitis.

Refers to the inflammation of the capsule, a fibrous coating surrounding a joint or organ. Capsulitis is the acute inflammation of the joint capsule and is only identifiable on MRI. Capsular high signal intensity is noted on STIR or contrast enhanced T1FS. May extend medially or laterally into the periosteum as an enthesitis. Often seen in conjunction with other acute inflammatory changes

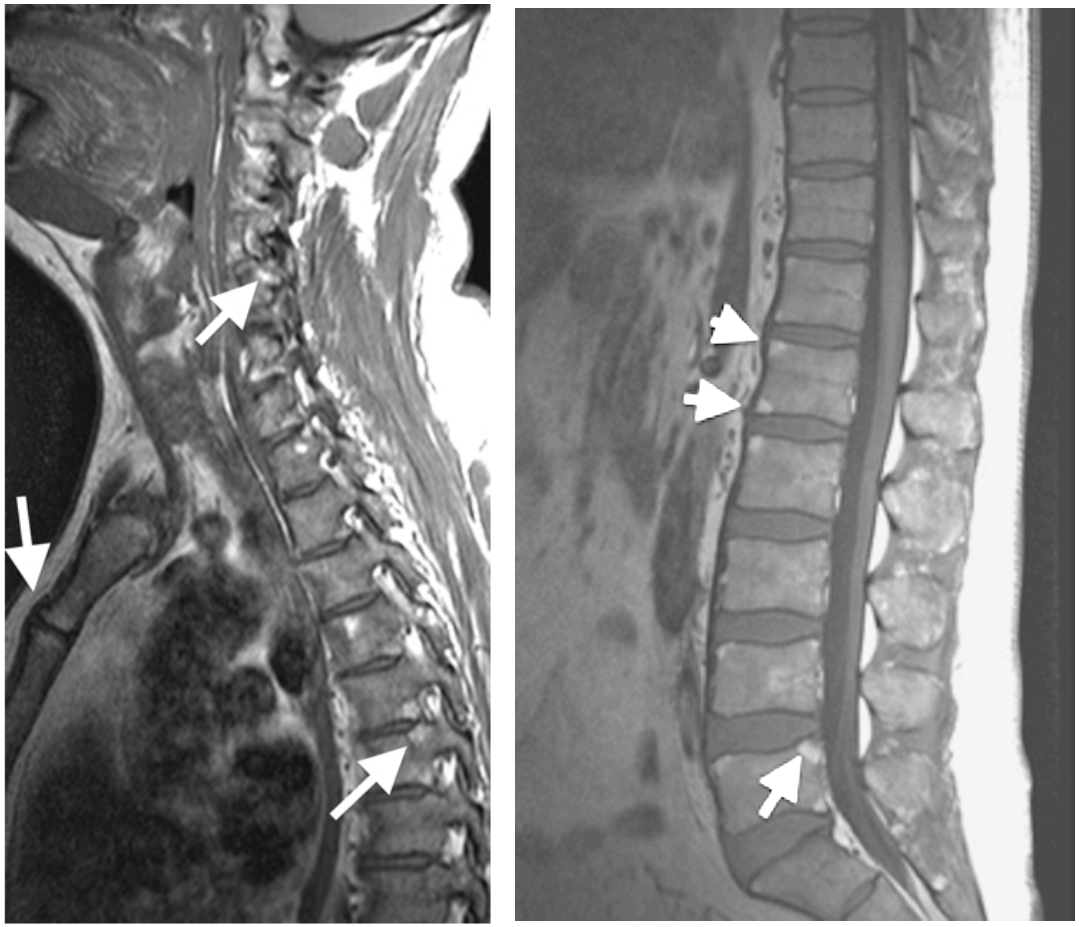
Fat Metaplasia



Magnified Sag T1 with several corner fat metaplasia

Fat metaplasia is identified as periarticular high signal intensity on T1 and low signal intensity T1FS and STIR (both have fat suppression) and is also termed post inflammatory fat accentuation (PIFA).

Normal bone marrow signal intensity for comparison is noted in the centre of the same or adjacent vertebral bodies. It is most commonly seen at the corners of the vertebrae.



MRl in a 45y M with chronic AS. Sag T I lower spine (right image) with multiple corner fat metaplasia (arrows). Sag Tl upper spine similar changes with additional fat metaplasia related to the manubriosternal joint and cervical facet joint

Syndesmophytes

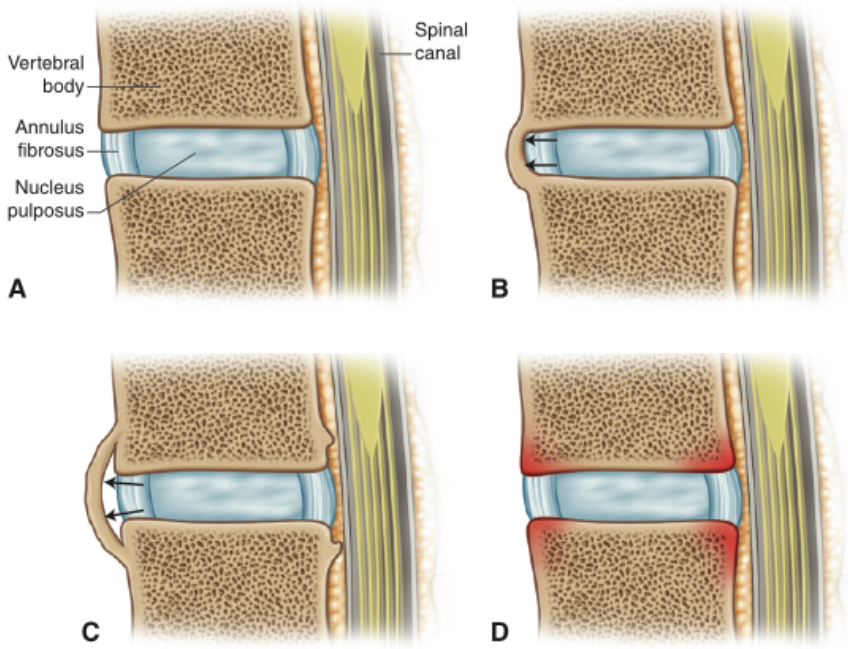
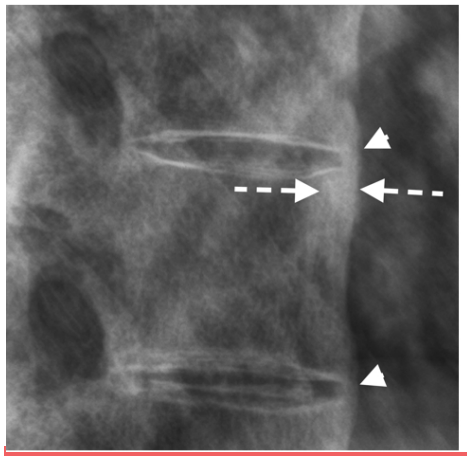
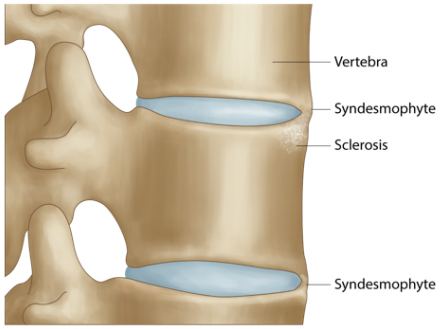


Illustration spinal changes in SpA, a) normal, b)syndesmophyte formation (arrows) in ankylosing spondylitis, c) versus syndesmophyte in psoriasis and Reactive arthritis, d) vertebral anterior and posterior corner osteitis (outlined in red)

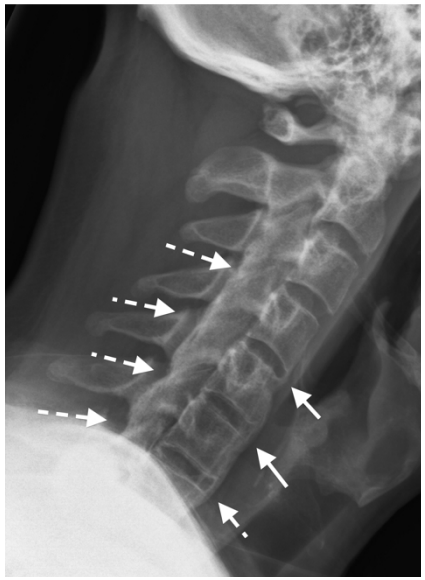
A syndesmophyte is new bone formation within the outer fibres of the annulus fibrosis of the intervertebral disc commencing at the juncture with the vertebral body, sharpey's fibres. Ankylosing spondylitis patients are particularly prone to developing syndesmophytes. Bone growth eventually forms a bridge between the involved vertebral bodies. They are most pronounced at the anterior and lateral margins of the vertebral body. This is a late finding in the disease; approximately 25% of patients will demonstrate syndesmophytes by 10 years and 65% by 20yrs of disease. Syndesmophytes are best visualized on CT and radiographs.

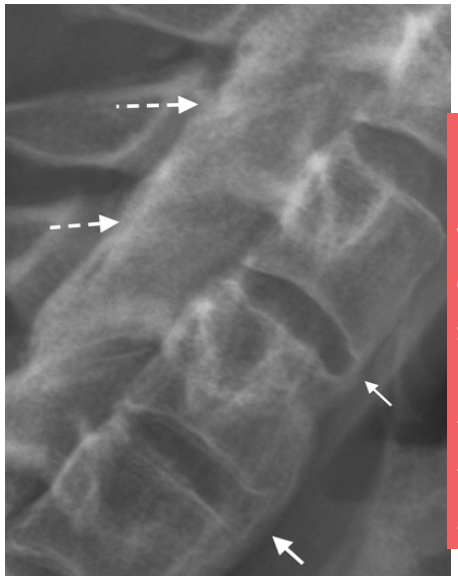
MRI is less sensitive due to a larger acquired field of view and decreased resolution. Sag T1 is more sensitive than STIR in assessing syndesmophytes. Need to be differentiated from DISH where the anterior longitudinal ligament is ossified and extends over the anterior vertebral body on side opposite aorta (requires involvement of 4 adjacent vertebrae for a diagnosis of DISH). Endplate osteophytes are more triangular in nature and grow outwards. Psoriasis and Reactive arthritis related *paravertebral ossification* begins proximal to the juncture of the intervertebral disc and vertebra.



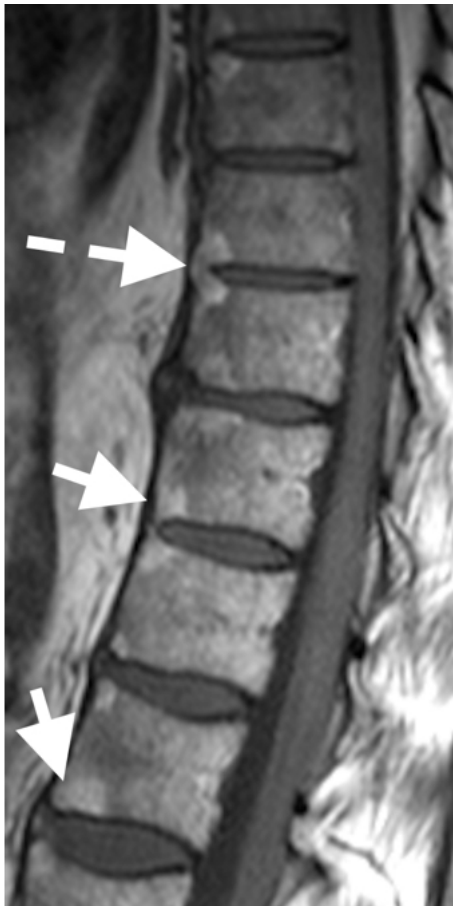


Thoracic sydesmophyes (arrowheads) and adjacent corner sclerosis, early squaring, with corresponding illustration.

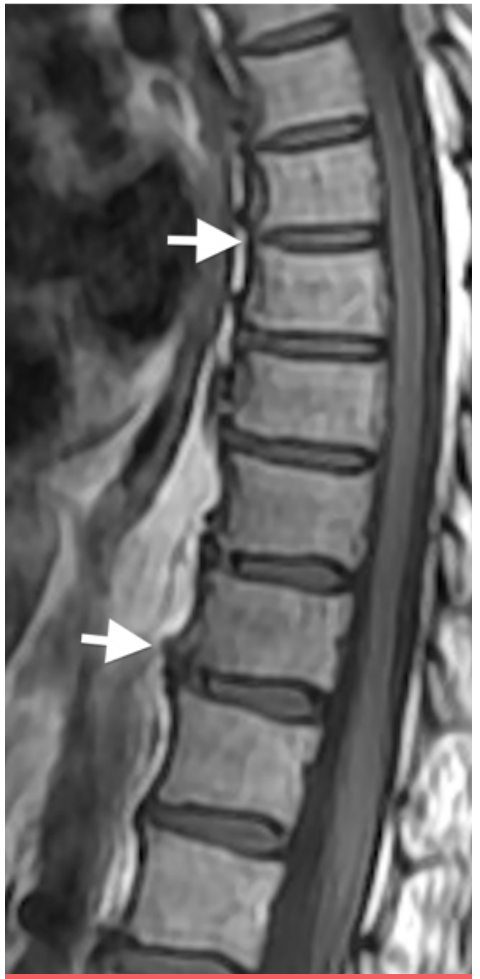




Longstanding Psoriatic SpA with multilevel cervical sydesmophyes (arrows) and facet joint fusion (dashed arrows)

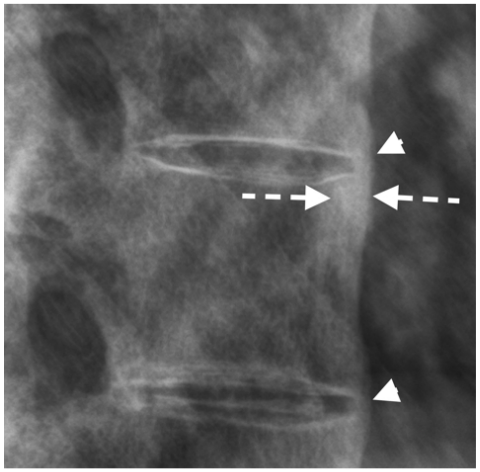


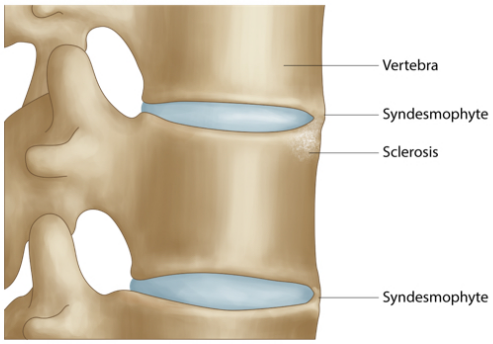
Sag MRI T1 thoracic spine, magnified image, with syndesmophyte (dashed arrow) and anterior corner metaplasia (arrows)



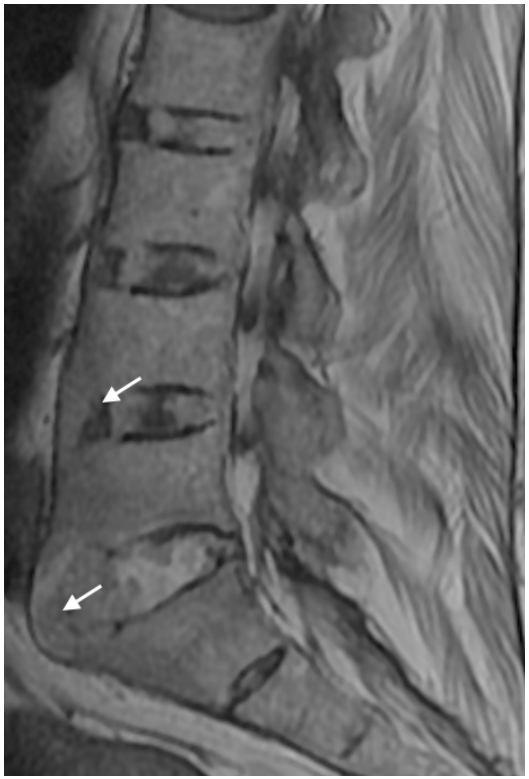
Sag MRI T1 thoracic spine, magnified image, with early syndesmophyte formation (arrows)

Squaring Vertebra

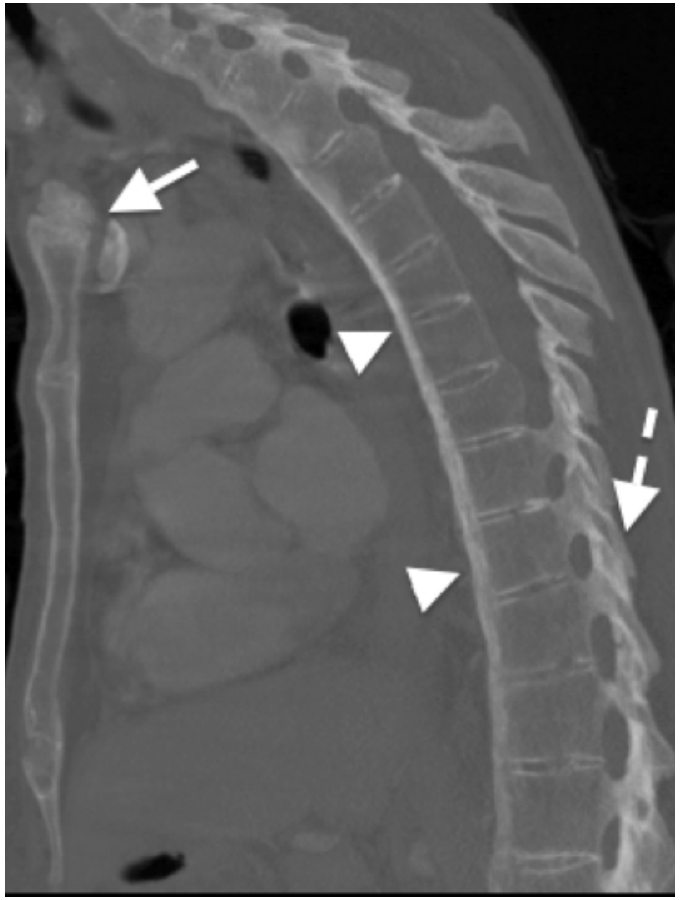




Thoracic sydesmophyes (arrowheads) and adjacent corner sclerosis (Romanus lesion), early squaring, with corresponding illustration



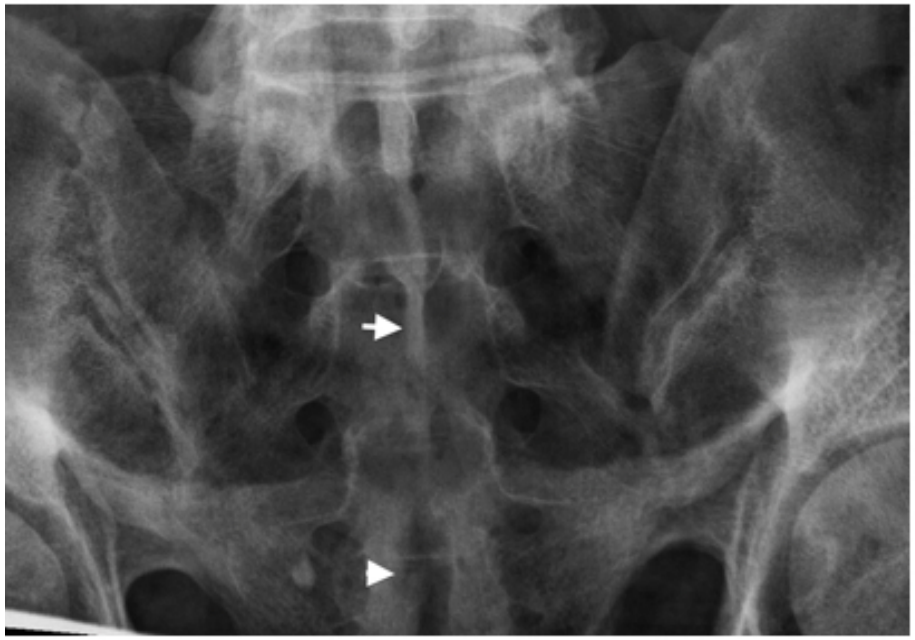
MRI lumbar spine , Sag Tl, syndesophyte formation (arrows), squared vertebra, with widened intervertebral discs and mild endplate convexity.

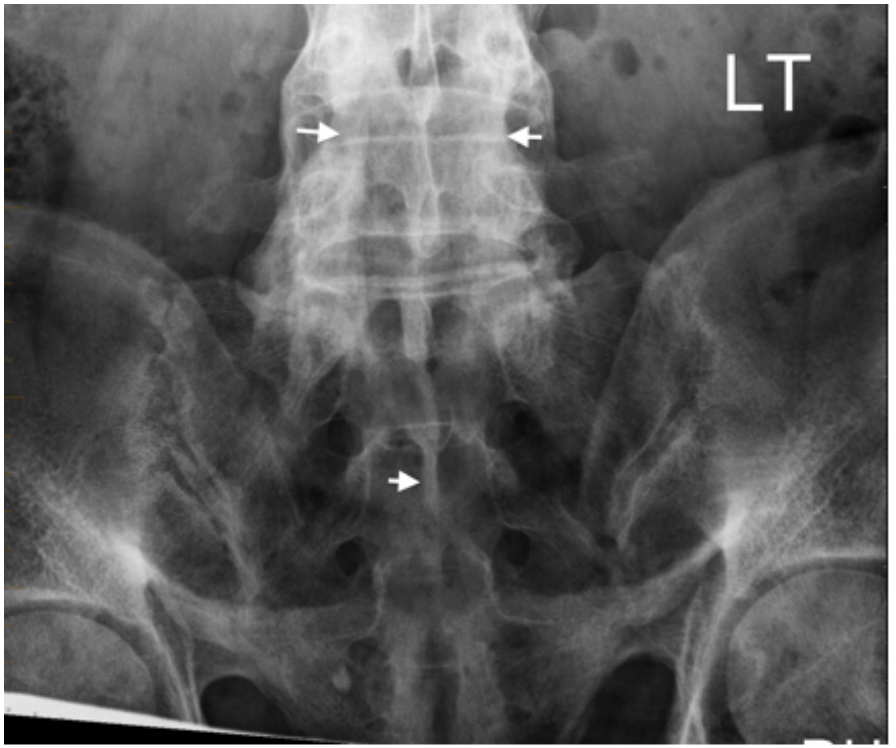


Longstanding AS with extensive syndesmophytes (arrowheads), facet fusion (dashed arrow) ,squaring vertebrae, erosions and sclerosis sternoclavicular joint (arrow)

Squaring of the vertebra is loss of the normal anterior concavity due to vertebral corner erosion. Best seen in lumbar vertebra (cervical and thoracic vertebra normally have a less anterior concavity)

Ligamentous Ossification



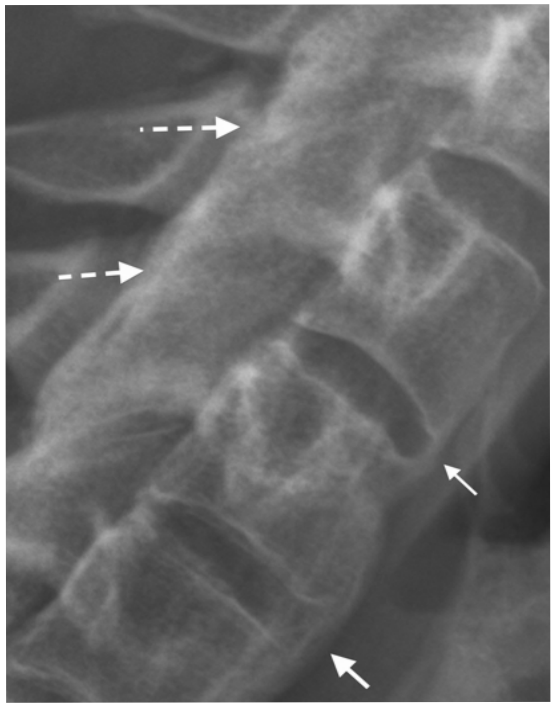


59y M with chronic AS, *Dagger* sign (arrow) on AP radiograph SIJs,left image, with central radiodense band due to ossification supraspinous and interspinous ligaments, note erosions of the symphysis pubis (arrowhead).
Trolley track sign, same patient, right image, with ossification across the apophyseal joints causing bilateral lateral linear radiodense bands

Ligamentous ossification is common in chronic disease. The **dagger sign**, a linear band of radiodensity, white band, on frontal radiograph, is secondary to ossification of the supraspinous and interspinous ligaments.

When there is additional apophyseal capsule ossification a **trolley track** sign can be seen on frontal radiographs as three bands of radiodensity superimposed over the spine. These changes are usually more evident within the lumbar region.

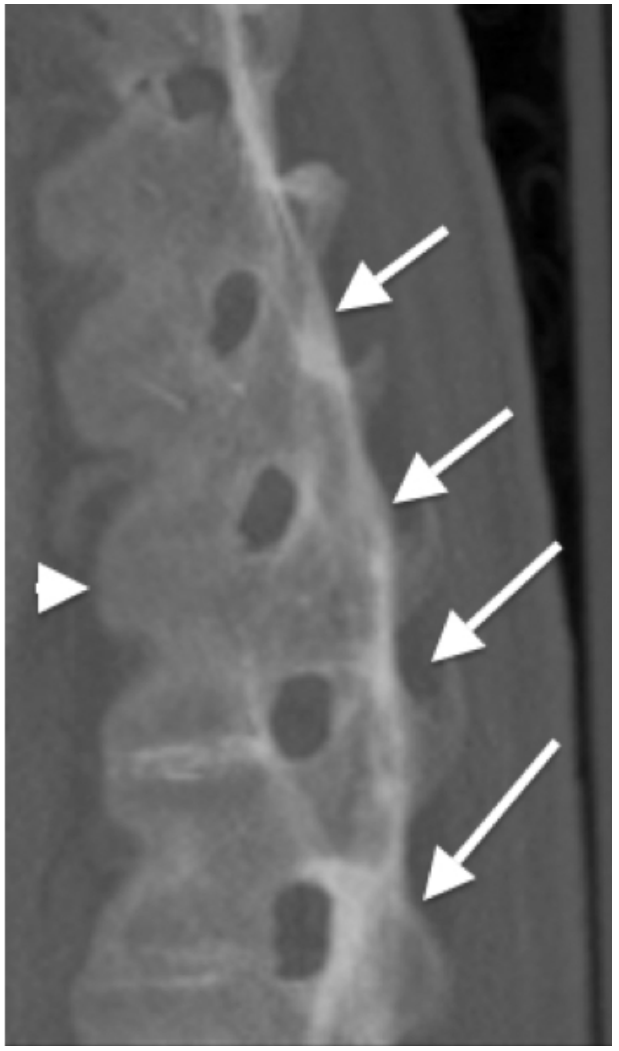
Ankylosis



Longstanding Psoriatic SpA - Magnified view with multilevel cervical sydesmophyes (arrows) and facet joint fusion (dashed arrows)

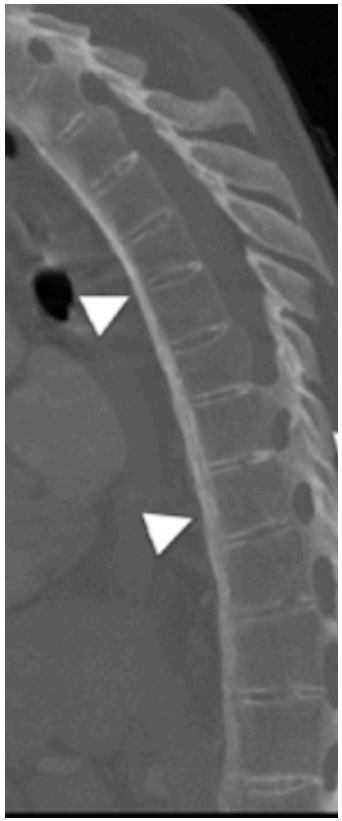
On radiographs joint space is lost, the subchondral bone plate becomes indistinct and is eventually lost and bone trabeculae can be seen transversing the previous joint space.

CT is excellent in demonstrating bone detail and ankylosis. MRI demonstrates continuation of bone marrow signal intensity across the previous joint space with loss subchondral bone plate. In the spine the facet joints may become fused.



Longstanding AS with multilevel thoracic sydesmophyes (arrowhead) ,facet joint fusion (arrows). Note also loss intervertebral disc space height and disc ossification

Osteoporosis

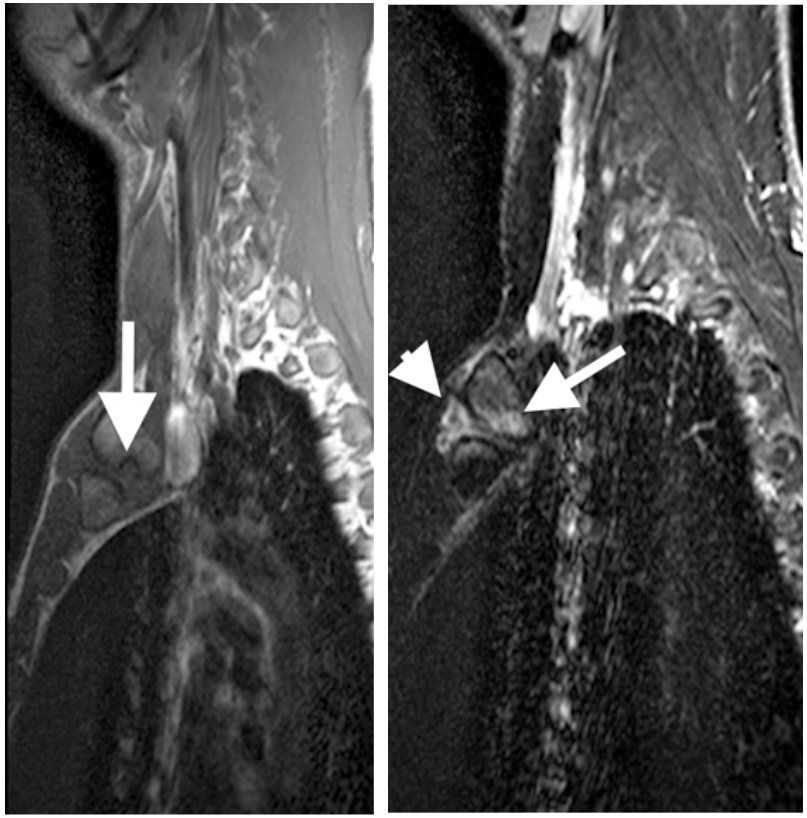


Sagittal reconstruction thoracic spine in patient with longstanding AS with diffuse osteopenia and extensive syndesmophytes (arrowheads)

Osteoporosis is common in longstanding AS.
Discal calcification occurs in chronic disease and may appear ballooned with disc endplate convexity. This is likely secondary to osteoporosis, common in chronic disease.

BMD assessment of the spine may be inaccurate due to spinal ankylosis and paravertebral ossification as described above and thus BMD assessment of the hip may be more accurate.

Non-Spinal Axial Disease



30y M with AS, Sag T1 (left image) and STIR (right image) cervical and upper thoracic spine demonstrate sternoclacicular erosion (arrow). Joint distension (arrowhead) and osteitis (arrow) left sternoclavicular joint (right image).

Assessment of the sternoclavicular joints and manubriosternal articulation are also often possible when assessing the upper spine.
Active disease includes osteitis, joint effusion and capsulitis at the sternoclavicular joint and osteitis at the manubriosternal articulation.
Structural changes include fusion at the manubriosternal articulation and erosions at the sternoclavicular joint

Notes

Imaging Algorithm

- Imaging of the sacroiliac joint has a primary role in the diagnosis of SpA.
- In routine clinical practice radiographic imaging has become an integral part of the investigation of patients with suspected sacroiliitis (SII). While plain x-rays remain the first and most widespread imaging modality employed in the investigation of SII, MRI has a significantly improved sensitivity and specificity for the diagnosis of SII.
- Unfortunately, the determination of the exact sensitivities and specificities of these imaging modalities is severely hindered by the absence of a 'gold standard' investigation. MRI is the defacto imaging gold standard.
-

Radiographs

- Screening examination of choice in the investigation of SpA -widely available, low cost
- However lack of sensitivity in detecting early SpA, high false positive rate, the use of ionizing radiation, and the high inter- and intra-observer variation are limiting factors.
- In addition radiographs can only assess chronic changes and are unable to assess presence and extent of acute inflammatory changes.
- If radiographs are diagnostic then no further imaging may be required.
- If non-diagnostic then further evaluation with MRI is advised

MRI

- MRI is the imaging gold standard
- Allows for assessment of acute/inflammatory and chronic/structural changes of the whole spine and sacroiliac joints
- Detects pre-radiographic changes of SpA.
- Can serve as a biomarker for active disease.
- Excellent at evaluating alternate pathology including degenerative disc disease, infection, insufficiency fractures, osteitis condensa ilia etc.
- However MRI is expensive and may not be widely available.
- Requires training and appreciation of imaging features of axial SpA and the differential diagnosis.

CT

- Not routinely used in the diagnosis SpA
- High radiation dose and can not assess acute inflammatory changes
- Excellent in demonstrating the osseous anatomy of the SIJs and allows high-resolution axial acquisition with coronal and sagittal reconstruction

CT cont'd

- Comparative studies between plain radiographs and CT have demonstrated marked advantage of CT in the delineation of chronic changes including erosions, subchondral sclerosis, and ankylosis.
- May be helpful if the patient is not MRI compatible and radiographs are non-diagnostic, in the assessment of alternate pathologies e.g. fractures.
- Note prior CT imaging should be reviewed which may include non-dedicated imaging of the SIJs, e.g.CT pelvis

Ultrasound

- Ultrasound is not currently utilized in our clinical practice in the assessment of SII.
- Ultrasound can evaluate the posterior portions of the sacroiliac joints with Doppler and has shown in some studies increased vascularization with decreased resistive indices in this portion of sacroiliac joint in patients with active SII.
- Further research is warranted to assess what role ultrasound will play in the clinical assessment SII.

Nuclear Medicine

- Scintigraphy had previously been a commonly used modality in the investigation of SII in clinical practice.
- It is very sensitive in the detection of early articular inflammatory change but is non-specific. Radionuclide normally accumulates at the SIJs and the differentiation of normal uptake and early SII can be difficult.
- Quantitative analysis of the SIJs has proven more sensitive however limited by the the wide range of variation in quantitative evaluation in the normal population. Other factors including age and prominent first sacral spine may all cause difficulties.
- Scintigraphy has poor sensitivity when compared with MRI in symptomatic spondyloarthropathy patients.
- Due to the above limitations, and given the significant associated radiation dose, scintigraphy is not part of our diagnostic imaging algorithm.

Conventional Tomography &Tomosynthesis

- Conventional tomography is associated with a higher radiation burden than plain radiographs and are no longer used.
- The newer technique of tomosynthesis holds promise but our initial evaluation demonstrated a higher radiation burden than low dose CT and is not indicated until further research is performed to evaluate its position in the investigation of sacroiliitis.

Diagnosis Axial SpA

Diagnostic & Classification Criteria

A diagnostic criterion allows for the identification of a disease and allows the separation of those patients with the disease from the general population. Diagnostic criteria have a high sensitivity but lower specificity and are used in the diagnosis of the individual patient. Ideally diagnostic criteria would allow for the identification of patients throughout the spectrum of the disease, however in doing so will inadvertently include patients without the disease.

Classification criteria allow for the systematic arrangement of similar entities on the basis of certain differing characteristics creating a homogenous group with a high specificity but low sensitivity for the disease. Classification criteria are often used in clinical research in patients with a known disease however have a low sensitivity for early disease and do not automatically apply to the general population.

In many rheumatological diseases there are well-established classification criteria but less well-formed diagnostic criteria. This holds true for SpA. Criteria applied to date for axial spondyloarthropathy are classification criteria and include the following:

ASAS

(Assessment of SpondyloArthritis International Society)

Modified New York

ESSG

(European Spondyloarthropathy Study Group)

AMOR

The current gold standard for diagnosis of SpA is the expert opinion of a rheumatologist of the clinical and imaging findings.

The modified New York Criteria is helpful in the radiographic assessment of the sacroiliac joints and diagnosis chronic sacroiliitis. Plain radiography has and continues to play an important role in the investigation of SII and is an integral part in the diagnosis of AS.

MODIFIED NEW YORK GRADING CRITERIA FOR ANKYLOSING SPONDYLITIS

Clinical Criteria

1. Low back pain present for at least 3 months not relieved by rest and improves with exercise
2. Limited lumbar spine motion in sagittal and frontal planes
3. Limited chest expansion*

Radiological Criteria

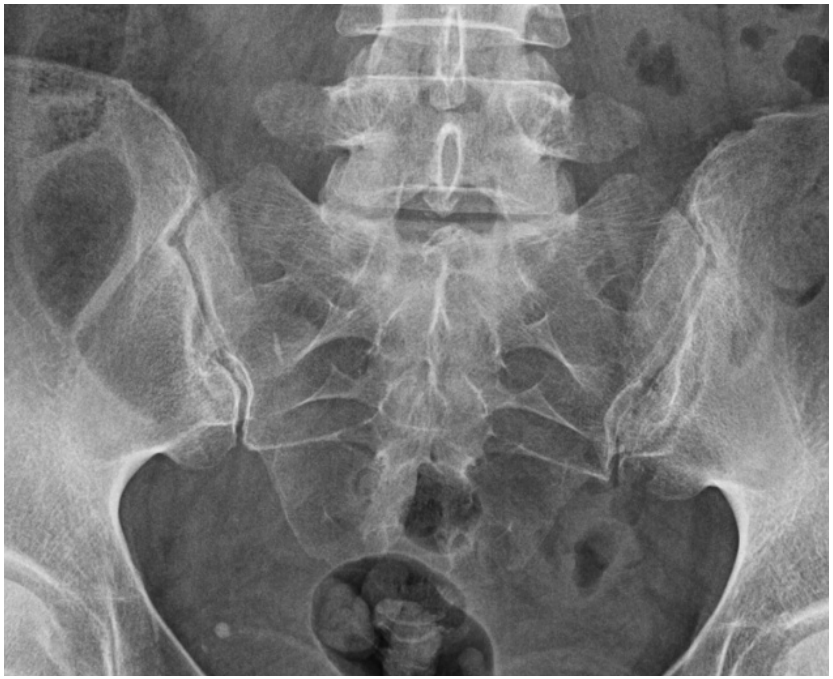
Sacroiliitis: Grade 2 bilaterally or unilateral grade 3-4

Ankylosing Spondylitis if radiological criteria plus one clinical criteria

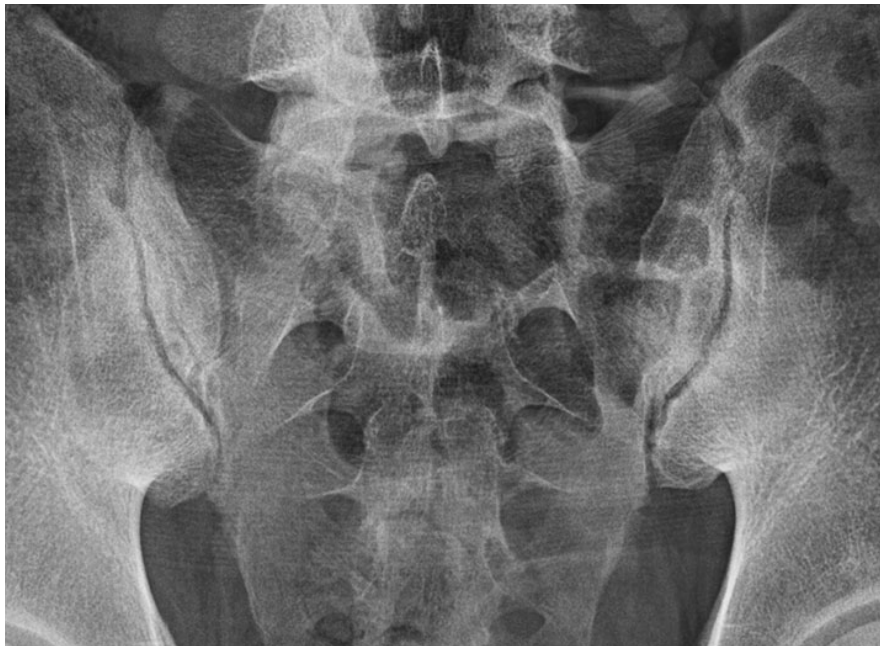
Relative to normal values for age and sex.

GRADE	IMAGING FINDINGS
Grade 0	Normal
Grade 1	Suspicious change
Grade 2	Minimal Abnormality-small localised areas with erosion or sclerosis without alteration in joint width
Grade 3	Definite Abnormality- moderate or advanced disease including partial ankylosis
Grade 4	Severe abnormality- total ankylosis

Radiographic changes include: Periarticular osteopenia, erosions, initial joint space widening progressing to narrowing joint space in later disease, subchondral sclerosis and bony ankylosis

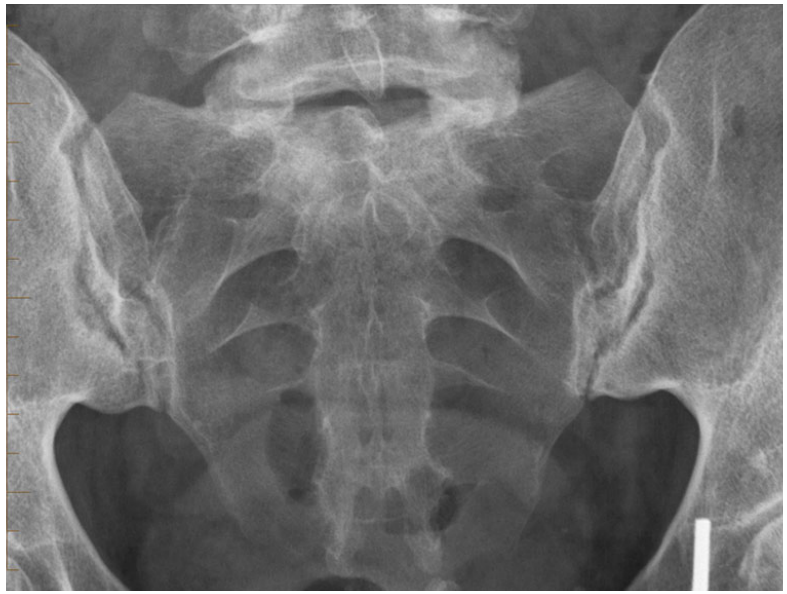


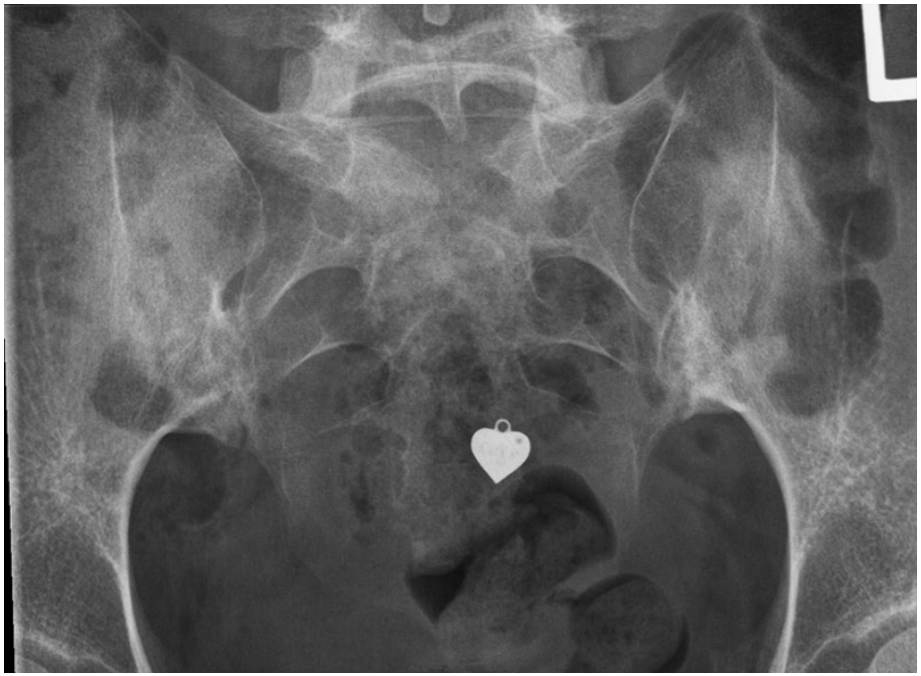
Grade 0-Normal



Grade 1 with suspicious changes, possible early erosions inferior sacroiliac joints bilaterally

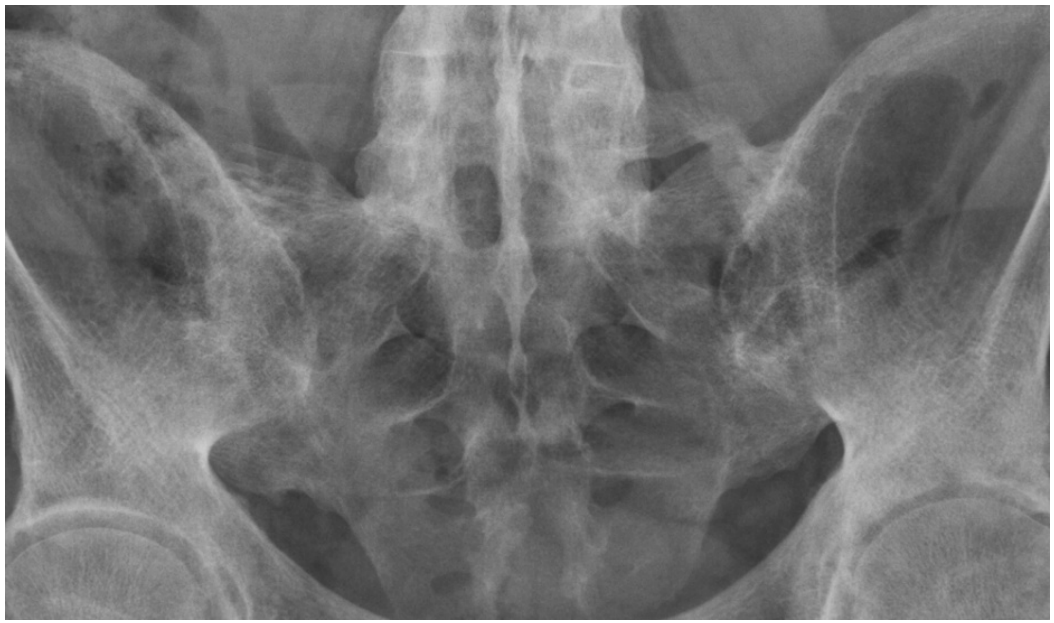
Grade 2 in this 36y F with bilateral erosions and maintained joint space





Grade 3 18F with bilateral erosions, joint space loss and partial ankylosis

Grade 4 Bilateral SIJ ankylosis



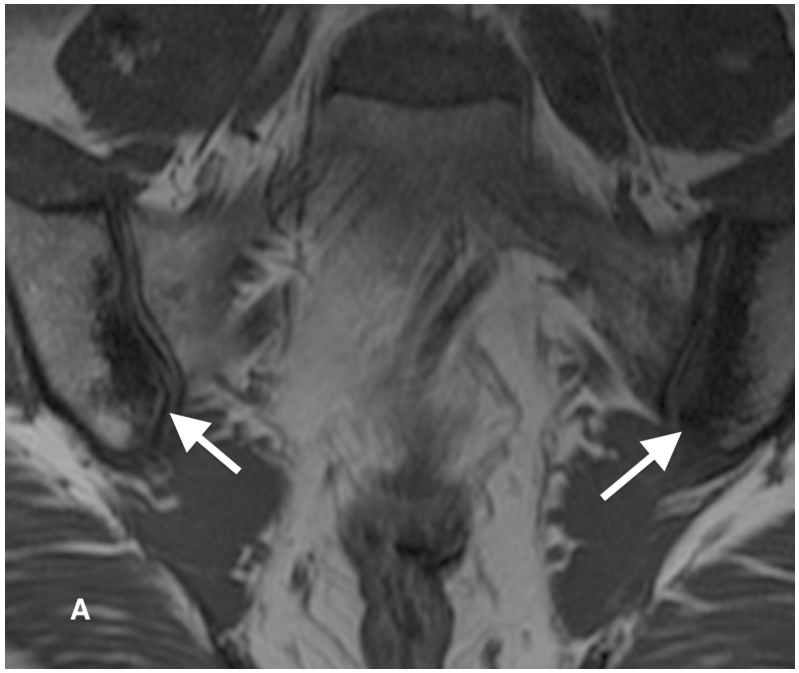
Notes

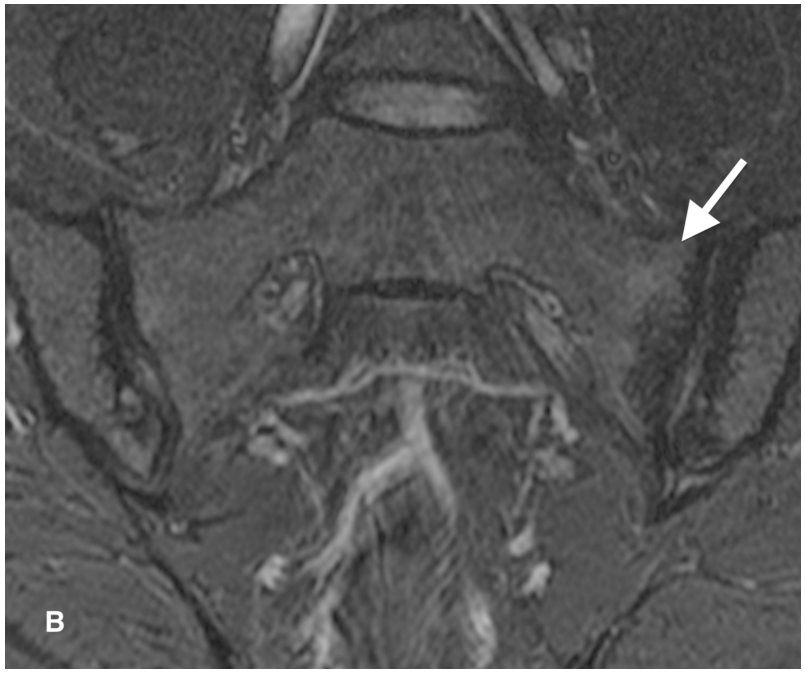
Alternate Pathologies

Pathologies That May Simulate Features Of Axial Spa Sacroiliac Joints

OCI	Alternate Inflammatory arthropathies
Infection	SAPHO
Fractures Including Insufficiency & Stress fractures	SIJ Degeneration
Trauma incl peripartum	Normal Variants Including Transitional Vertebra & Accessory facets with secondary degeneration
DISH	Paraplegia
Hyperparathyroidism	Primary & Secondary Malignancies

OSTEITIS CONDENSANS ILIA

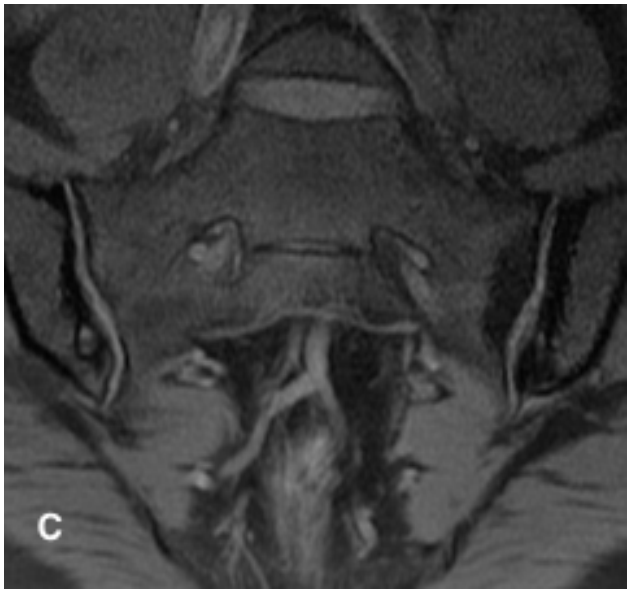


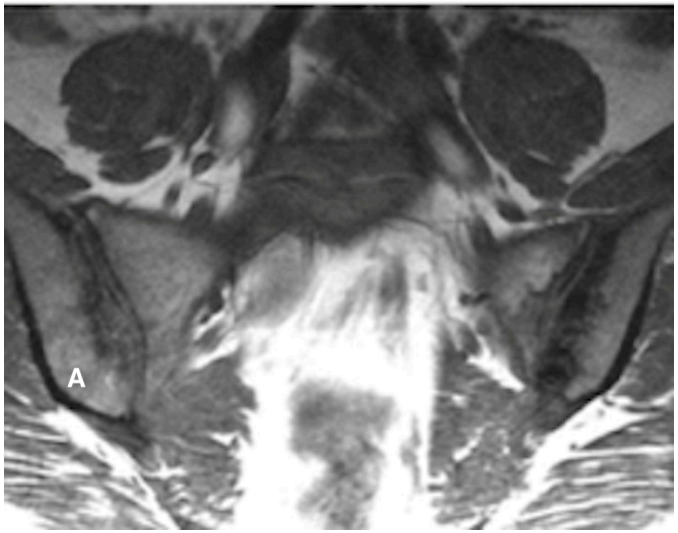


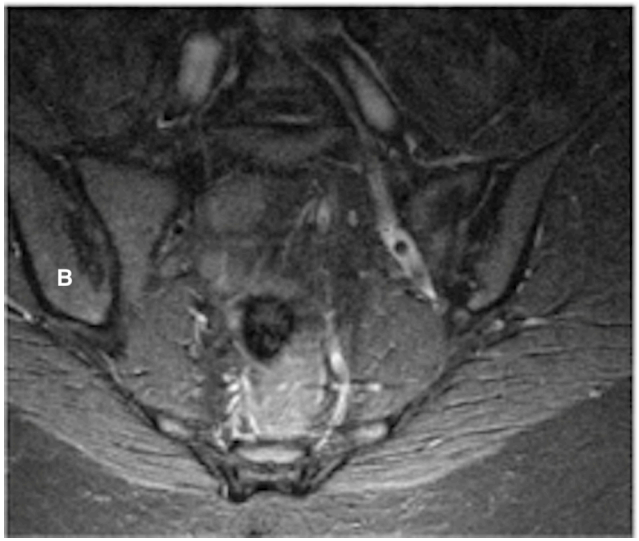
35y F with OCI. A) CorT1 MRI with maintained joint space, no erosions, prominent lilac aspect subchondral sclerosis (arrows) and no fat metaplasia, B)- Coronal T2FS with mild edema (arrow) deep to sacral subchondral sclerosis, C)- CorT1FS demonstrating maintained articular cartilage, no erosions and bilateral low signal intensity subchondral sclerosis

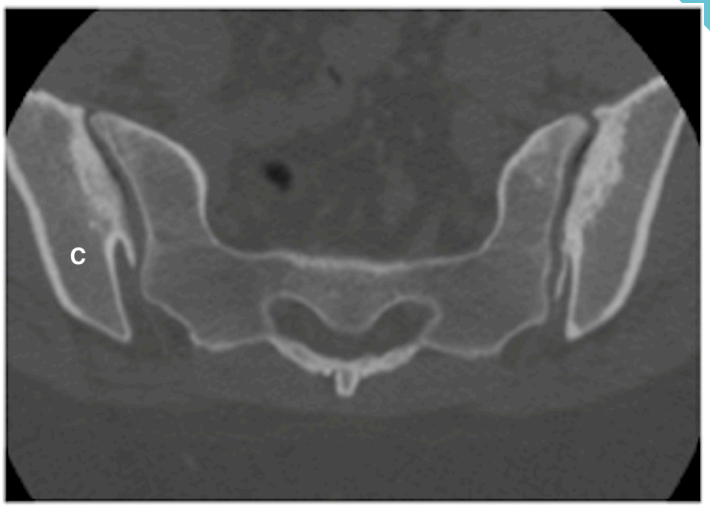
Osteitis Condensans Ilia (OCI) is a benign pathology presenting usually in young to middle aged adults with bilateral subchondral sclerosis related to the sacroiliac joints It is thought to be a reactive change with bone remodelling with lamellar bone secondary to mechanical stress at the sacroiliac joints.

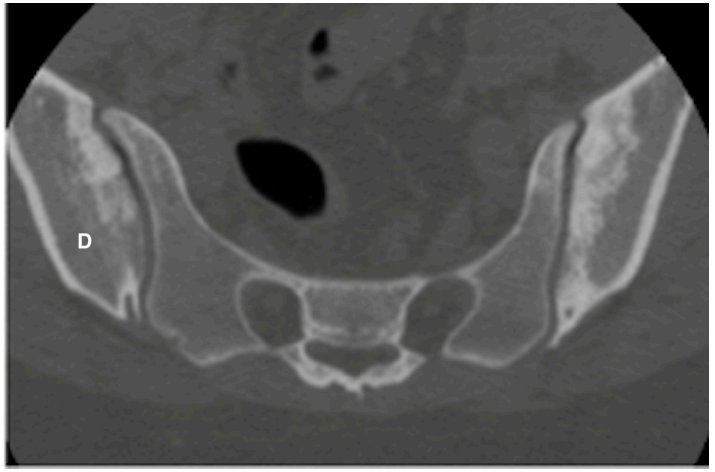
Patients may be symptomatic or it may be identified as an incidental finding on imaging. Symptoms, if present, are usually of a chronic mechanical low back pain. Inflammatory markers are negative and there is no association with HLA-B27. OCI affects up to 2.5% of the population.







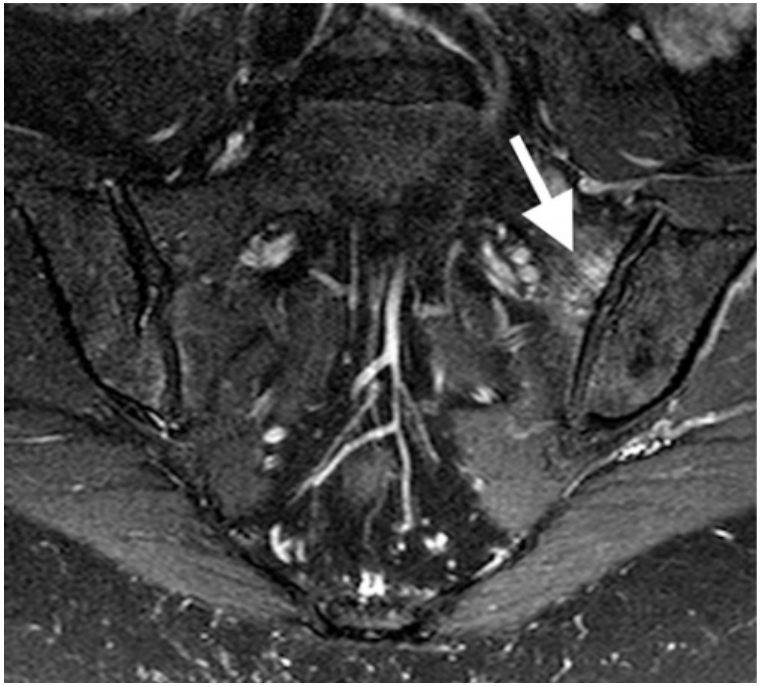




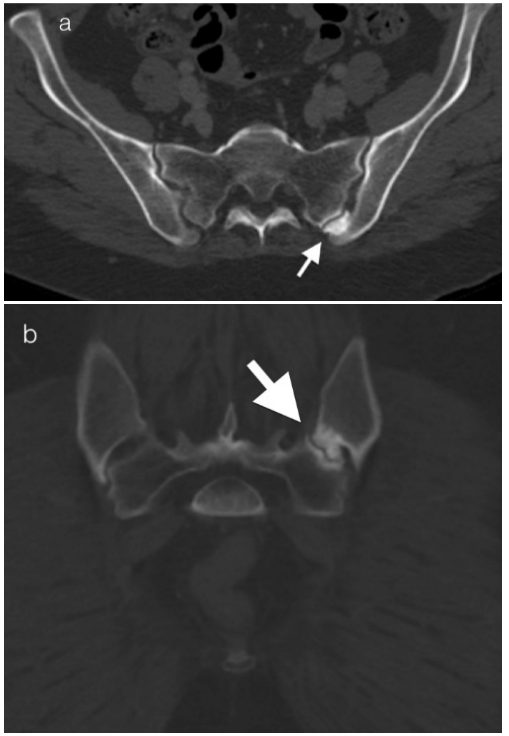
A) & B) Cor T1 & Cor T2FS MRI with bilateral subchondral ilac sclerois in keeping with OCI. Note joint space is maintained, there are no erosions and sclerosis is predominantly on the iliac aspects joints C) & D) same patient cropped axial CT from an unrelated CT study abdomen & pelvis demonstrating subchondral sclerosis without joint space loss or erosions as seen on MR

Radiographs demonstrate subchondral sclerosis anteroinferiorly with a triangular configuration most pronounced within the ilium. It is usually bilateral and symmetrical but unilateral involvement has been described. There is no joint space narrowing, unless superimposed degeneration, and no erosions. CT demonstrates the same findings albeit in greater detail. On MRI sclerosis is low signal intensity on both T1 and T2. There is no erosions or fat metaplasia although mild bone marrow edema may occur deep to the subchondral scelerosis.

Degenerative Disease Sacroiliac Joints



Mild left sacral subchondral bone marrow edema on Cor STIR image (arrow) secondary to early degerative disease. Remainder SIJs and spine negative for SpA but did have lower lumbar degenerative disc disease.

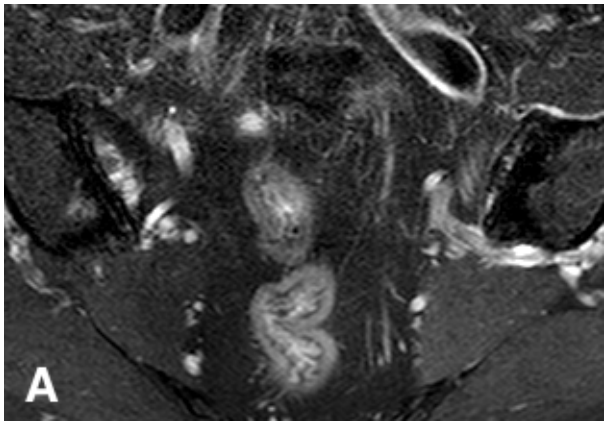


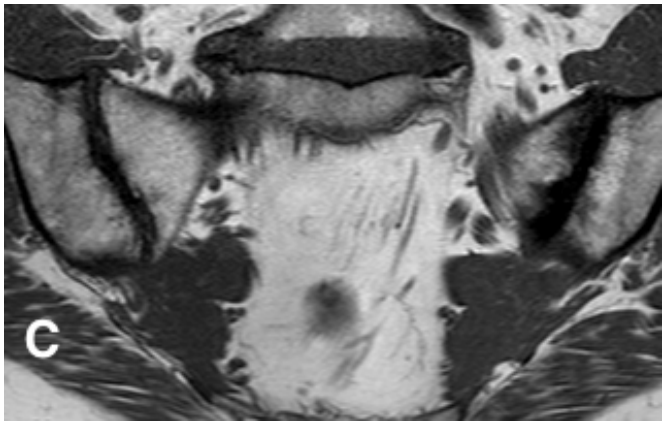
Left symptomatic accessory facet joint (arrow) on axial a) and b) coronal reformat CT with secondary degenerative changes.

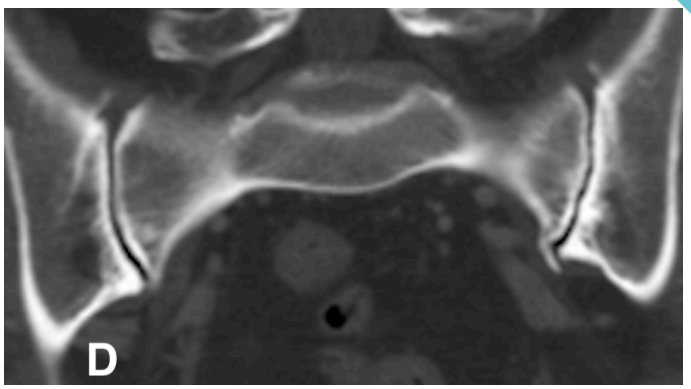
Osteoarthritis is a complex interaction of advancing age, genetic predisposition, mechanical stress, obesity, as well as metabolic and biochemical factors all of which may affect the degree, extent, and progression of disease. It may be primary or secondary (previous trauma, inflammatory arthropathies etc) Degenerative disease of the sacroiliac joints is common and increases with age. Degenerative disease occurs at a younger age in women and is thought to be related to the increased stress across the joint in natural deliveries. Early changes are also noted in manual labourers.

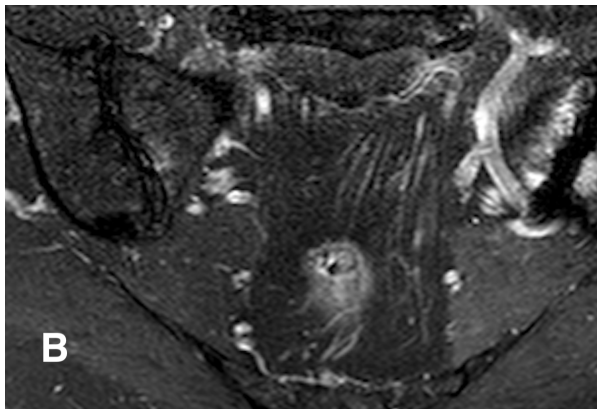
Transitional vertebrae, lower lumbar degenerative disc disease, spondylolisthesis and spondylolysis may predispose to degeneration due to the altered dynamic across the sacroiliac joint. Key radiographic features of osteoarthritis include joint space narrowing, osteophytosis, altered bone contour, bone sclerosis and subchondral cysts formation. No erosions are present.

Radiographic changes overlap with Grade 1 sacroiliitis (New York modified criteria). CT is excellent at demonstrating bony architecture and changes of osteoarthritis. MRI will demonstrate similar changes although axial imaging may not be acquired through the SIJ making assessment of anterior osteophytosis more challenging.

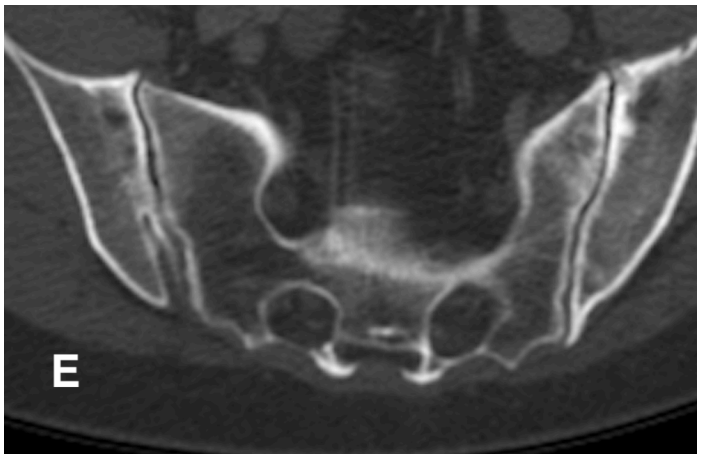




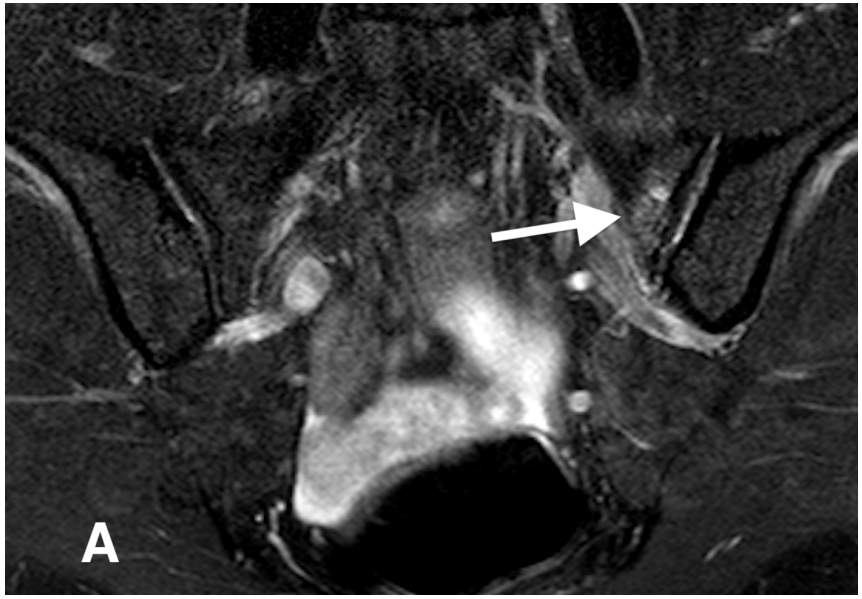


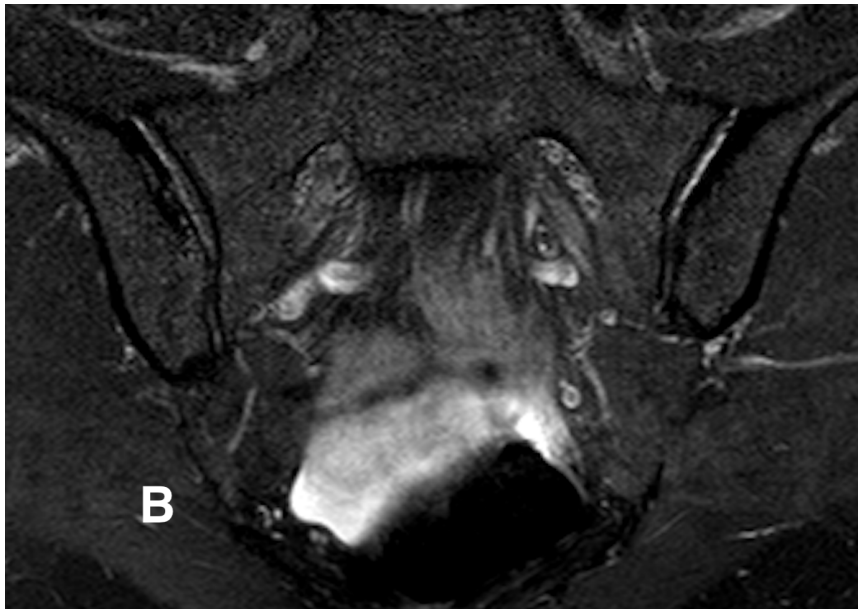


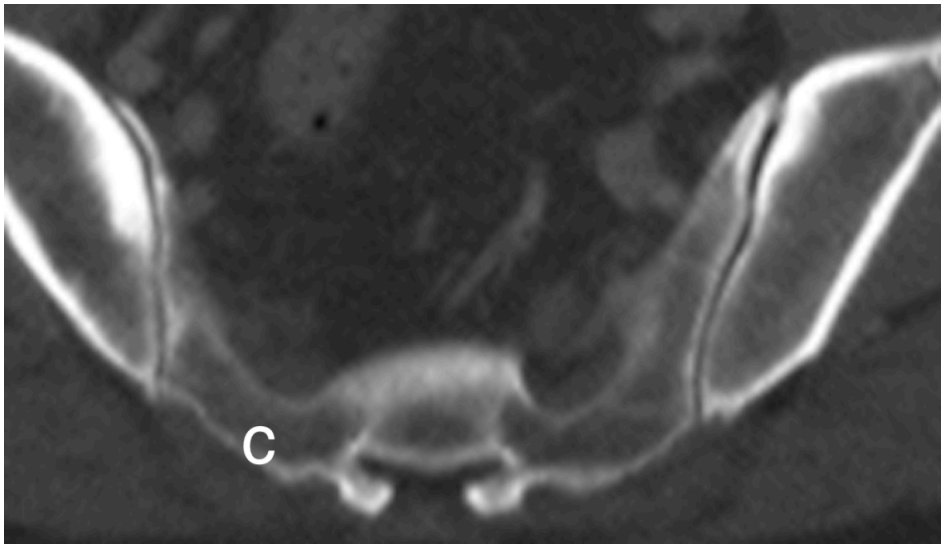
60 F with hx PsA, IBP. A & B) Cor STIR SIJ with subchondral sacral bone marrow edema, joint space loss and subchondral sclerosis, C)- corresponding Cor T1 with joint space loss and low signal subchondral changes consistent with scelerosis. Recent unrelated CT abdomen, D)- reformatted magnified image SIJ and E)- axial confirming degeneration with joint space loss and subchondral sclerosis



MRI may however demonstrate bone marrow edema, not evident on x-ray or CT. Osteoarthritis may demonstrate subchondral bone marrow edema, usually as a thin band of high signal intensity on T2. Edema is more commonly anteriorly on the sacral aspect and is usually most evident on the first three semicoronal images. Erosions, subchondral fat metaplasia, capsulitis, enthesitis are not seen in degenerative disease. Exclude normal variants which may be a potential cause of degenerative disease such as accessory articulations. In addition all imaging findings should be reviewed in conjunction with the clinical context

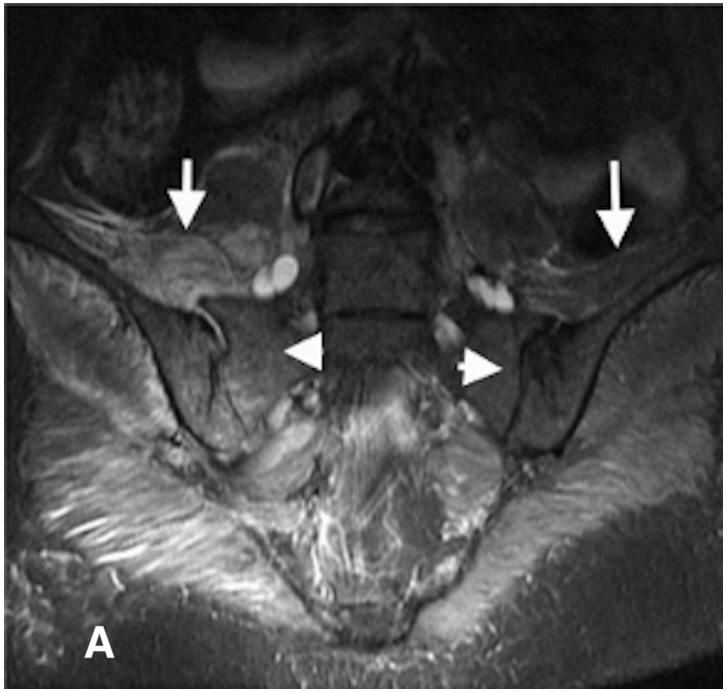




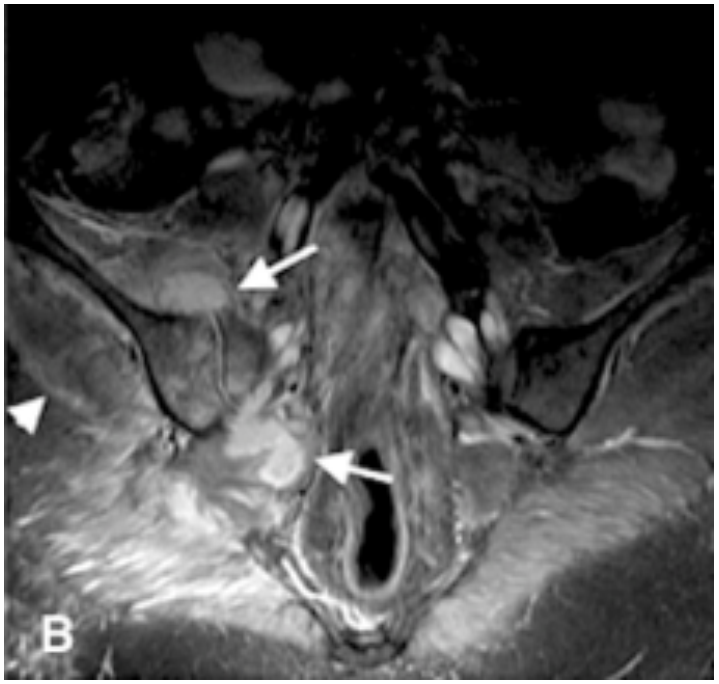


55F, IBP with clinical suspicion of axial SpA. A & B) Cor STIR MRI demonstrating bone marrow edema on the sacral aspect left SIJ anteriorly and minor bilateral minor joint effusions, internal high signal intensity. C)- Axial magnified image on bone windows from CT abdomen demonstrating joint space loss and subchondral sclerosis predominantly on the iliac aspect SIJs. Findings are consistent with degenerative disease likely superimposed on chronic OCI (given triangular subchondral sclerosis on CT). Case demonstrates the classical finding of subchondral edema in degeneration been present along the anterior and sacral aspect of the SIJs and value of using available additional imaging, in this case a prior CT of the abdomen, was available to confirm the diagnosis.

INFECTION



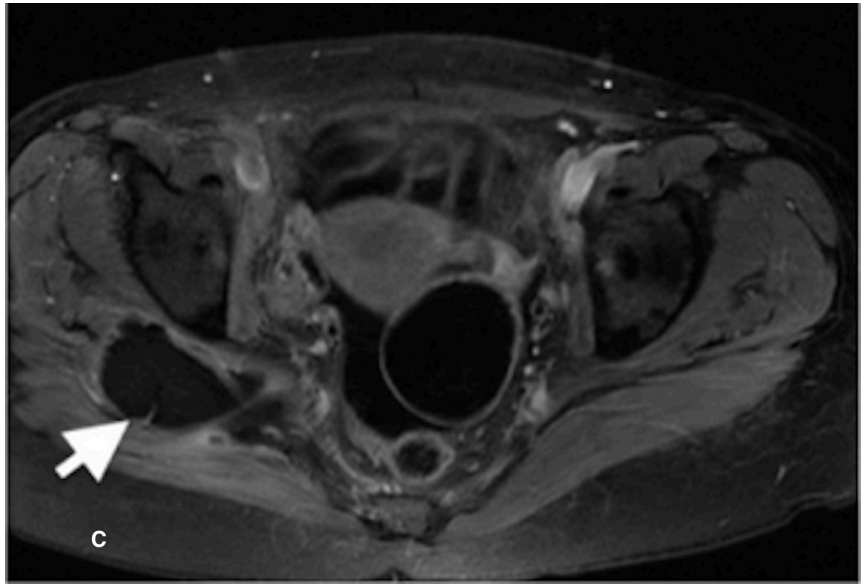
35y F with SLE on steroids developed acute onset right sacroiliac joint pain with limited range of motion and fever. A) Cor T2FS demonstrates periarticular right SIJ osteitis (right arrowhead) and surrounding myositis (right arrow), note normal contralateral side, B) periarticular high SI collections (arrows) from right SIJ and surrounding myositis (arrowhead)



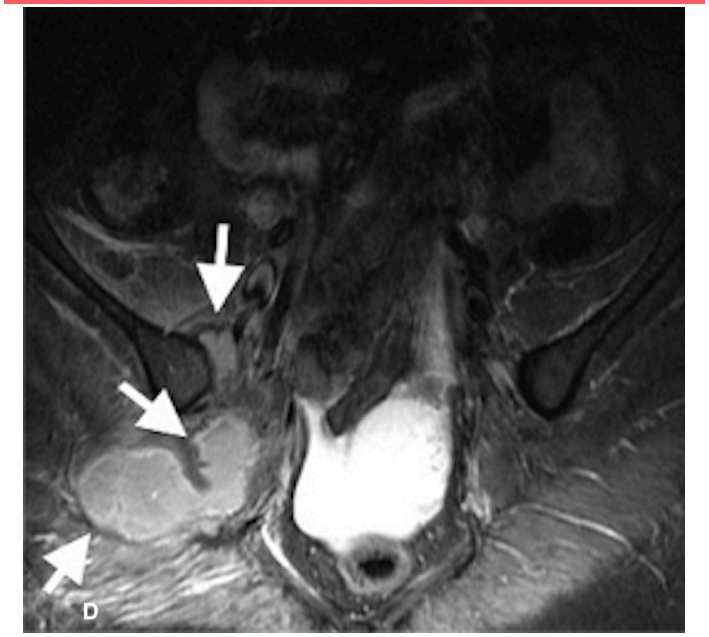
The sacroiliac joints may become infected, septic arthritis. The underlying bone may also become infected, osteomyelitis. Periarticular soft tissue abscesses may develop. Septic arthritis is uncommon, is almost always unilateral and is more common in young adults. Symptoms initially are non specific and include lower back and posterior thigh pain before developing the classical symptoms of infection. Staph Aureus is the most common organism.

Radiographs are usually normal early in the course of disease. Early changes include joint space widening, periarticular osteopenia with progression to erosions and joint destruction. Normal radiographs do not exclude a septic arthritis and further imaging with CT or MRI (preferable) is required.CT changes include widening of the joint cleft with erosions, thinning of the periarticular fatty tissue layer, increase in size of adjacent muscles and abscess formation. Review of the examination on soft tissue windows is essential lest soft tissue abnormalities be missed. CT however may appear normal in the early course of the disease. Therefore in the relevant clinical setting, more sensitive imaging modalities in the acute phase ,MRI, should be employed.

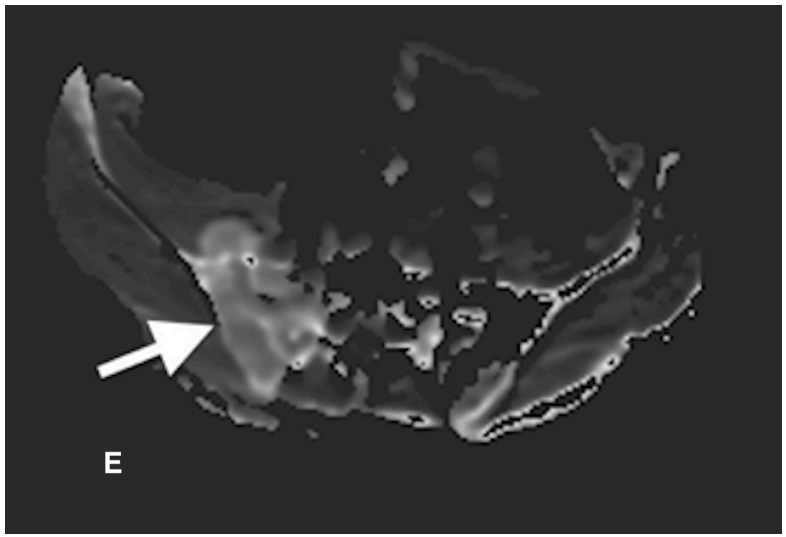
C) periarticular collection is low SI on this axial T1FS PG with thin rim enhancement (arrow)

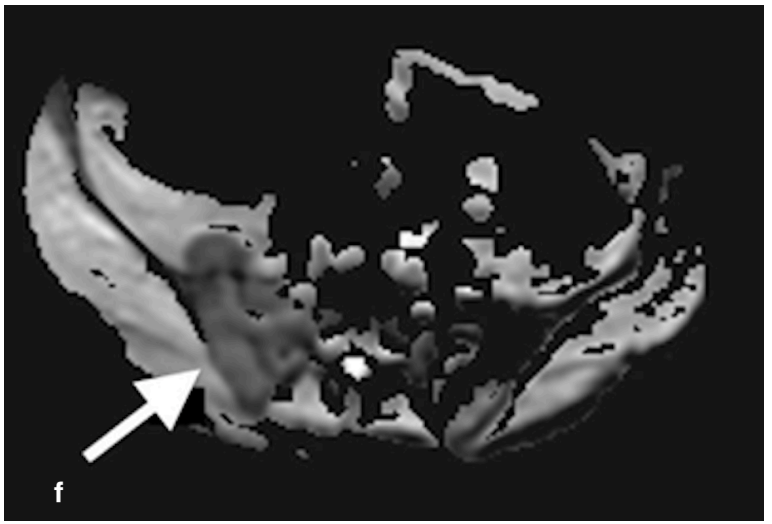


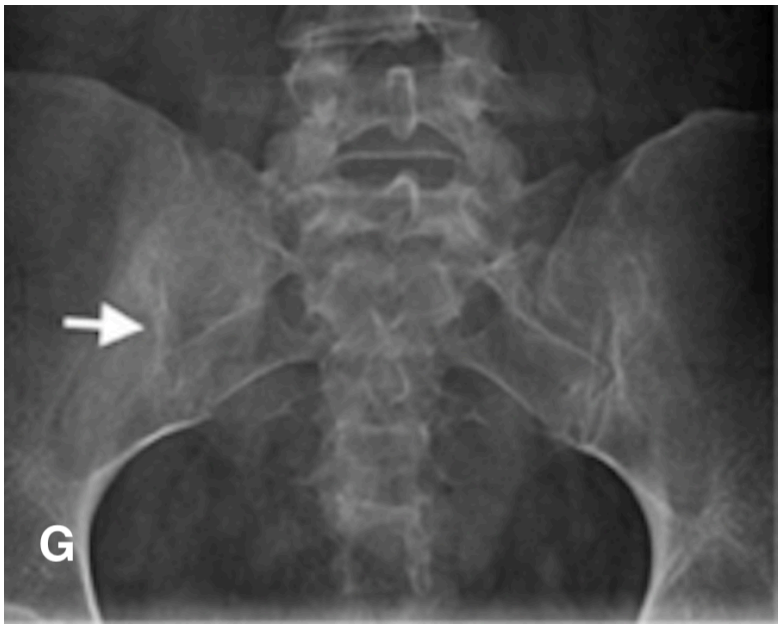
D) more anterior image from (b) demonstrating anterior extension periarticular collection (arrows)



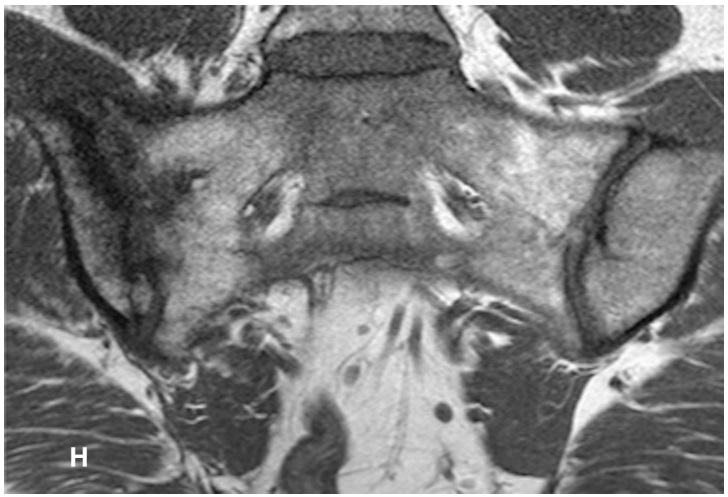
E) Exponential diffusion weighted imaging with increase signal right SIJ and surrounding tissue, low on ADC map (F), consistent with restricted diffusion (sensitive indicator of infection.)





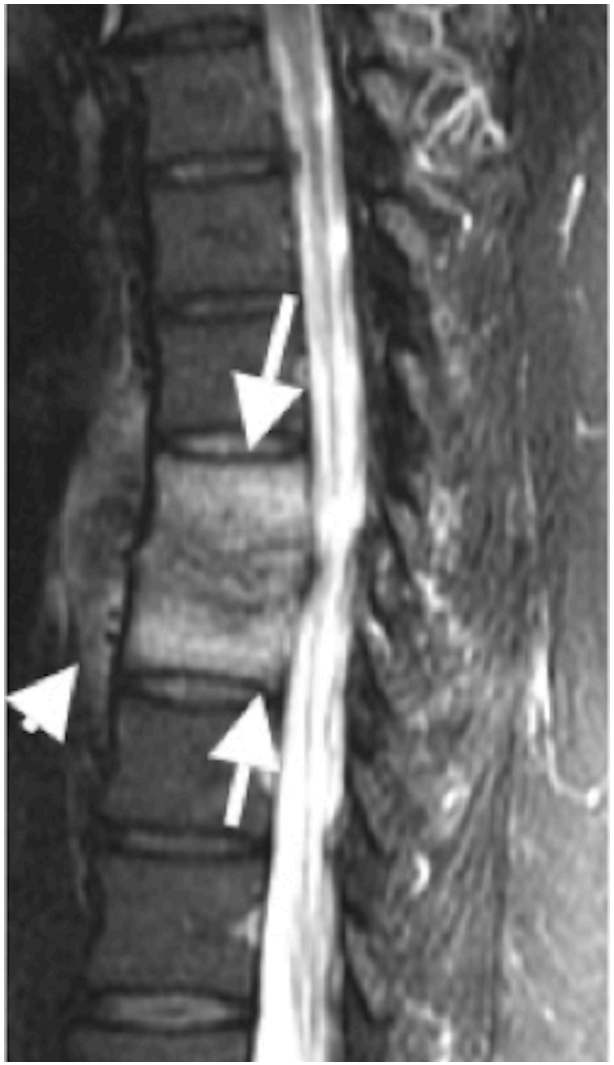


G) AP SIJ on 6 month followup with secondary degenerative right SIJ changes including joint space loss(arrow), erosions and subchondral sclerosis



H) corresponding Cor T1 image with joint space loss, subchondral sclerosis iliac aspect and erosions from prior infection.

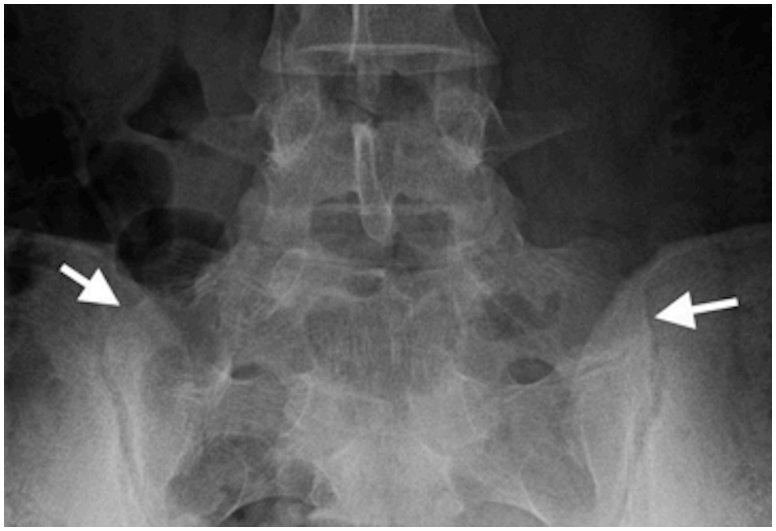
Spondylodiscitis



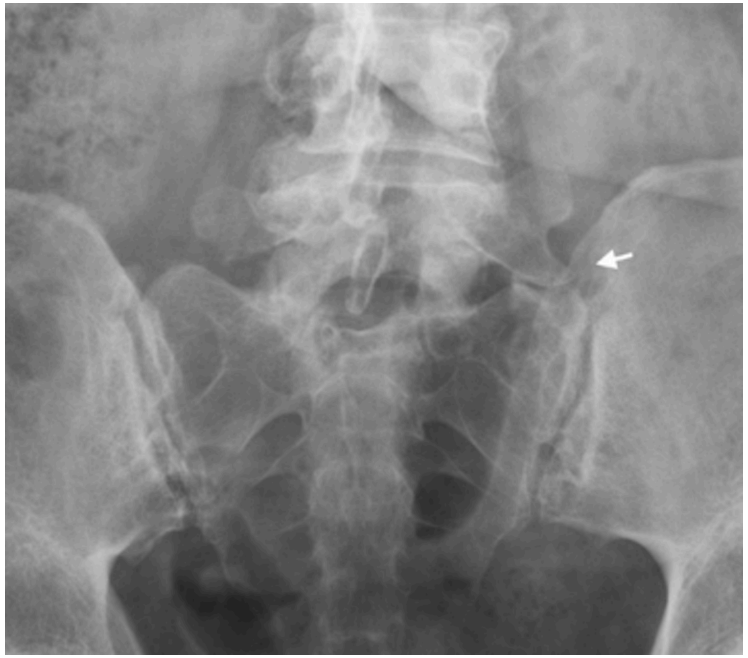
Spondylodiscitis in a 58 M secondary to Staph Aureus septicemia, Sag T2FS thoracic spine demonstrating osteomyelitis (arrows) with high T2 SI in both T8 and T9 vertebral bodies originating from a disciitis of intervening disc and anterior paravertebral abscess (arrowheads). Note the loss of height disc and endplate erosions

Spondylodiscitis is infection of the vertebra and intervertebral disc. Patients may present with non-specific back pain. Clinically there is little overlap with SpA and should be easily differentiated.

Transitional Vertebra



AP radiograph with enlarged transverse processes L5, fused with sacrum on the right and articulating with degenerative changes on the left type 4 Castevelli



AP radiographs transitional L5 vertebra, left enlarged transverse process articulating with the superior sacrum, Type 2A

Transitional vertebrae at the lumbosacral junction are a common congenital anomaly. The upper sacral segment can become lumbarized and likewise the lowermost lumbar segment can become sacralized. May be associated with lower back pain, Bertolotti syndrome. In *sacralization* of the lowermost lumbar vertebrae an elongated unilateral or bilateral transverse process is present which may or may not articulate with the sacrum or occasionally the ilium. This joint may also fuse. There is increased degenerative changes noted in the opposite facet joint, SIJs and increased risk of DDD at the level above due to altered dynamics.

In the case of *lumbarization* of S1 the S1 vertebra is more square in appearance, there maybe a fully formed disc and usually has facet joints present at at S1-2 instead of the normal fused appearance. Identification of transitional vertebrae is important particularly in surgical patients so correct nomenclature is employed. CT is more sensitive in identifying transitional vertebrae due to wider field of view and ability to differentiate hypoplastic 12th ribs from prominent transverse processes. Identification of the iliolumbar ligament, arises from the transverse process of L5 can be a useful landmark.

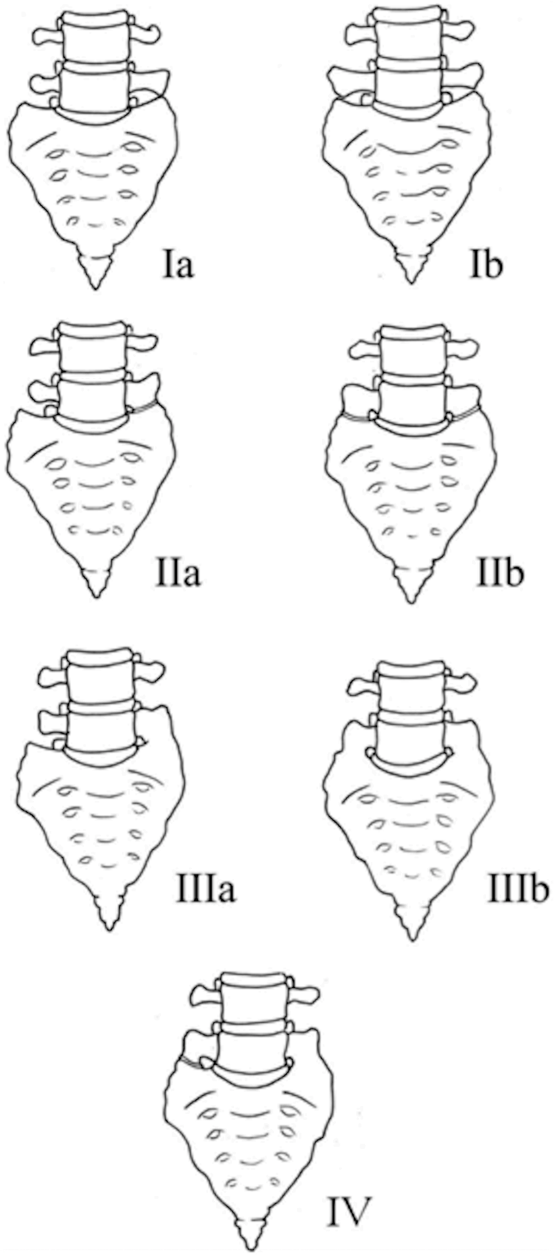
Castellvi Classification Lumbosacral Transitional Vertebrae

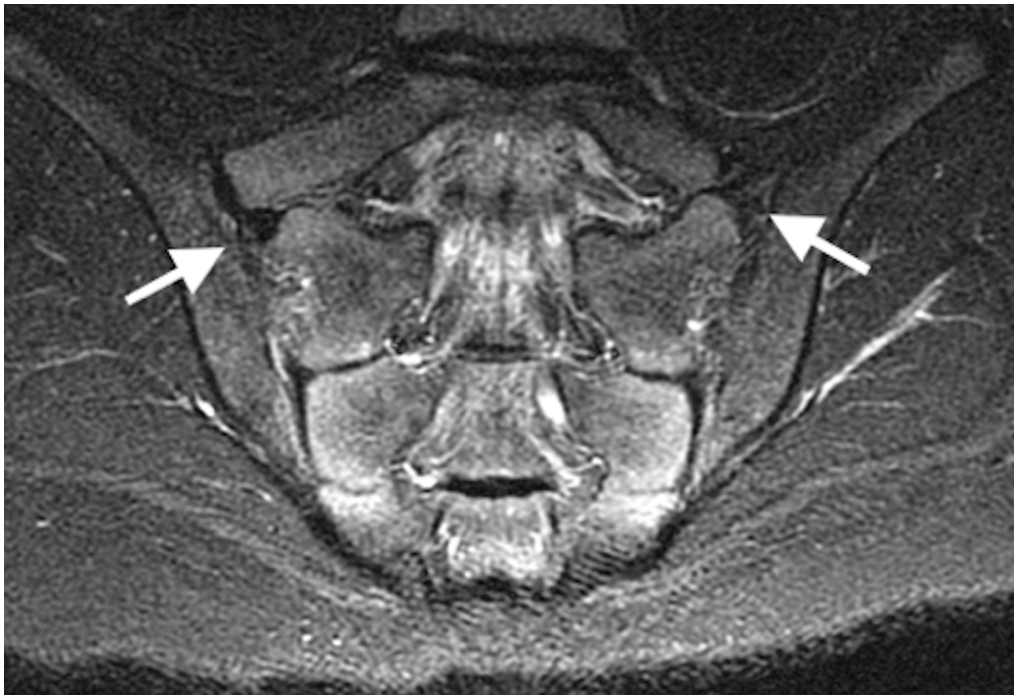
Type 1: Forme fruste, Dysplastic transverse process, >19mm height, a-unilateral, b-bilateral

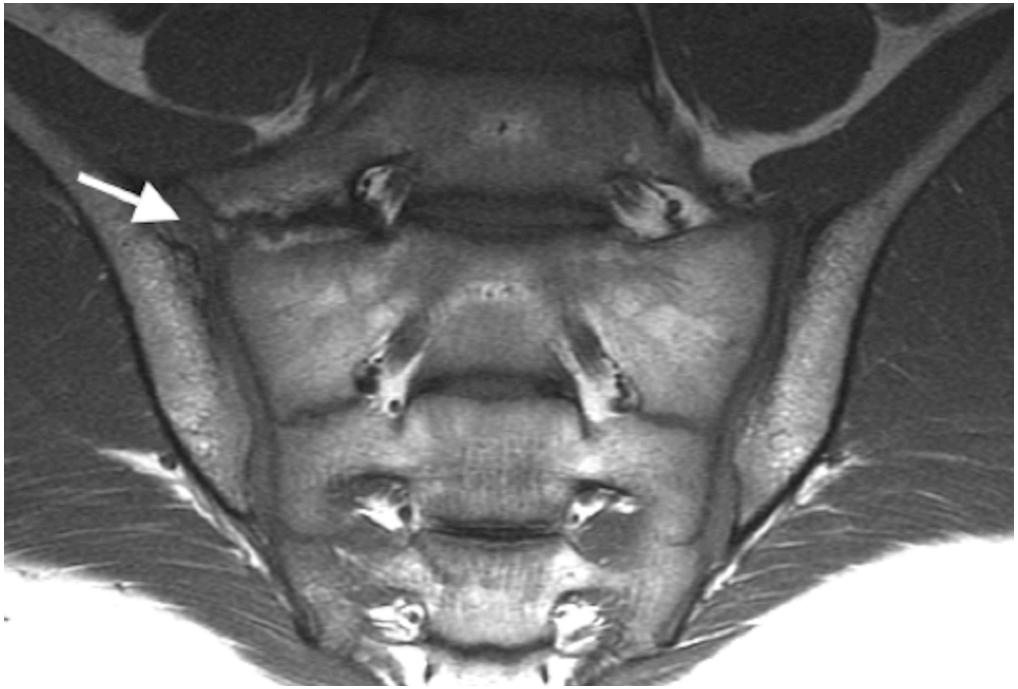
Type 2: Incomplete, Enlarged transverse process with pseudoarthrosis with the adjacent sacral ala

Type 3: Complete, Enlarged transverse process with complete fusion with the adjacent sacral ala

Type 4: Mixed, Type 2 and type 3 on alternate sides



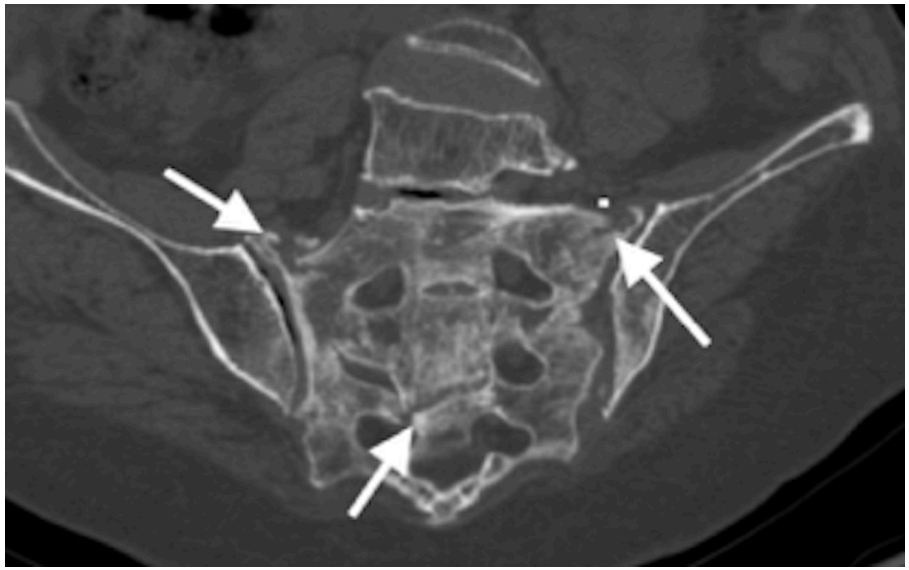




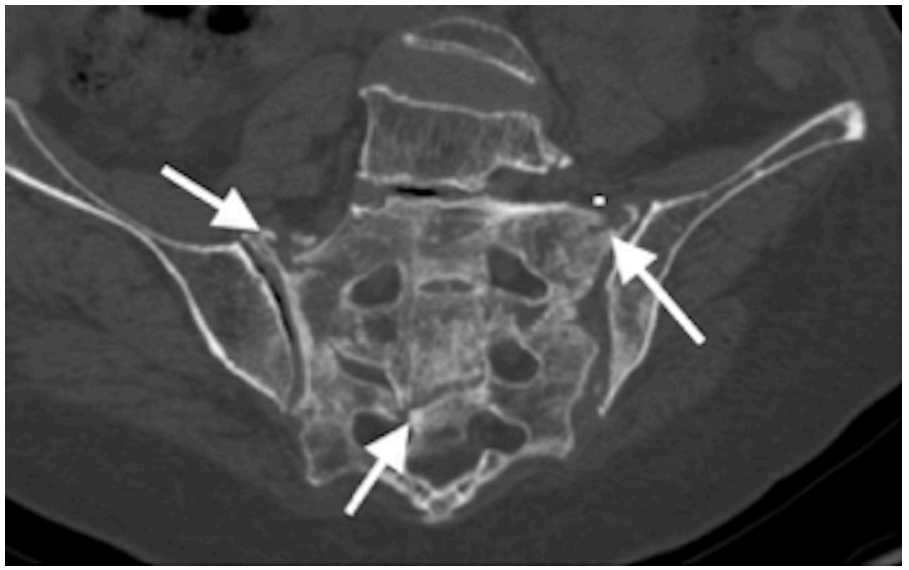
- MRI transitional vertebra Type 2 b in a symptomatic 15y F elite gymnast with Bertolotti syndrome a) no osteitis demonstrated on Cor T2FS b) Cor T1 does demonstrate cortical irregularity and post inflammatory fat accentuation at right synchondrosis (arrow)

FRACTURES

Coronal CT sacrum in a 76y female with chronic insufficiency fractures (arrows). The diffuse ill-defined surrounding sclerosis indicates chronicity.

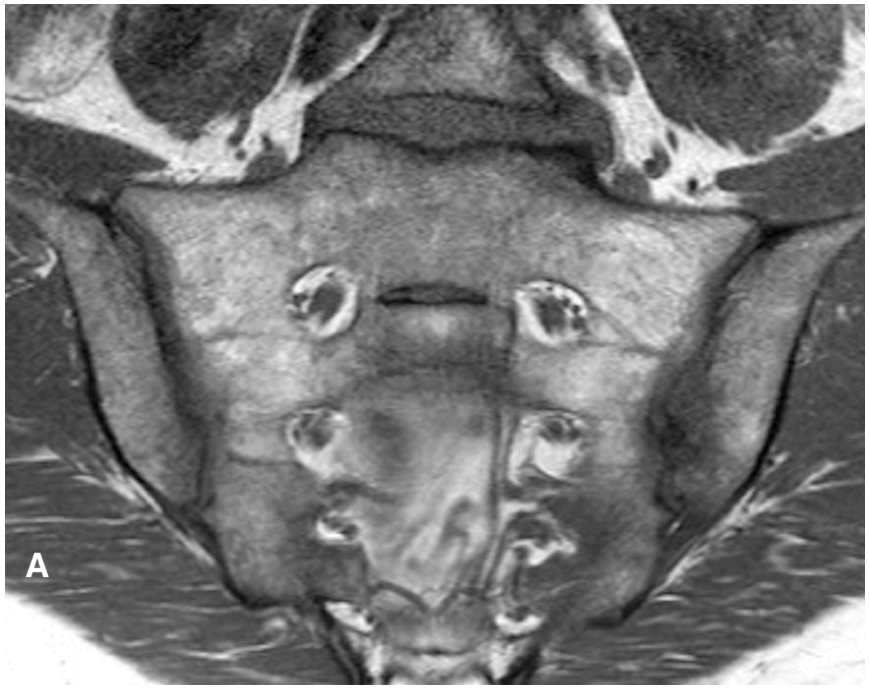


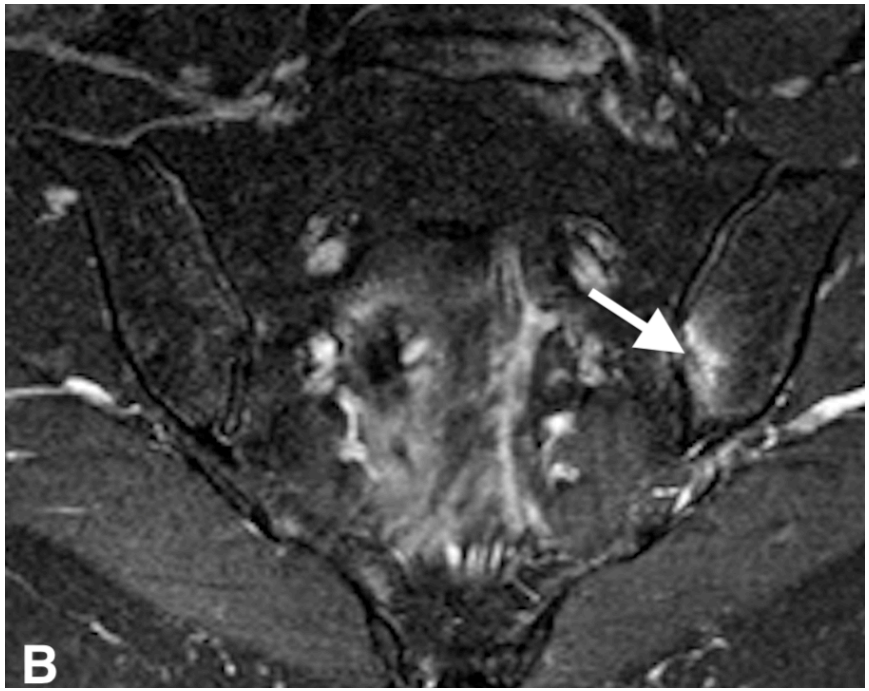
Sagittal reformatted CT sacrum in a 76y female with chronic insufficiency fractures (arrow). The diffuse ill-defined surrounding sclerosis indicates chronicity.

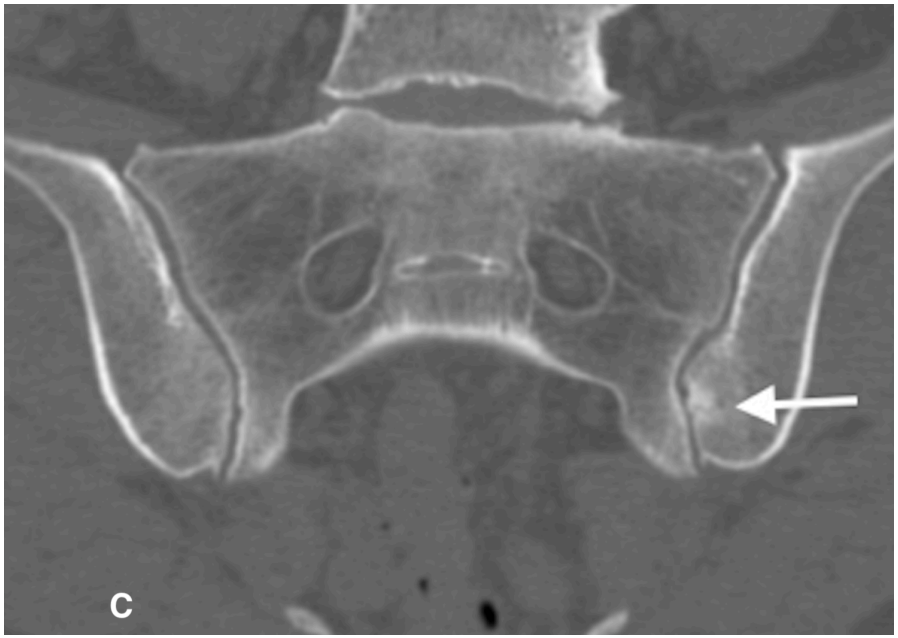


Acute traumatic, stress and insufficiency fractures may all involve the pelvis. Acute traumatic fractures have a corresponding appropriate history and are not a diagnostic imaging differential. Insufficiency fractures most commonly occur in elderly females with osteoporosis and are easily differentiated from SpA. The osteopenia may make assessment of plain X-rays difficult. The diagnosis can be confirmed by CT, which demonstrates patchy sclerosis, often with fissure-like fractures. MRI will demonstrate similar findings. The fracture line may be high or low signal intensity and is surrounding by mixed sclerosis and edema on MRI .

Stress fractures, abnormal stress on normal bone, can also occur and can occasionally be a diagnostic challenge when periarticular. CT will demonstrate a low attenuation line with surrounding sclerosis and as the fracture heals the fracture line becomes sclerotic. On MR there will be intense surrounding edema with high signal intensity on T2, low T1 with a central line of low signal on T1, low or high signal on T2 depending on the stage of healing. The key is identifying the linear line centrally within the oedematous marrow.



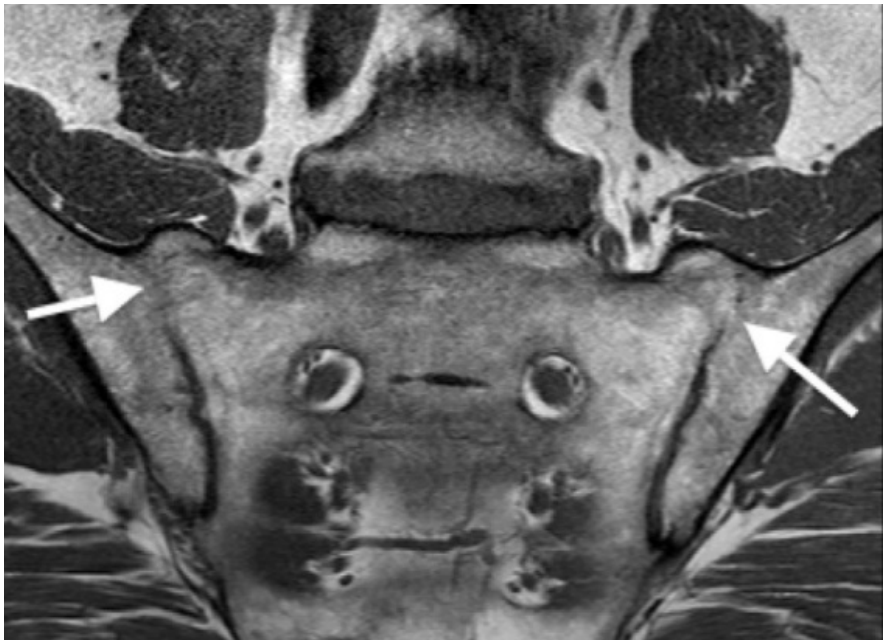




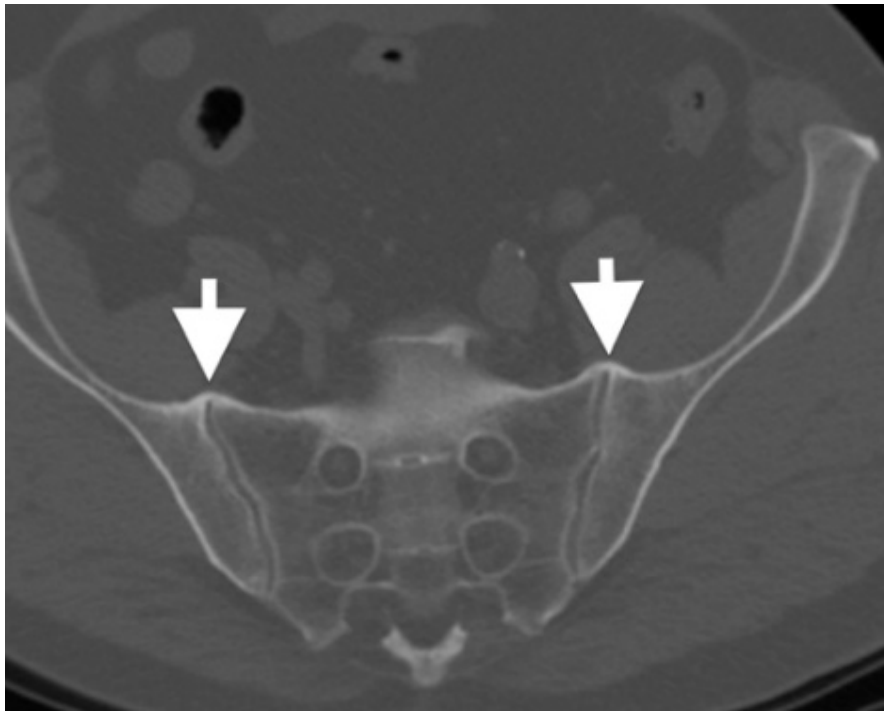
57y woman with history inflammatory back pain, recurrent iritis and HLA-B27 positive, referred by rheumatologist with high pre-test probability of axial spondyoarthropathy: A-Semrcoronal T1 with left iliac subchondral low signal intensity, B-Semicoronal T2FS focus is of diffuse ill-defined high signal with subtle low signal intensity transversing line (arrow). A diagnosis of stress fracture provided but given history patient was referred for CT, C, semIcoronal demonstrating a small stress fracture (arrow) with normal bone density. On further clinical assessment patient provided an additional history of heavy weight lifting at boot camp.

Diffuse Idiopathic Skeletal Hyperostosis

DISH-68yr M, Cor T1 MRI, ossification (arrows) superior SIJs and normal inferior joint space. Patient had typical changes of DISH on a lateral thoracic spine radiograph



DISH in a 66y F on axial CT pelvis with ossification anterior SIJ capsule and ligaments, note normal sacroiliac joint space deep to capsular ossification with absence subchondral changes

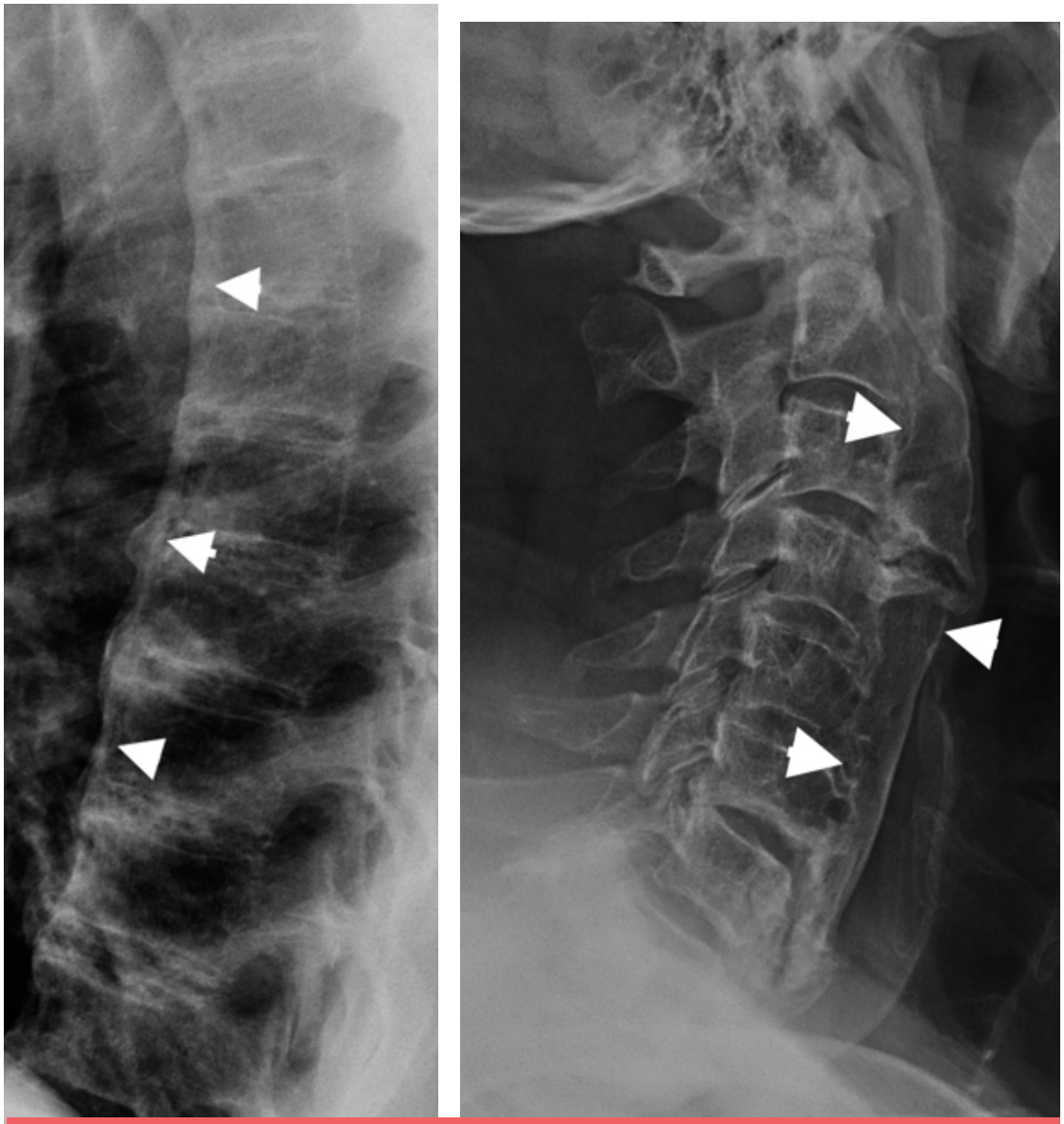


DISH, also commonly known as Forestier Disease, is a common idiopathic skeletal disorder producing hyperostosis within the axial and appendicular skeleton. It usually begins in middle age and is almost twice as common in men. Diagnosis requires spinal involvement with anterior flowing ossification of the anterior longitudinal ligament over four contiguous vertebrae and not associated with degenerative disc disease at these levels and absent ankylosis of apophyseal or sacroiliac joints. The latter helps to excludes spondyloarthropathy. It is slowly progressive and minor changes may be identified in middle age, which becomes more obvious as the patient ages. The patient is often asymptomatic but may complain of stiffness and spinal restricted range of motion. Peripherally tendinopathy at tendinous insertion may be present.

DISH is most commonly diagnosed within the mid to lower thoracic spine, followed by the lower cervical spine.

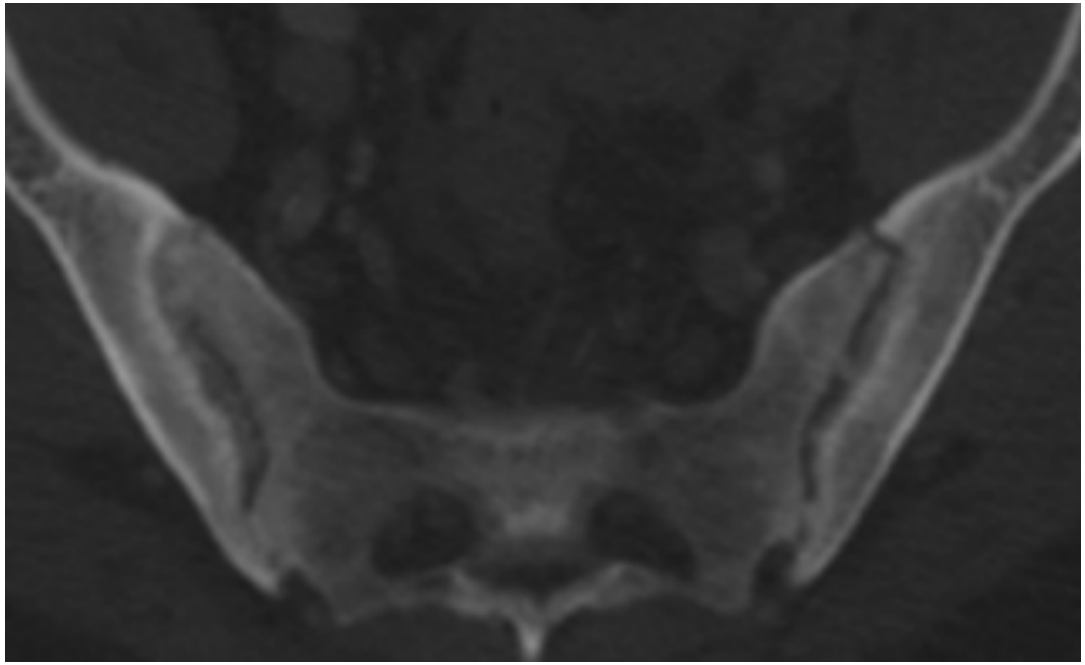
Ossification or calcification of the anterior longitudinal ligament and paraspinal connective tissue occurs over at least four contiguous vertebrae, this is usually central or right lateral due to the inhibiting effect of pulsations from the thoracic aorta.

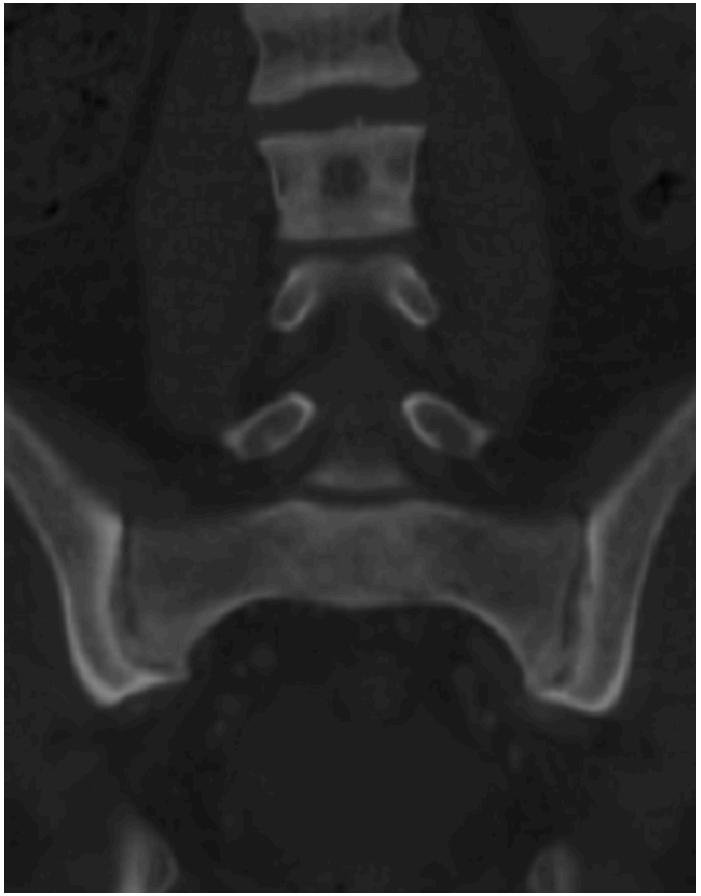
The sacroiliac joints may demonstrate prominent anterior bridging osteophytosis without joint ankylosis or erosions.



DISH Lateral radiograph a) thoracic b) cervical spine demonstrating thin ossification thoracic and thick ossification respectively of the anterior longitudinal ligament (arrowheads) in two different patients

Hyperparathyroidism

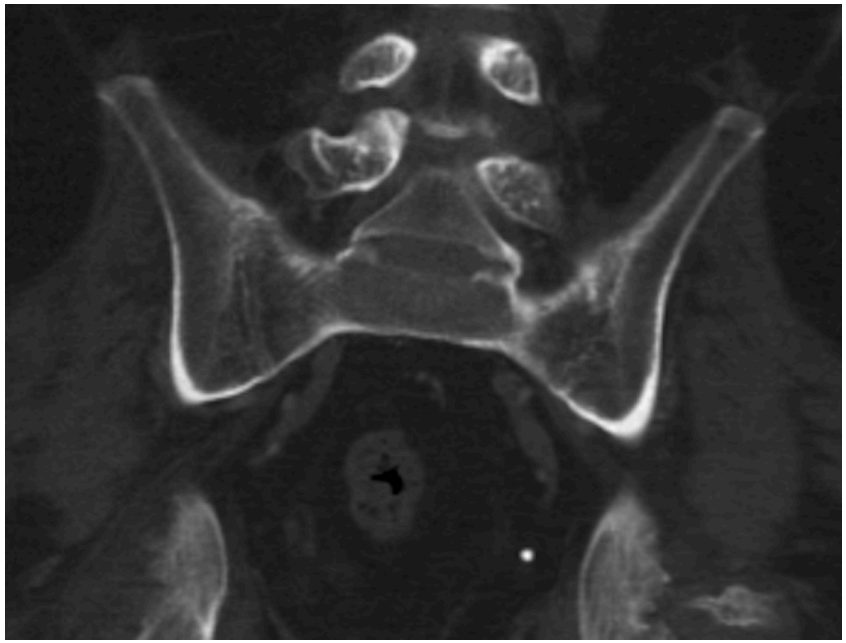




Axial (above) and coronal reformatted (right image) from a CT abdomen and pelvis in a patient with known chronic renal failure and secondary hyperparathyroidism with subchondral bone resorption at the sacroiliac joints, heterogenous bone attenuation with “rugger-jersey” spine demonstrating alternating bands of vertebral body high and low attenuation with high attenuation paralleling the endplates.

Hyperparathyroidism may lead to subchondral resorption and pseudo-widening of sacroiliac joints space, especially in advanced diseases. The process is usually symmetrical and more pronounced on the iliac aspect articulations. There is no ankylosis. In a study of primary HPTH erosions (4%), osteitis (16%), sclerosis (4%) capsulitis, fat metaplasia (4%) in similar % as control population (Tezcan et al in ref).

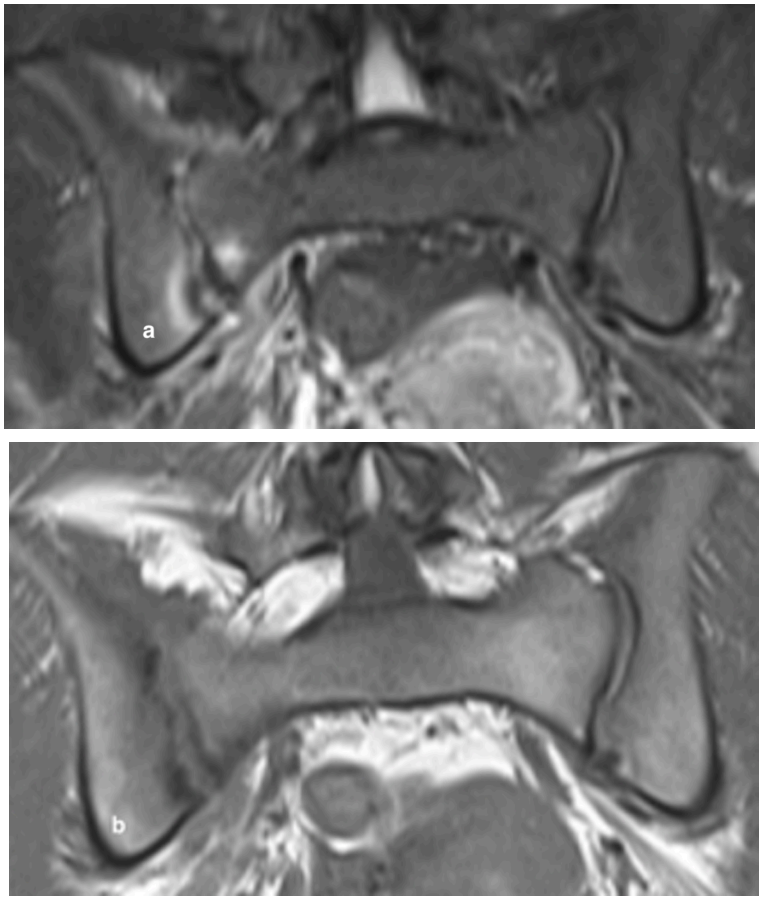
Paraplegia



Coronal reformatted CT with bone windows demonstrating fused sacroiliac joints secondary to longstanding paraplegia

Partial or complete fusion of the sacroiliac joints may occur in paraplegics. It is more common in high cord injuries and is thought to be related to the chronic lack of mobility across the articulations

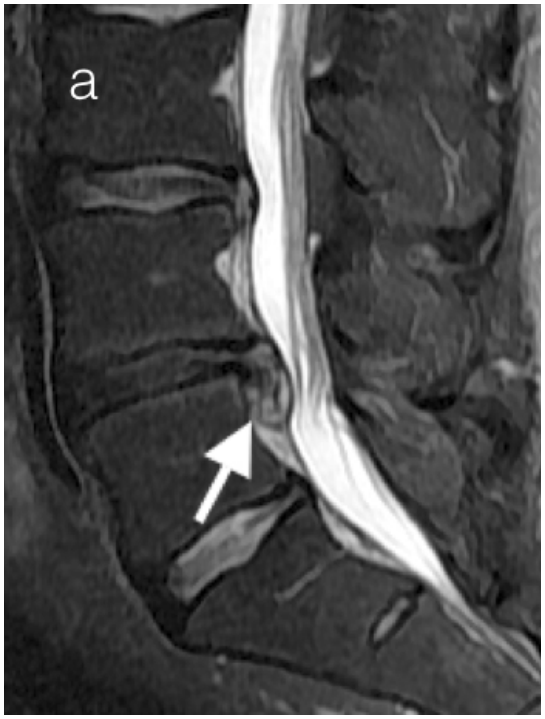
Postpartum

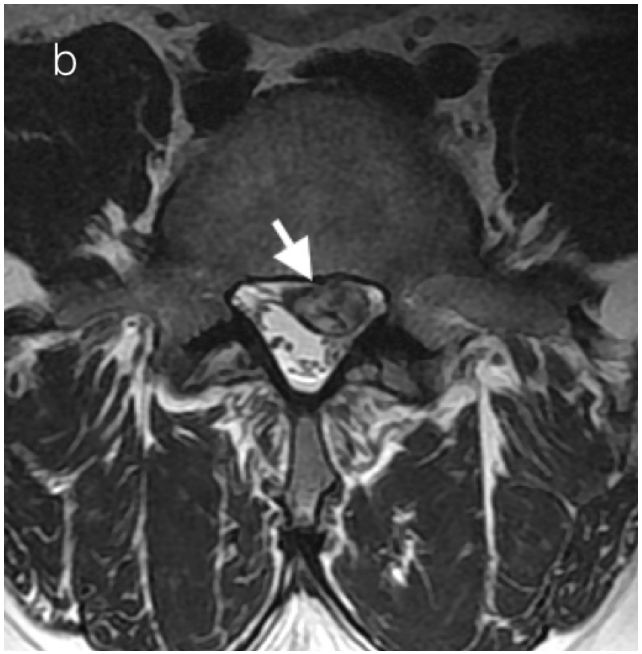


Coronal STIR (a) and (b) T1 SIJs in a female patient 3 months postpartum demonstrating right SIJ mild to moderate sunchondral edema and minor iliac sunchondral sclerosis. Symptoms and imaging findings resolved on followup (not shown)

The sacroiliac joints are exposed to significant mechanical stress in pregnancy, most pronounced during natural deliveries and may develop pregnancy induced low back pain with positive MRI imaging findings, the most significant of which is subchondral bone marrow edema. Joint effusions, capsulitis, enthesitis and subchondral sclerosis have also been reported. The majority of patients have resolution of symptoms and imaging findings on followup. Some may have persistent symptoms and develop OCI.

Degenerative Disc Disease

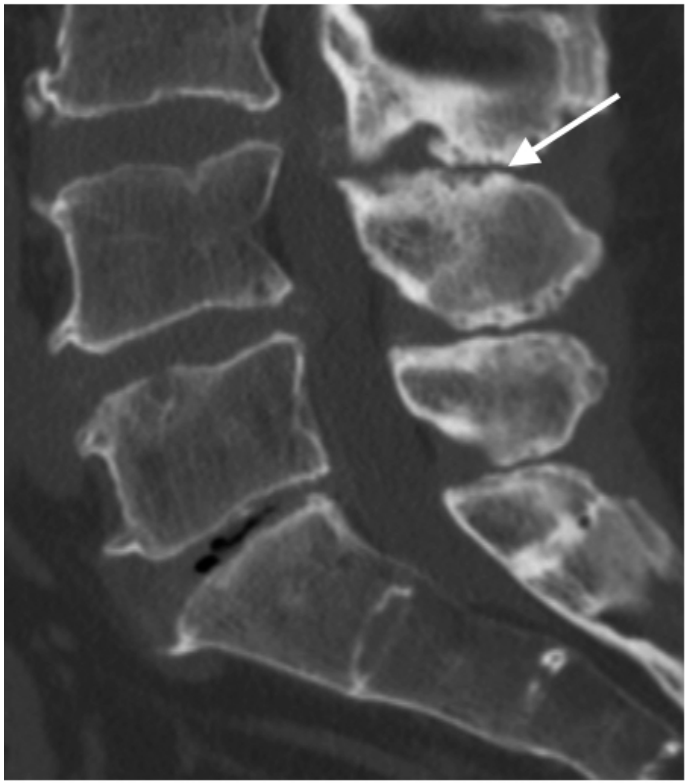




A-Sag T2FS B-Axial T2FS—Extruded disc (arrow) with inferior migration, without sequestration, at L4-5 extending into the left lateral recess and impinging the left L5 and upper sacral nerve roots

Degenerative disc disease (DDD), intervertebral osteochondrosis, is one of the commonest causes of low back pain. Predisposing factors include age, genetics and axial loading. DDD may impact upon the adjacent nerves and be a source of symptoms. However DDD may also cause low back pain from release of cytokines and stimulate nociceptors. There may also be related facet joint disease. DDD is present in the majority of imaged middle aged and older patients and may or may not be a source of symptoms and close clinical correlation is required.

Radiographs are limited in the assessment of DDD. Degenerative changes are common and non-specific. Radiographs can be acquired in patients with red flags as the initial line of investigation to help localize pathology for a more detailed cross-sectional imaging study. Vertebral body number, height and intervertebral disc space height should be assessed. In DDD there is loss of intervertebral disc space height, associated reactive vertebral endplate sclerosis and multidirectional endplate osteophytes. Vacuum phenomena are collections of gas, predominantly nitrogen, and occur in sites of negative pressure within the nucleus pulposus



Degenerative disc disease on reformatted Sag CT. bone windows, demonstrating loss of disc height, vacuum phenomenon and minor endplate osteophytosis at L5-S1. Less pronounced degeneration at L4-5.
Note imaging features of Baastrup disease, contacting adjacent spinous processes demonstrating cortical irregularity and sclerosis (arrow)

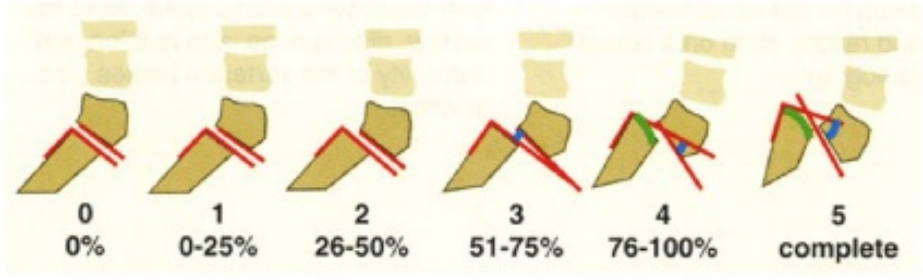
MRI

MRI is the non-invasive gold imaging standard in the imaging of DDD with excellent anatomical detail, soft tissue contrast and lack of radiation. MRI can assess the internal characteristic of the disc and adjacent marrow signal intensity. CT is less commonly used in imaging the lumbar spine due to radiation dose and less soft tissue contrast. It is not used in imaging of the cervical or thoracic spine for degenerative disease unless MRI is contra-indicated.

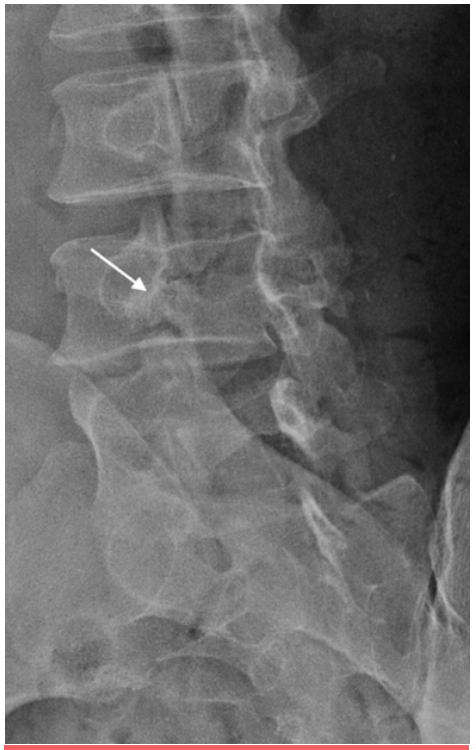
Intervertebral disc space height, vacuum phenomena, vertebral endplate osteophytes, erosions and sclerosis are assessed.

Disc bulge may be in many forms: a diffuse disc bulge, asymmetrical diffuse disc bulge, a focal protrusion, a broad based protrusion, an extrusion, an extrusion with migration with/out sequestration

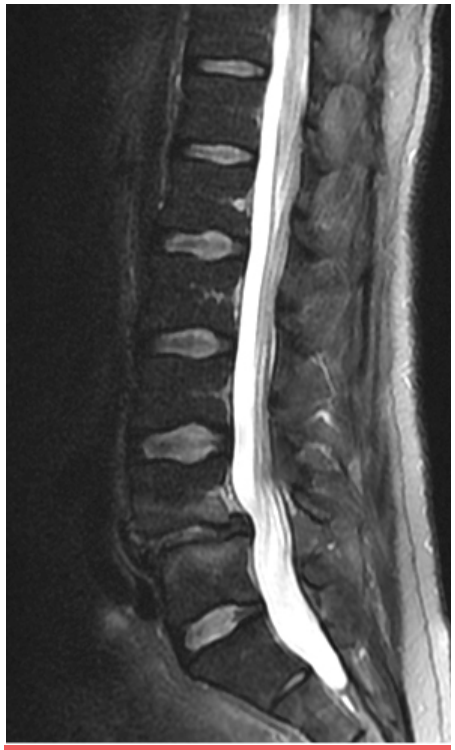
Spondylolisthesis & Spondylolysis



Grading Spondylolisthesis



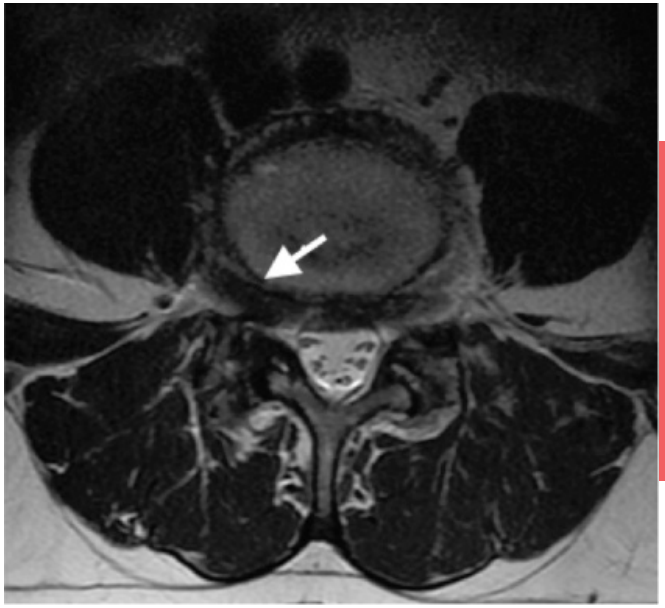
Oblique radiograph unilateral pars defect L4 (arrow)



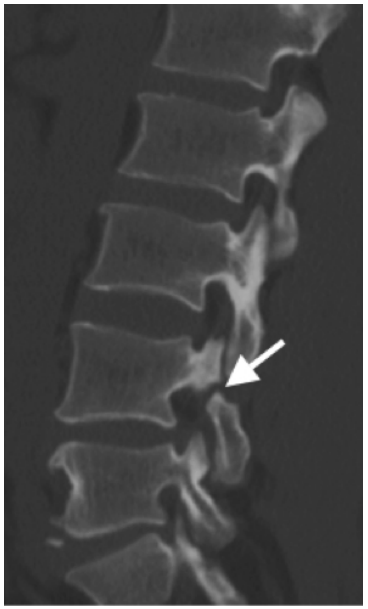
Sag T2FS same patient with grade 1 spondylolisthesis

Spondylolisthesis, from the Greek “a vertebra that slips”, indicates anterior or posterior translation, slippage, of a vertebra upon a vertebra above or below it. Occurs in up to 4% of the population, commonest at the two lowermost lumbar levels. It is divided into open or closed arch. Retrolisthesis, posterior slippage, may occur, although less common, related to DDD. The cervical and lumbar spine are the most frequently involved.

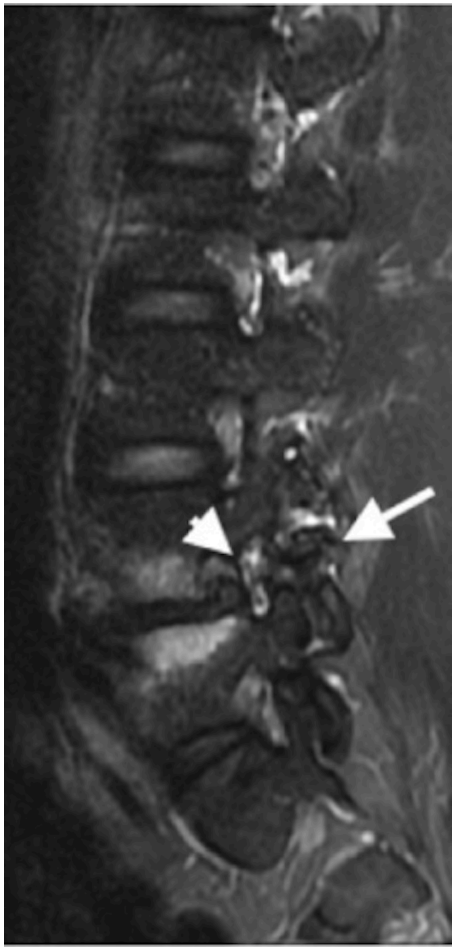
In *open arch* there is bilateral spondylolysis, a defect in the pars interarticularis i.e. that portion bone between the superior and inferior articular facets. This is usually secondary to a stress fracture related to recurrent micro-trauma rather than a single traumatic event. In *closed arch*, degenerative spondylolisthesis, the pars is intact however there is instability at the facet joint usually related to degenerative change.The anterior and posterior elements of the vertebra remain connected and as such the posterior elements move forward and encroach upon the spinal canal and may cause a spinal canal and foraminal stenosis.The lateral radiograph best demonstrates the spondylolisthesis. The degree of spondylolisthesis can be measured or graded, grades 1-4 with each grade equivalent to 25% of the AP diameter of the vertebra, i.e. grade 2 equates to 26-50%.



Axial T2FS -Bilateral spondylolysis and spondylolisthesis of L4 on L5 uncovered disc occupying right neural foramina (arrow)



Sag CT with left L4 pars detect (arrow)

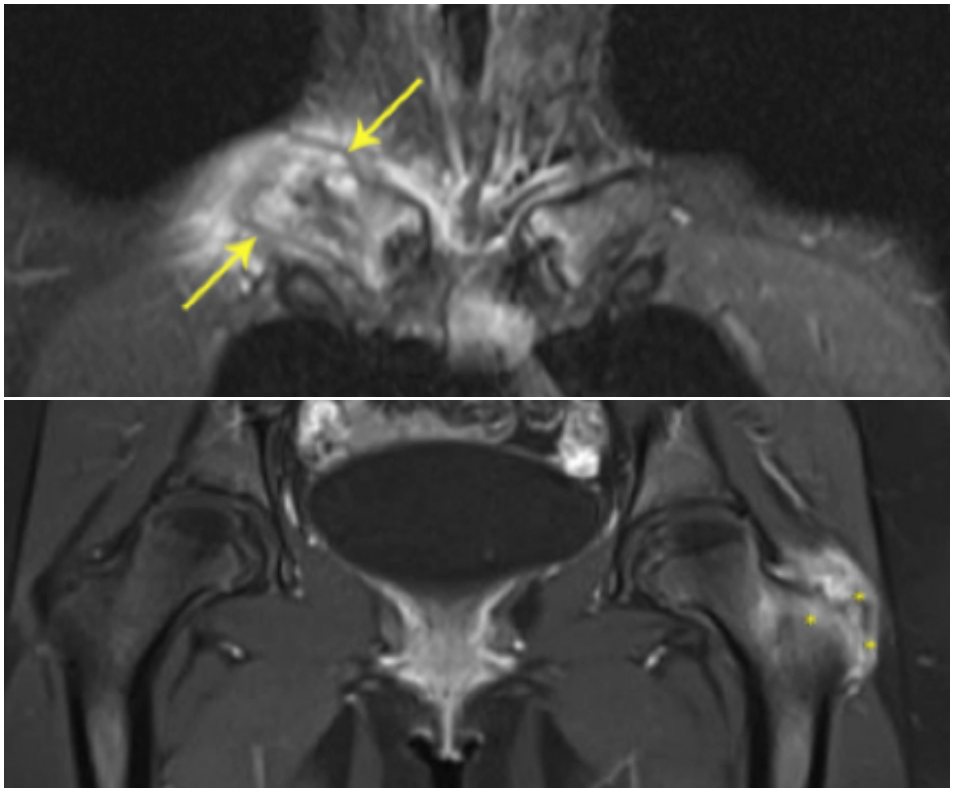


Sag T2FS at neurofaramina with secondary foraminal stenosis (arrowhead) secondary to uncovered disc

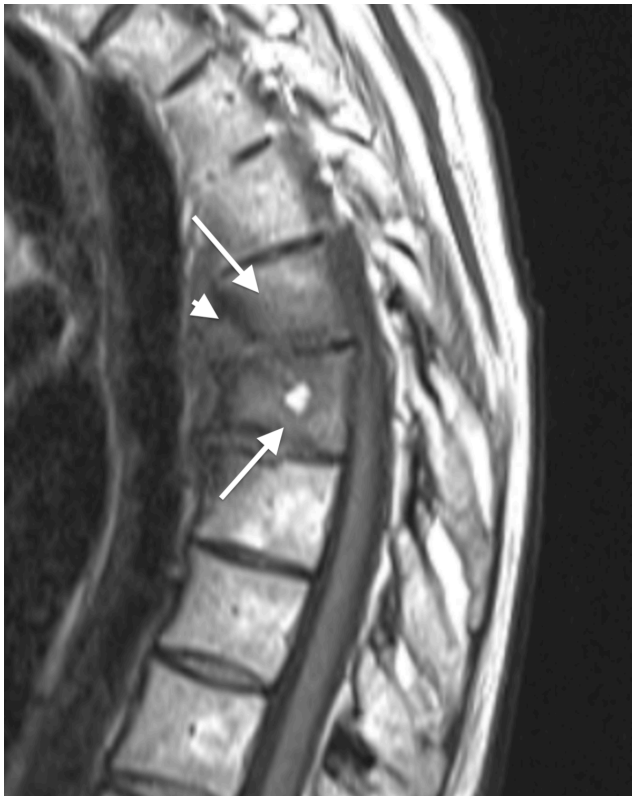
Anterior slippage of the posterior elements occurs in degenerative spondylolisthesis. In spondylosis a bony defect in the pars is best visualized on the oblique radiograph. Instability can be assessed with flexion and extension views.

CT demonstrates excellent bony detail of the pars and the facet joints. It can also assess any associated intervertebral disc disease. MRI is less sensitive in assessing pars defect than CT. MRI is excellent however is assessing associated degenerative disc disease and neuroforaminal/canal stenosis. MRI can also demonstrate Modic endplate type 1 changes, which may relate to instability.

SAPHO

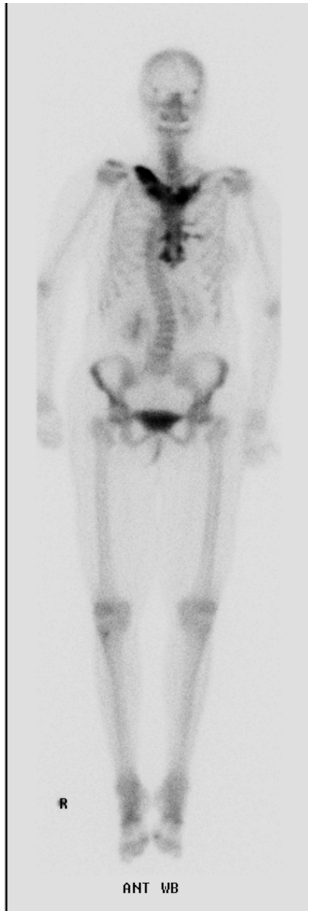


MRI findings of expanded, irregular clavicle (arrows) with BME, left image, andB:BME and enthesitis at greater trochanter in SAPHO case.

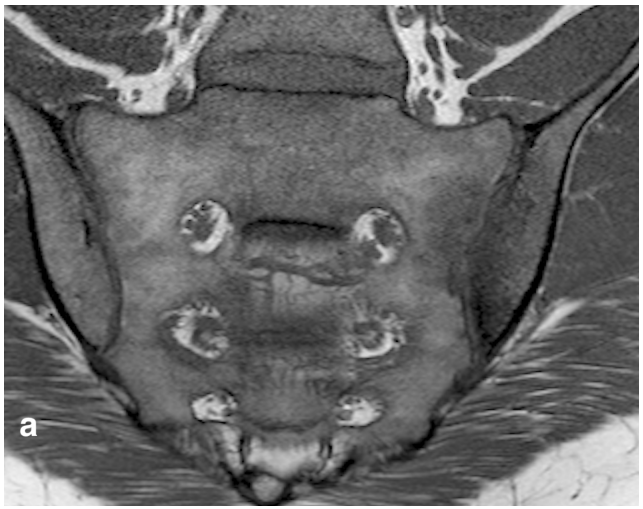


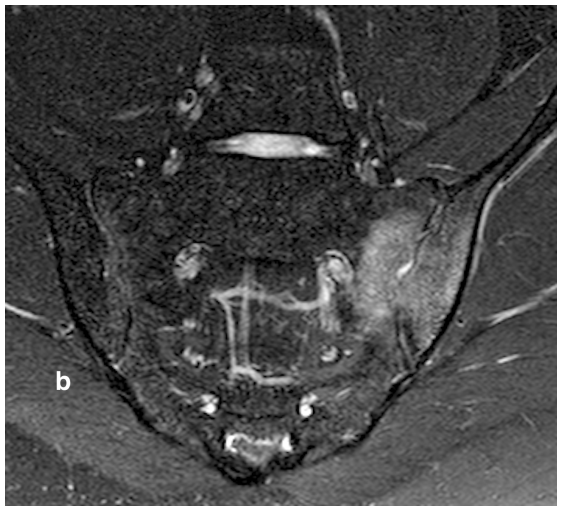
Sag T1 mid thoracic spine in patient with known SAPHO demonstrating low signal intensity vertebral bodies (arrows), high on corresponding STIR image, not shown. Anterior vertebral body erosion (arrowhead) and early VB ankylosis at the level above

SAPHO- Synovitis, Acne, Pustulosis, Hyperostosis and Osteitis is within the spectrum of the seronegative arthritides, characterized by sterile osteomyelitis. SAPHO syndrome can present at any age and is characterized by recurrent episodes of local sterile inflammation in any bone, but particularly the anterior chest wall including the sternoclavicular joint or the medial clavicle.



Bone scan in patient with SAPHO demonstrating bilateral, right greater than left, expansion with increased uptake proximal clavicles and adjacent manubrium





23 M with known SAPHO demonstrating left SIJ joint space loss, iliac erosions, extensive subchondral osteitis and mild joint effusion. Sacroiliitis in SAPHO is commonly unilateral.

In children, it most frequently affects the long bones and clavicles, while in adults, it particularly affects the anterior chest wall and axial spine. It is often multifocal. The associated sacroiliitis is often unilateral and axial involvement may be indistinguishable from the spondyloarthropathies Axial disease includes corner lesions on vertebral bodies, discitis, sclerosis adjacent to endplate erosions, paravertebral ossification, and destructive vertebral lesions (often resulting in bony collapse), along with sacroiliitis (usually unilateral with hyperostosis on the iliac side). The medial third of the clavicle is the most typical site with hyperostosis, sclerosis and hypertrophy of the medial ends, followed by lateral extension as the disease progresses.

Notes

Categorization MRI for Clinical Practice

Why is a categorization system needed for MRI Reporting?

O'Neill J, Carmona R, Maksymowych W

MRIs are being increasingly utilized in the diagnosis and monitoring of axial SpA, and are therefore a key tool in the clinician's toolbox. In one study of clinicians, diagnostic confidence for AS improved from 29% pre-MRI to 80% post-MRI ($p<0.001$). Of the patients for whom biologics were proposed pre-MRI, only 52% were recommended biologics post-MRI. Additionally, among the patients for whom biologics were not recommended pre-MRI, 31% were recommended biologics post-MRI. Overall, 40% of patients had a change in treatment recommendation after MRI. The MRI report therefore significantly impacts diagnosis, clinical decision-making and subsequent management, including the use of biologic drugs. Equally important, the MRI report profoundly impacts the individual patient, carrying with it all the implications of receiving (or not receiving) a particular diagnosis. The importance of an accurate interpretation could not be more important.

The radiological diagnosis of sacroiliitis is a global assessment of both the acute and chronic changes of sacroiliitis in conjunction with the provided clinical history and clinical findings. The current ASAS MRI definition of a positive MRI, which focuses on BME for assessment of sacroiliitis, should not be automatically equated with the presence of spondyloarthritis. In our experience however, with an overwhelming stream of publications, the ASAS classification criteria for axial SpA, and thereby the ASAS definition of a positive MRI, continue to have a significant impact on diagnosis in clinical practice.

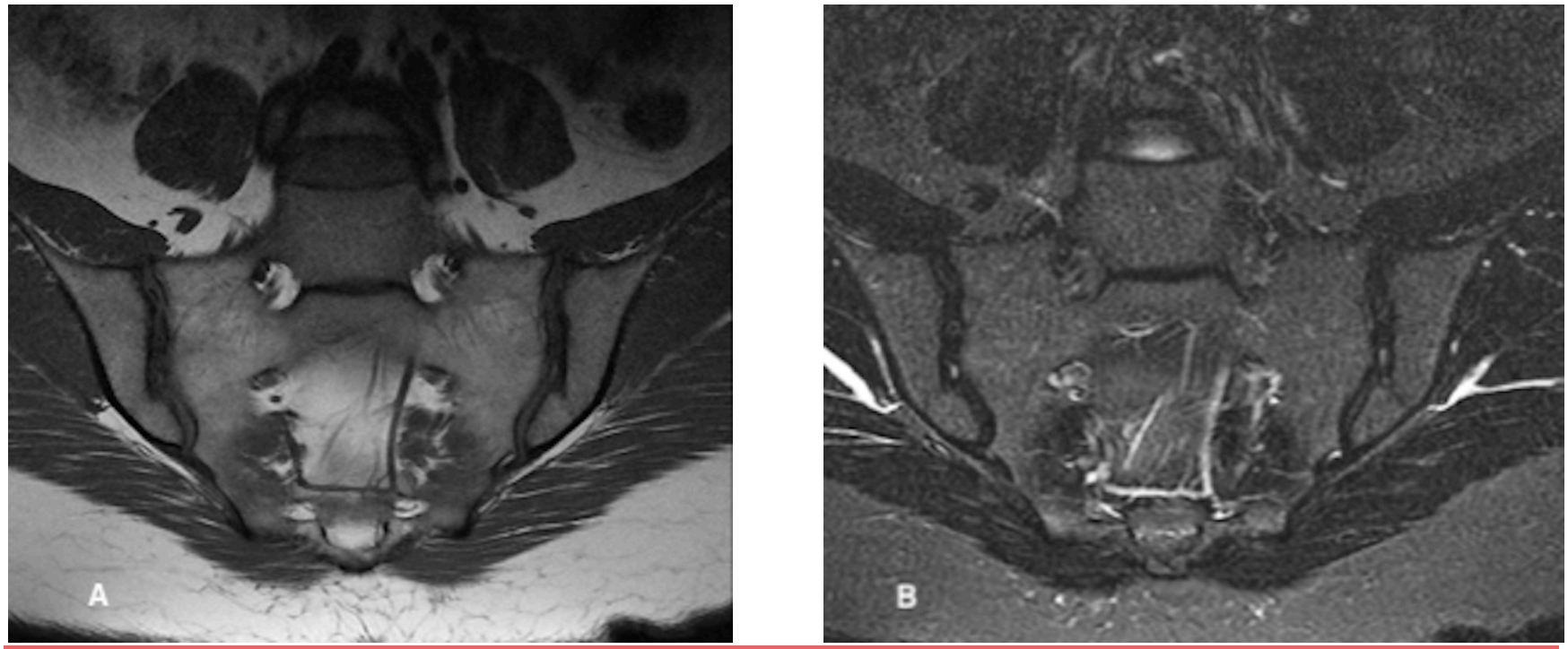
Basing MRI diagnosis solely on the presence of BME may lead to over-diagnosis as many conditions may cause a similar appearance on MRI. Additionally, in the absence of BME, the diagnosis may be overlooked despite the presence of structural changes. The indispensable role of MRI in the diagnostic work-up of axial SpA, accompanied by the many potential pitfalls discussed herein, led to the proposed categorization system for MRI reporting in clinical practice. In addition the system introduces a universal vocabulary for communication between radiologists and clinicians, and within each group. This can reduce misinterpretation and miscommunication of the MRI report.

Differential diagnosis for BME on MRI of sacroiliac joint

Category	Description
Normal	Possible related to normal mechanical stress
Anatomic Variants	Accessory sacroiliac joints, Transitional Lumbosacral Vertebra (Predispose to mechanical stress and premature degeneration)
Spondyloarthritis	
Alternative Rheumatic & Metabolic Disease	Degeneration/Osteoarthritis Osteitis Condensans Ilii Crystal Disease Paget's Disease Diffuse Idiopathic Skeletal Hyperostosis SLE Bechet's Disease Familial Mediterranean Fever Insufficiency Fracture Hyperparathyroidism
Trauma	Fractures including Stress Fractures Peripartum
Septic Sacroiliitis	
Malignancy	Leukemia, Lymphoma, Sarcoma, Metastatic
Other	Imaging Artifact

Proposed MRI Reporting Categorization System

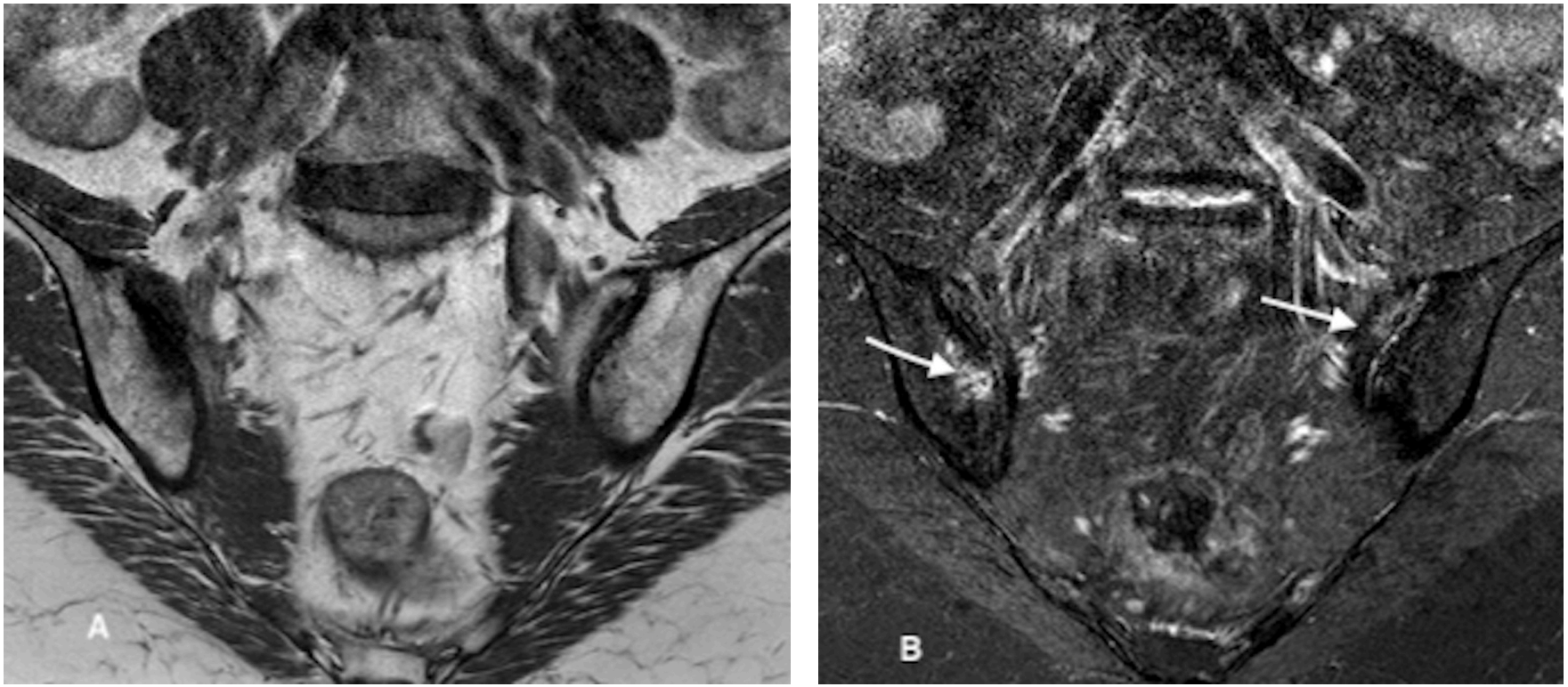
Category	Description
1	**Normal**
2	**Alternate diagnosis** E.g. Osteoarthritis (degeneration), DISH, OCI, stress fracture, insufficiency fracture, septic sacroiliitis, etc.
3	**Indeterminate findings (not diagnostic for sacroiliitis)** E.g. Minor subchondral BME, cortical irregularity without erosions, single erosion, isolated mild enthesitis, capsulitis.
4	**Sacroiliitis** A. Acute (Inflammatory): Osteitis/BME, enthesitis, capsulitis and/or synovitis **B.** Chronic (Structural changes): subchondral sclerosis, erosions, peri-articular post-inflammatory fat metaplasia, new bone formation, bony bridges / ankylosis **C.** Acute-on-Chronic: Active sacroiliitis with structural changes



32 year-old female with 10 year history chronic inflammatory back pain with normal (a) Semi-Coronal T1and (b) STIR of the sacroiliac joints demonstrating maintained joint spaces, intact subchondral bone plate and normal periarticular marrow signal intensity.

Category 1: Normal.

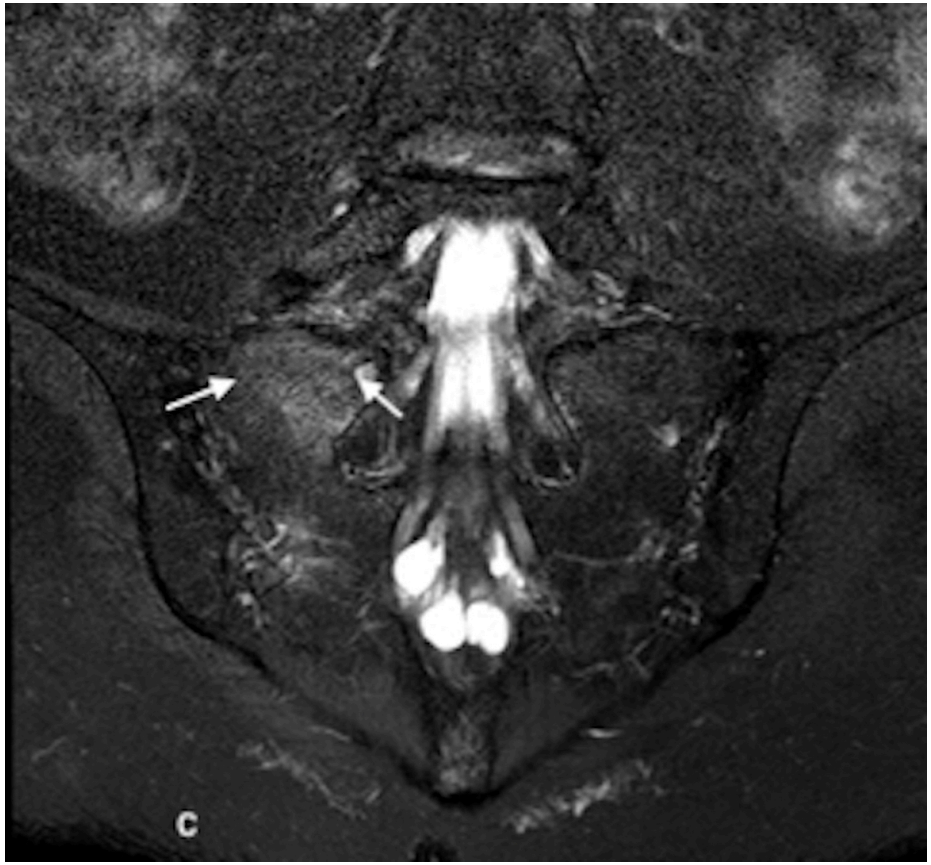
There are no abnormal findings of spondyloarthritis or alternative diagnosis.

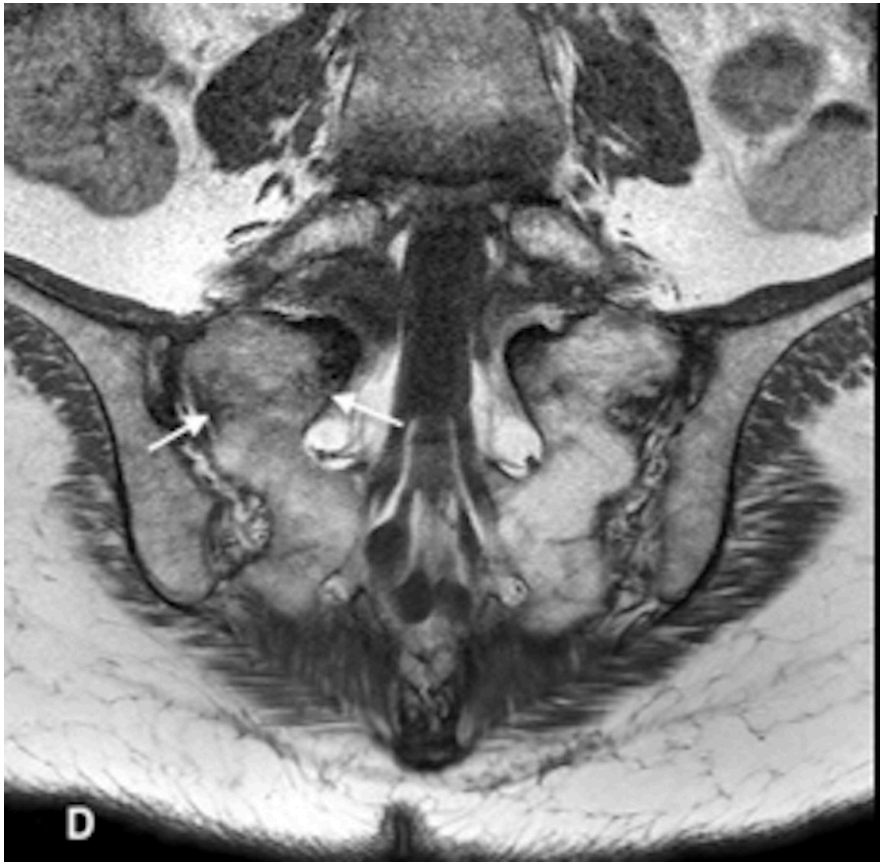


54 year-old female referred with inflammatory back pain, history degenerative disc disease, fibromyalgia. (a) Semicoronal TI and (b) STIR images demonstrating bilateral joint space narrowing of the sacroiliac joints with associated mild to moderate subchondral bone marrow edema along the anterior iliac aspect of the right SI joint and anterior sacral aspect left SI joint (arrows), without evidence of erosive disease or fat metaplasia. Features are in keeping with degenerative disease.

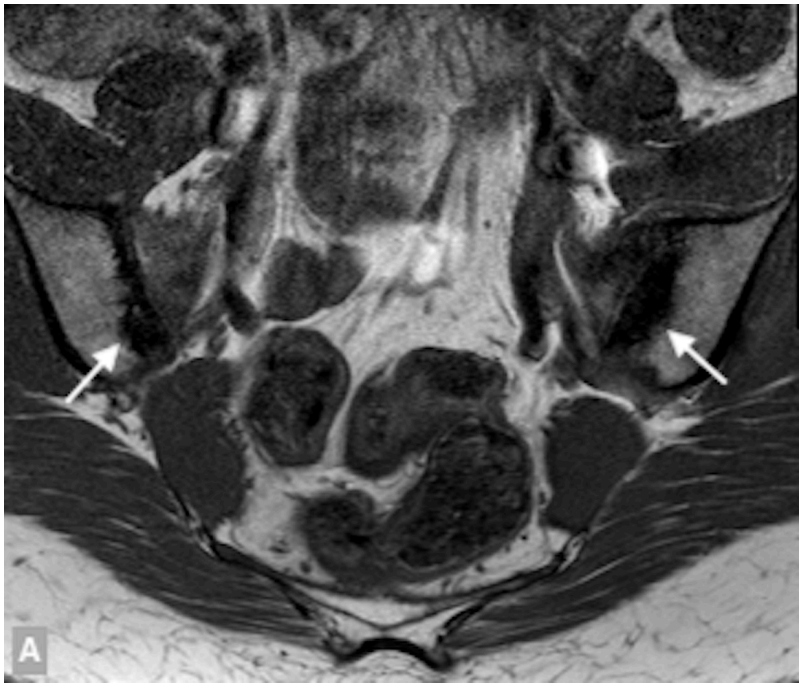
Category 2: Alternate diagnosis.

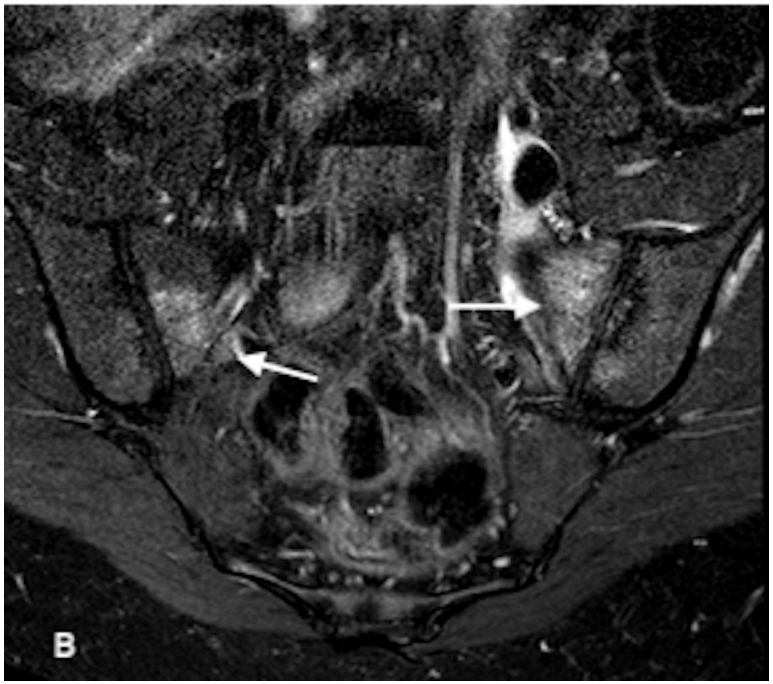
The MRI demonstrates features consistent with an alternate diagnosis and which may explain the patient's symptoms. Alternative diagnosis include degenerative disease, OCI, fractures and infection (see alternative diagnosis section). Findings have to be reviewed in conjunction with patient's presentation and clinical findings. Review of prior imaging may be helpful, e.g. prior CT examinations which may have been performed for alternate reasons, and may provide useful structural assessment of the sacroiliac joints to supplement the findings on MRI.





Additional image same patient, (c) Semicoronal STIR, demonstrates localized bone marrow edema (arrows) along the superior right alae extending to involve the body of the first sacral vertebra with associated traversing low signal intensity line (small arrows) and confirmed on semicoronal T1 (d) , representing an insufficiency fracture.

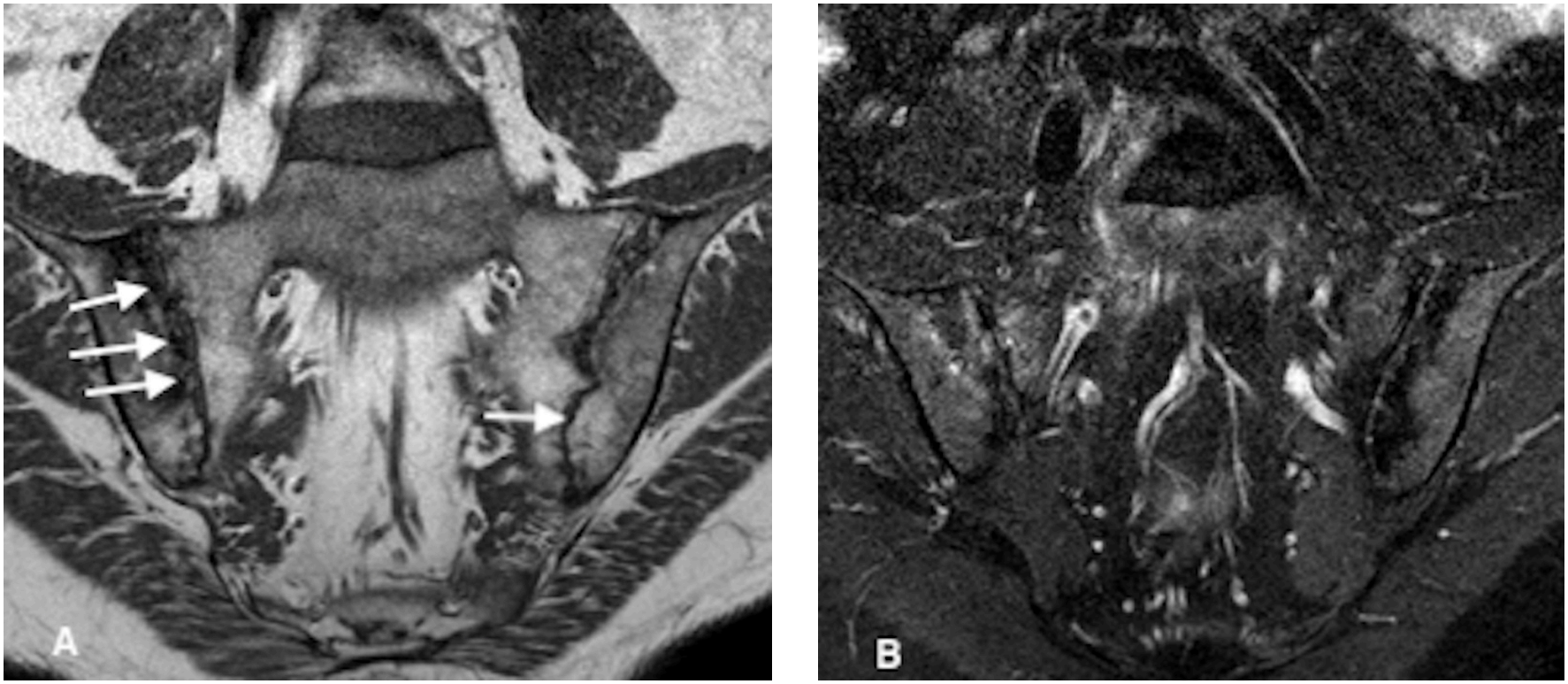




34 year old female with 2 year history inflammatory back pain. Semi-coronal (a) T1 sequence demonstrate moderate subchondral sclerosis present on the iliac aspect anteriorly (arrows), mild joint space loss without erosive disease, (b) STIR -prominent subchondral bone marrow edema, left greater than right without erosions, capsulitis or enthesitis identified. Imaging is non-diagnostic without additional clinical information. The imaging differential is OCI with bone marrow edema related to a recent additional mechanical stress such as postpartum changes, OCI with superimposed sacroiliitis is less likely but remains within the differential.

Category 3: Indeterminate.

The MRI demonstrates findings that may be suspicious for sacroiliitis but are not diagnostic and do not fulfill one of the other categories. Findings may include isolated findings such as minor subchondral BME, cortical irregularity without erosions, a single erosion on one image without additional findings, isolated mild enthesitis, or isolated capsulitis. Allows the interpreter the option of calling such findings "indeterminate" rather than attributing a diagnosis when faced with uncertainty. These patients can be reassessed clinically, and follow-up imaging performed at 6-12 months if there is ongoing clinical concern. This timeline was selected as studies have demonstrated little change over short term interval followup with few patients going from a negative MRI to a positive study. 6-12 months timeline may also allow additional clinical features to become apparent or presenting symptoms to resolve.



24-year-old female with mixed mechanical and inflammatory back pain, negative HLA-B27 and normal inflammatory markers, but chronic bilateral iritis. Semi coronal (a) and (b) STIR demonstrate narrowed sacroiliac joint spaces bilaterally, with bilateral extensive erosive disease (arrows) on both sides of the articulation but without bony ankylosis. Bilateral post-inflammatory fat metaplasia of moderate severity is seen. Asymmetrical, predominantly right-sided, subchondral bone marrow edema of moderate severity. Features are is in keeping with acute-on-chronic sacroiliitis.

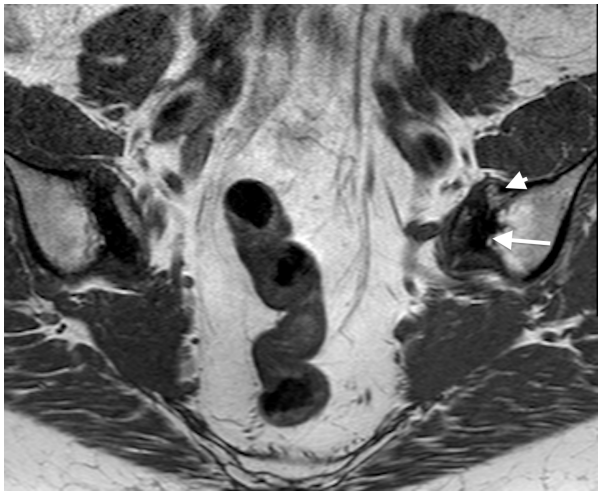
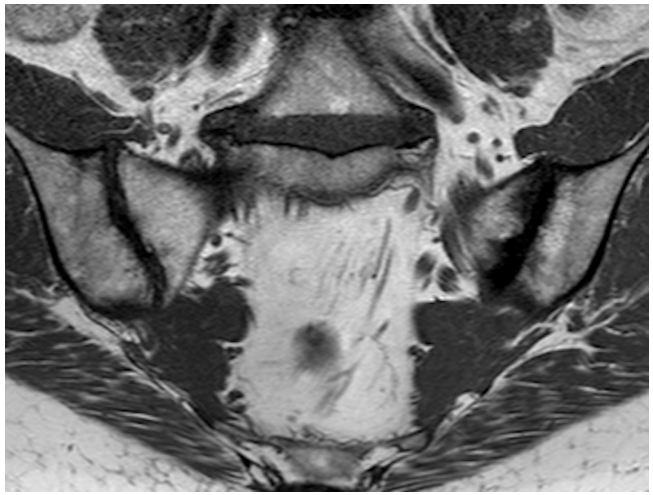
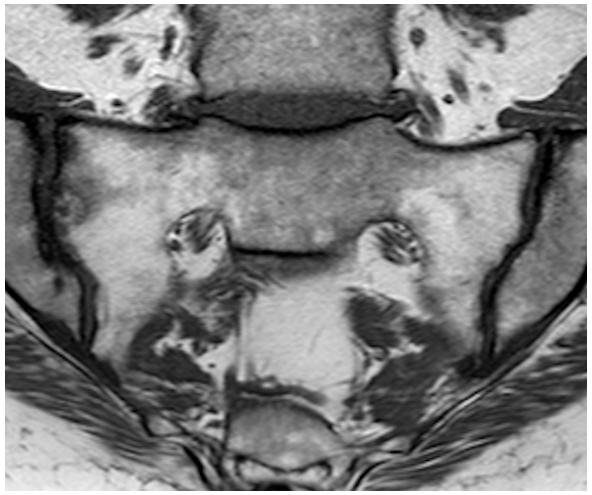
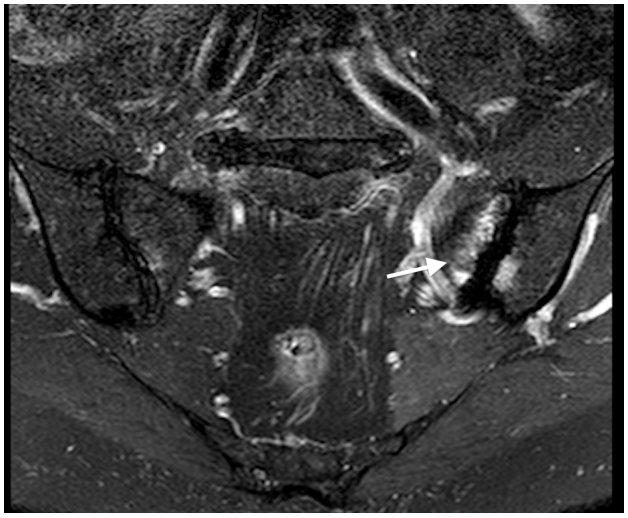
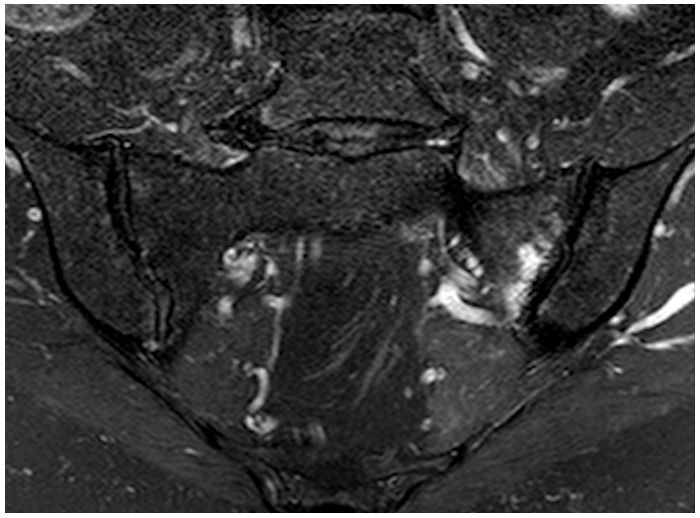
Category 4: Sacroiliitis.

Findings are consistent with the presence of acute (active inflammation), chronic (structural changes), or acute-on-chronic sacroiliitis in the appropriate clinical context and after the exclusion of category 2 pathologies.

Notes

Clinical Case Challenge Answers

Case 1

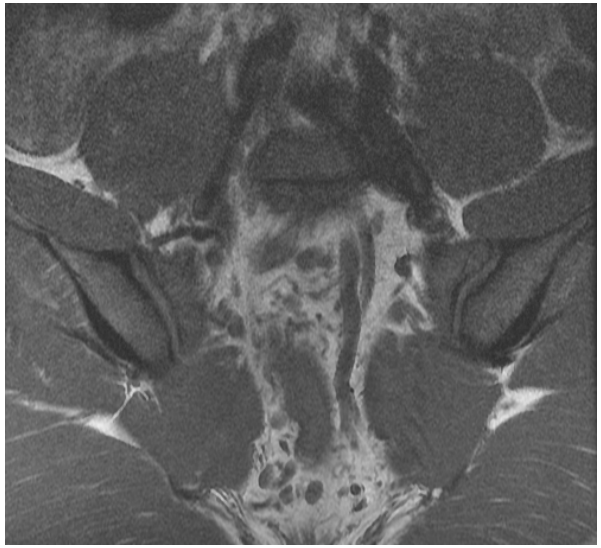
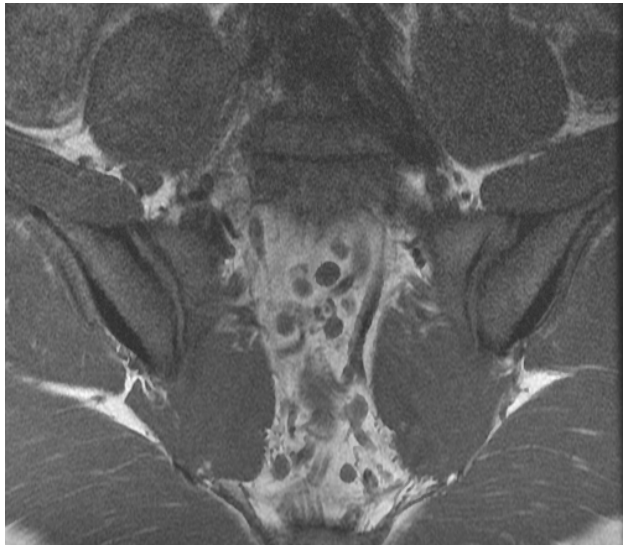
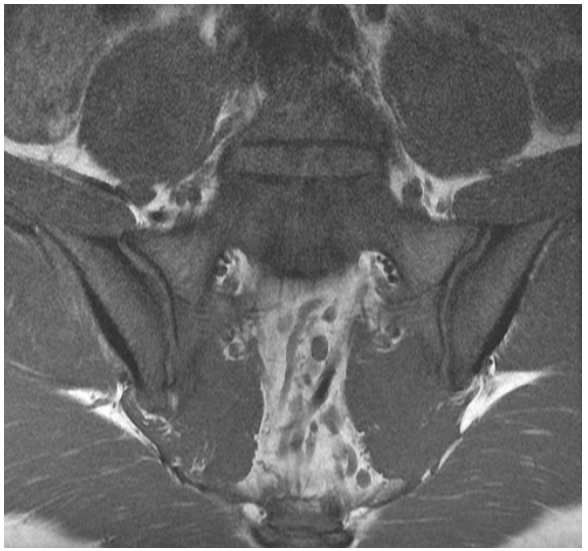
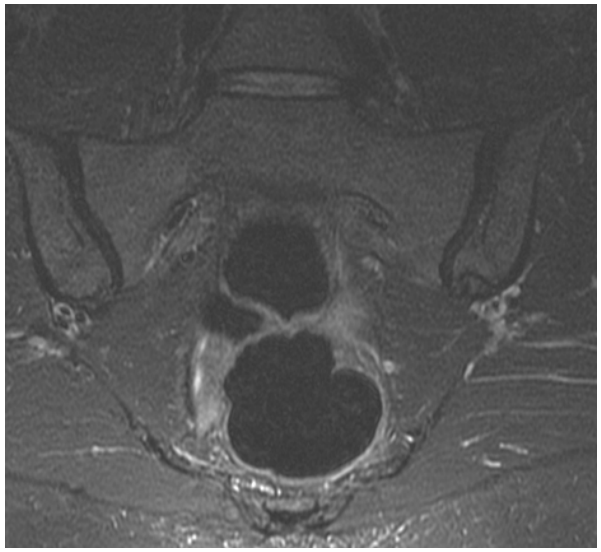
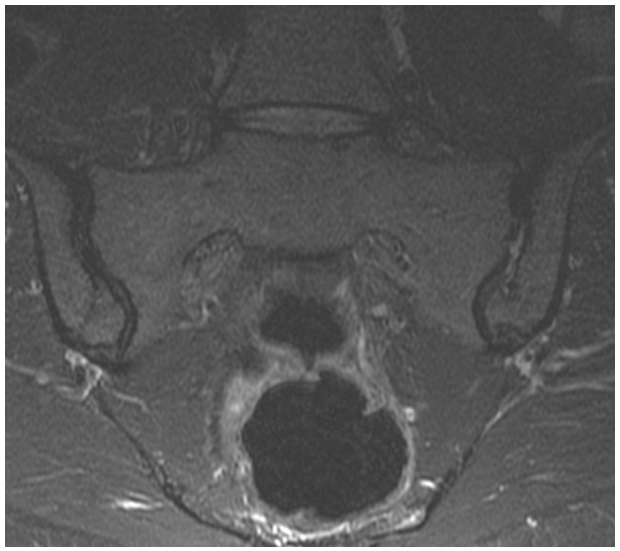
51 yr old female, longstanding inflammatory type back pain with recent worsening .

Semicoronal T1 (top row) and STIR sequences MRI SIJs (bottom row)

There is bilateral SIJ space lost anteriorly, returns to relatively normal width by mid SIJ (top right). Low subchondral signal intensity is present bilaterally (arrow, top left) with minor adjacent left osteophyte (arrowhead). There is mild to moderate subchondral bone marrow edema most pronounced anteriorly on left sacral aspect articulation (arrow, bottom left). No erosions are seen.

Diagnosis: Degenerative disease SIJs (joint space loss, subchondral sclerosis, mild edema which is typically more pronounced on the sacral aspect joint with a gradual return to normal imaging appearance by mid-articulation.

Case 2

21 male with new onset IBP, family history AS .

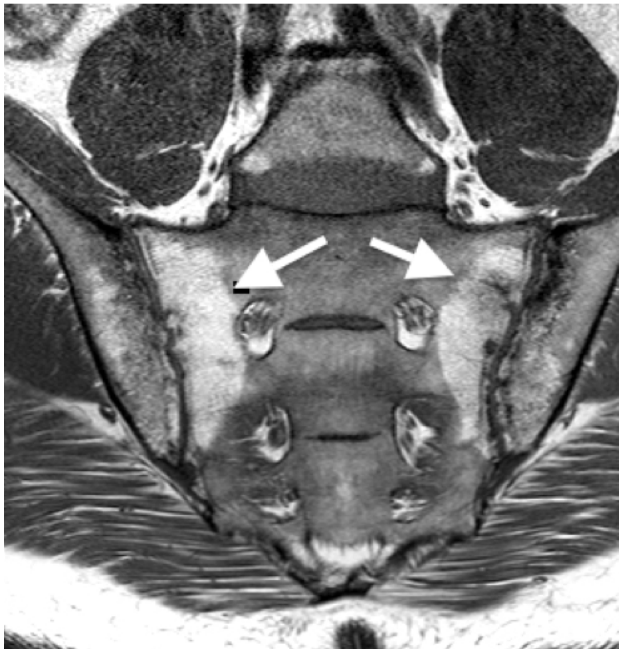
The remainder SIJs and whole spine imaging were normal.

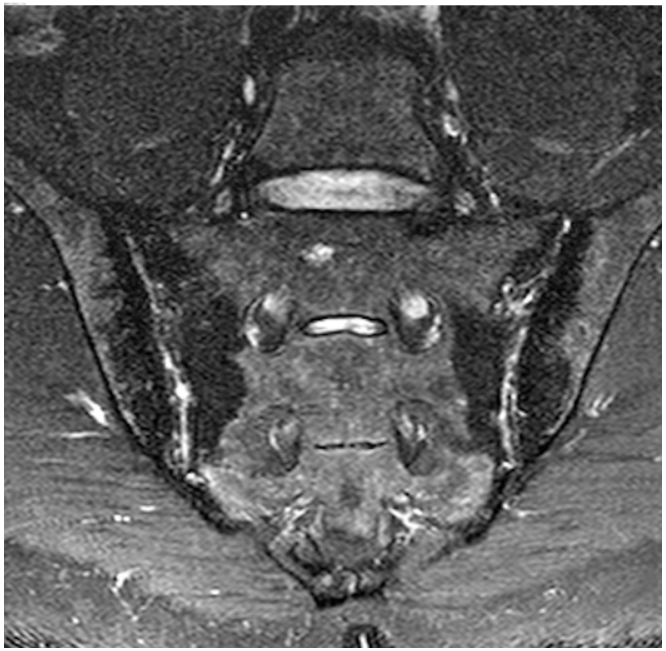
Semicoronal T1 (top row) and STIR sequences MRI SIJs (bottom row)

The SIJs are normal

Diagnosis: Normal MRI study. MRI may be normal in early disease. Repeat clinical assessment at 6 months is advised and if ongoing clinical concern a repeat MRI can be performed.

Case 3



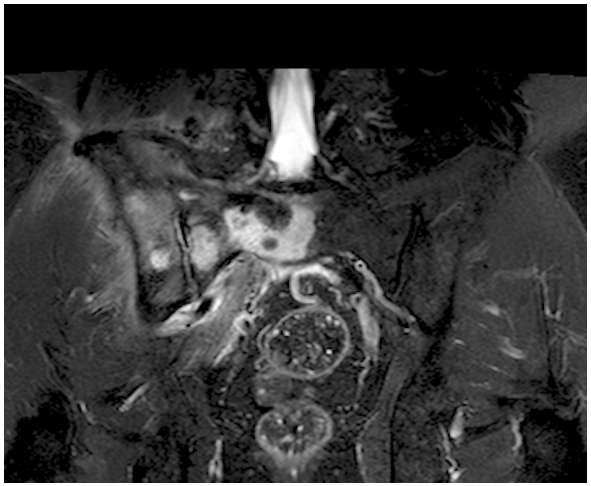


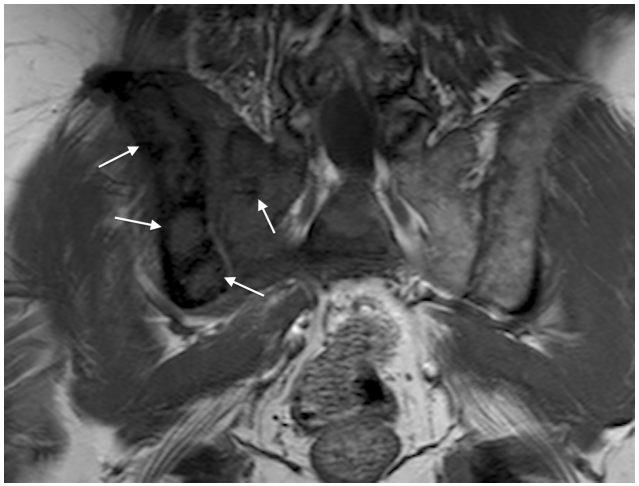
MRI SIJ in a 24y F, HLA positive, Cor T1 (left image) and Cor T2FS (right image) demonstrate bilateral periarticular fat, more pronounced on the sacral aspect, with defined margins (arrows). Note the normal marrow signal mentally at the level sacral foramina. Note the fat is high signal on T1 and becomes low signal on T2FS (fat saturated ssequence). Bilateral extensive erosions and small bilateral SIJ effusion on the Cor STIR

Diagnosis:

Chronic sacroiliitis consistent with axial SpA

Case 4



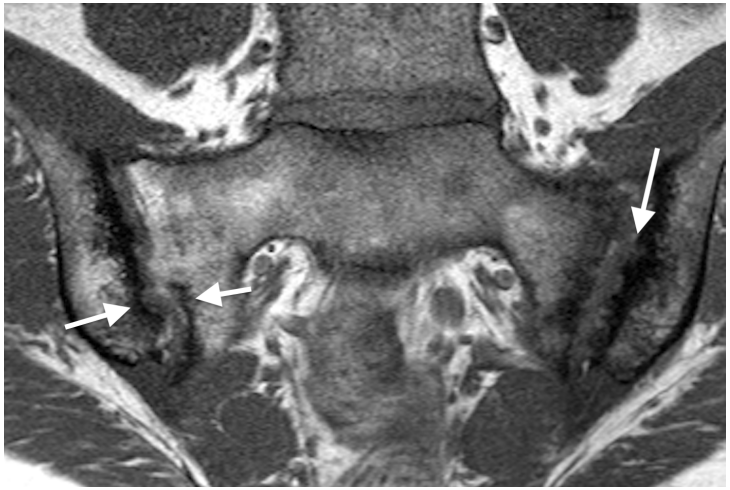


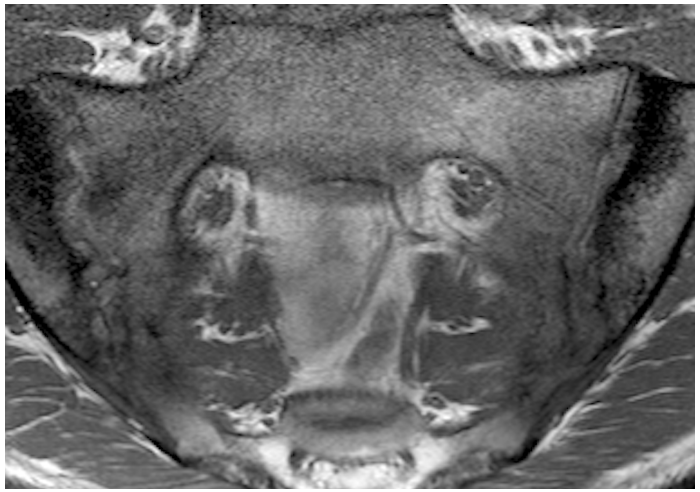
Coronal STIR (left image) and T1. Coronal to pelvis and not semicoronal to SIJs. Withheld history is that of lung cancer. Demonstrates right iliac and sacral diffuse bone marrow edema with discrete lesions (arrows on T1). Right iliac cortical thickening and additional edema in surrounding soft tissues. Normal left SIJ

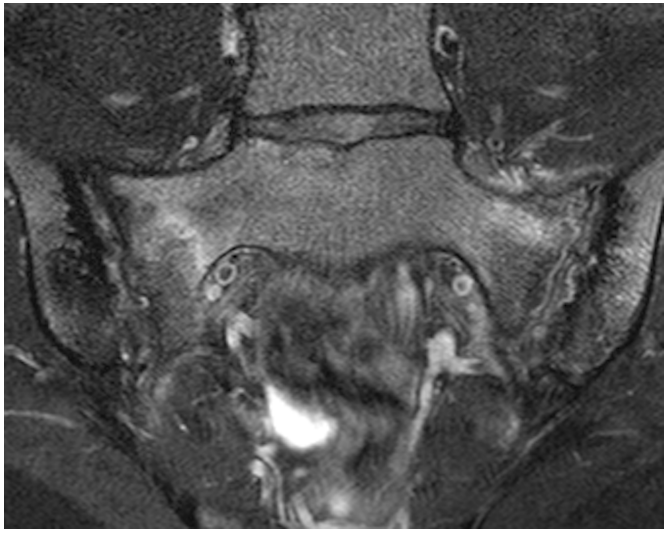
Diagnosis:

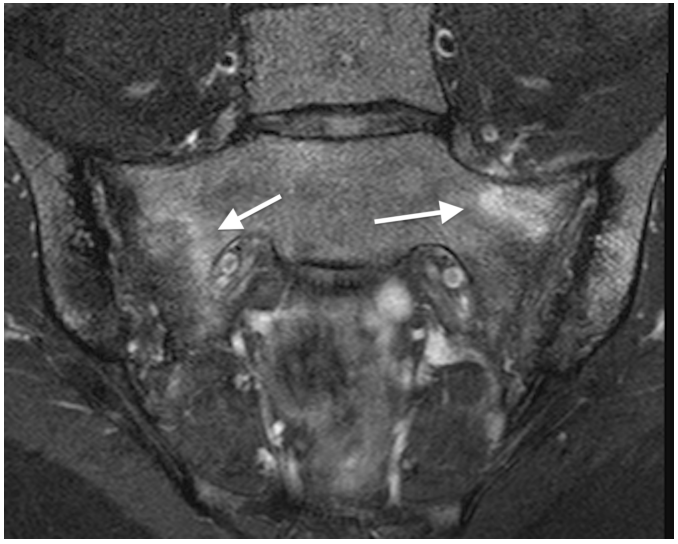
Diffuse bone metastatic disease

Case 5







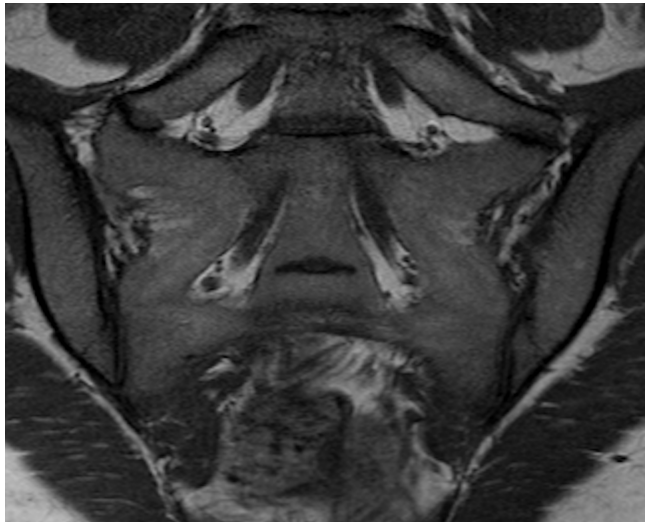


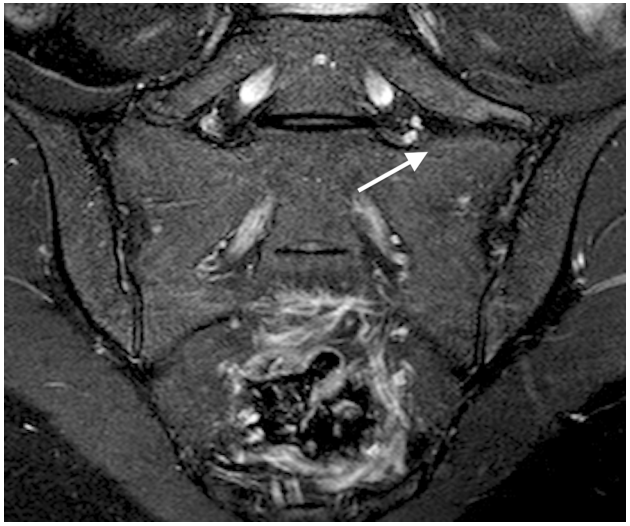
Semicoronal T1 (top) and STIR (bottom row) sequences.
Sacroiliac joint spaces are widened bilaterally, with extensive bilateral erosive disease most pronounced on the iliac aspect (arrows top left) with related mild to moderate subchondral sclerosis (low signal T1 and STIR). There is extensive osteitis related to both aspects of the articulation more pronounced on the sacral aspect (arrows bottom left).
Mild capsular thickening superior aspect left SIJ, capsulitis.

Diagnosis:

Acute on chronic sacroiliitis

Case 6



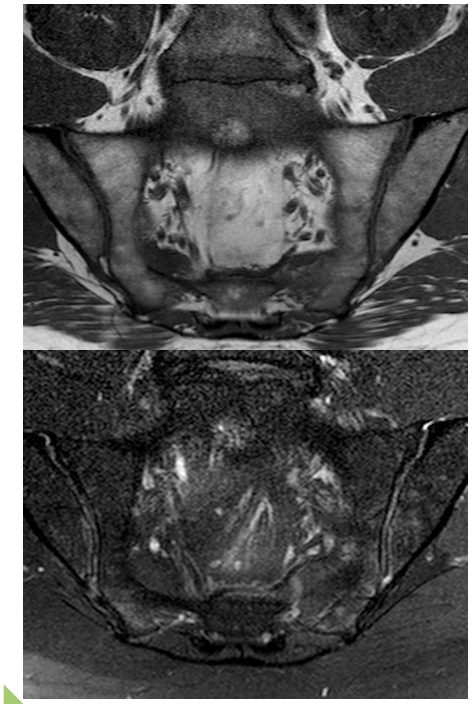


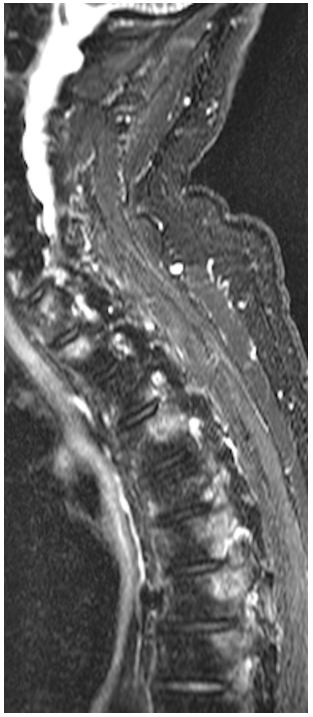
Semicoronal T1 (top) and STIR (bottom row) sequences.
Transitional L5 vertebrae with enlarged transverse processes articulating with the superior sacrum at a synchondrosis, Castellvi type II. Mild degenerative changes on the right and moderate left synchondrosis with related left-sided bone marrow edema (arrow).

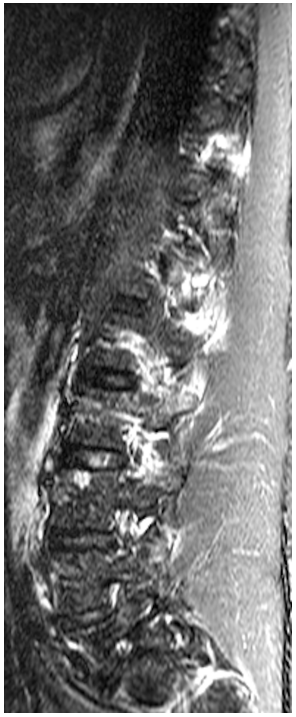
Diagnosis:

Castellvi type II transitional lumbosacral vertebra with Bertolotti syndrome.

Case 7







Semicoronal T1 and STIR SIJs and parasaggital STIR spine
Normal SIJs. Multilevel osteitis thoracic and lunar spine with costotransvers and costovertebral osteitis consistent with acute spondylitis

Diagnosis:

Acute spondylitis/axial SpA. In a small % of patients MRI of the SIJs are normal and disease is initially limited to the spine

Notes

Notes

Further Reading & References

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BACKCOVER

Practical comprehensive visual guide to the complex imaging appearance of axial spondyloarthritis in clinical practice.This atlas is a *collaboration* between diagnostic imaging and rheumatology meeting the educational needs of both rheumatologists and radiologists by proving an *extensive array of images* that illustrate the *diverse pathology* that occurs in the SIJ and spine in patients with axial SpA. While the primary focus is on MRI there are also examples of plain radiographic and CT findings to highlight the comparative advantages and disadvantages of different imaging modalities. Additional images also illustrate the *potential pitfalls* of MRI and the wide imaging and clinical *differential diagnosis* that can be confused with axSpA.

- **User friendly with clear and concise descriptions of pathology with *over 220 images*.**
- **Over 100 images of normal imaging anatomy**
- **State of the art imaging.**
- **All cases are derived from rheumatology referral and offer excellent insight into everyday practice.**
- **Supported by reference drawing, summary tables.**
- **Includes a *clinical case challenge* with multiple MRI cases for review.**
- **Provides an in-depth review of a new *MRI reporting system* for for axial SpA in clinical practice.**