

IMAGING ATHLETIC PUBALGIA AND CORE MUSCLE INJURY

RELEVANCE FOR SPORTS MEDICINE

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INTRODUCTION

Refractory groin pain related to activity is commonly encountered in the sports medicine, orthopaedic surgery, general surgery and now radiology communities. This clinical scenario, often termed athletic pubalgia, is now generally accepted as a syndrome of musculoskeletal injury with acute, chronic and acute on chronic variations. While athletic pubalgia lesions are often associated with high level athletes, this injury group can be encountered across many age and gender demographics and in recreational athletes or casual fitness enthusiasts and even in the setting of occupational medicine¹. As understanding

of the complex musculoskeletal anatomy about the pubic symphysis, sometimes termed the pelvic core, has increased, accurate diagnosis and successful treatment of specific athletic pubalgia lesions or core muscle injuries has dramatically increased. Accurate clinical history and physical examination often generate suspicion for athletic pubalgia, but there are numerous musculoskeletal, visceral, gynaecologic and urologic confounders for groin pain, with the most frequently encountered being internal derangements of the hip. Therefore imaging, particularly MRI, plays a vital role in accurately identifying and delineating athletic pubalgia and core muscle

injuries². This review will help the reader appropriately prescribe and protocol MRI for activity-related groin pain and will outline patterns of MRI findings most commonly seen in patients with athletic pubalgia.

ANATOMY AND BIOMECHANICS

The bony pelvis includes the ilium, ischium and pubis bilaterally, collectively termed the innominate bones, and the sacrum and coccyx posteriorly. The innominate bones meet at midline anteriorly where numerous muscle and tendon attachments and the midline pubic symphysis form the centre of core injuries and athletic pubalgia. This pubic symphysis is a fibrous joint with

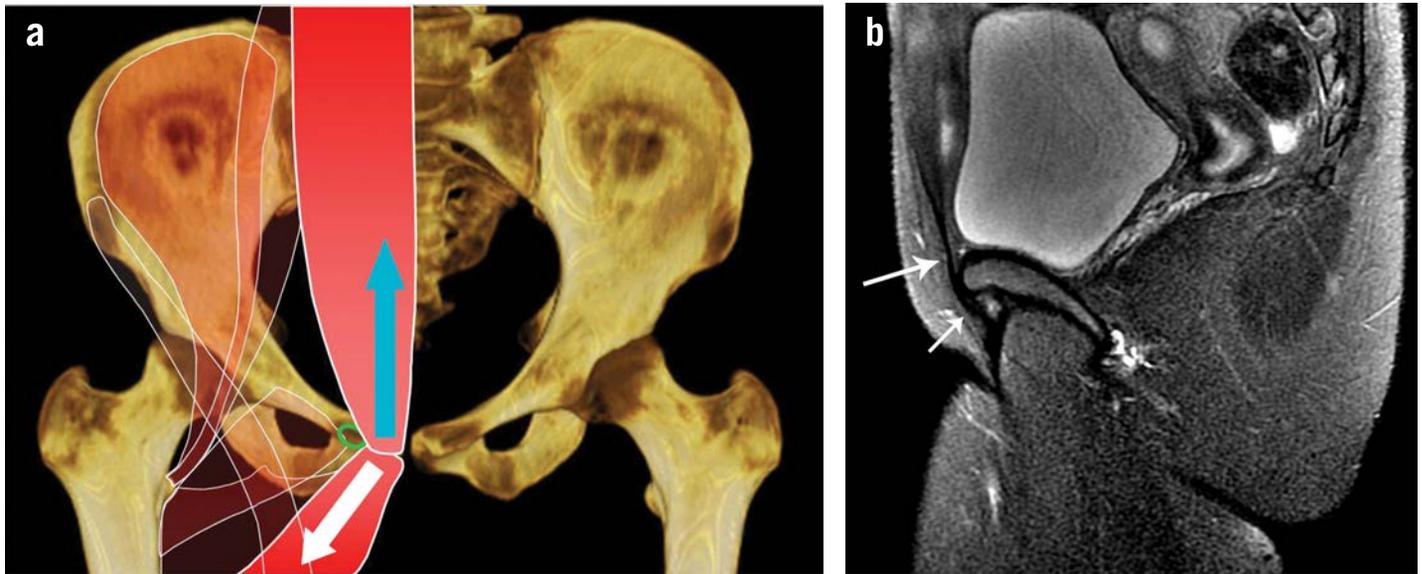


Figure 1: a) A diagram of the pelvic core from a frontal aspect showing the tangential vectors of force produced with contraction of the rectus abdominis (blue arrow) and the adductor longus (white arrow). Note the relation to the superficial inguinal ring (green ring). b) A sagittal T2-weighted fat suppressed image from an athletic pubalgia MRI at the level of the pubic tubercle, 2 cm off midline, showing the relation of the normal rectus abdominis (large arrow) and adductor longus (shorter arrow).

limited motion in the craniocaudal direction and thus distributes shear forces to the innominate bones and muscle attachments during ambulation. A fibrocartilage articular disc is present between the pubic bones and there are four pubic ligaments spanning the symphysis, including the broad arcuate ligament along the anterior, inferior margin of the joint and attaching on the symphysis capsule, both pubic tubercles and providing a superficial attachment site for regional muscles and tendons³. The paired rectus abdominis muscles play an integral role in stabilising the muscular core, and blend with the adductor longus origins to form a dense, fibrous aponeurosis attaching broadly to the anterior pubic bones, and particularly the pubic tubercles. These left and right rectus abdominis/adductor aponeuroses (RA/AL aponeuroses) meet at the midline pubic symphysis where there is some variability from a small vertical raphe to cross interdigitation forming a dense midline pubic plate. Other adductor muscles originate in close proximity to the RA/AL aponeurosis including the pectineus anteriorly, and the adductor brevis, gracilis and adductor magnus posteriorly. Immediately lateral to the RA/AL aponeurosis is the superficial

inguinal ring, an anatomic nuance that may have contributed to confusion between musculoskeletal injuries and hernias. Just cephalad and lateral to the superficial ring, the external oblique blends with the lateral margin of the rectus abdominis, sometimes termed the external oblique aponeurosis, tracking superficial to the inguinal canal (Figure 1)⁴.

The rectus abdominis creates superoposterior tension, while the adductors create inferoanterior tension during core rotation and extension. This tangential opposition along with the broad attachment of the aponeurosis is essential for anterior pelvis stability. Disruption or injury to either component leads to abnormal biomechanical forces on the opposing component leading to instability of the muscular core and many of the lesions encountered in the setting of athletic pubalgia. Ligamentous injury from pregnancy or axial loading trauma, or detachment of the RA/AL aponeurosis from its osseous attachment can lead to instability of the pubic symphysis itself, rendering the joint susceptible to osseous stress response and even osteoarthritis. Unilateral injuries or instability at the pubic symphysis can alter gait mechanics and

KEY POINTS

- *Athletic pubalgia and core muscle injury refer to a group of musculoskeletal lesions centred around the pubic symphysis manifesting clinically as activity-induced groin pain.*
- *MRI is the standard imaging modality for identification and delineation of athletic pubalgia lesions, and a non-contrast athletic pubalgia MRI protocol is recommended.*
- *The most commonly encountered injuries in the setting of athletic pubalgia involve the rectus abdominis/adductor aponeurosis or the midline pubic plate.*
- *Imagers should be aware of confounders for athletic pubalgia that may be remote from the pubic symphysis, including musculoskeletal and visceral pelvic lesions and internal derangements of the hip.*

TABLE 1

Sequence	FOV	Matrix	NEX	Slice thickness/gap (mm)	TR	TE	TI	Echo train
Coronal STIR	28-36 (both hips)	256 × 192	2 to 3	4 / 1	>2000	20-40	150	8
Coronal T1	28 (both hips)	256 × 256	1 to 2	4 / 1	400-800	minimum	N/A	N/A
Axial T2 fatsat	28 (both hips)	256 × 256	2 to 3	5 / 1	>2000	50-60	N/A	8
Coronal oblique PD	20	256 × 256	1 to 2	4 / 0.5	3000 (max)	25-30	N/A	4
Coronal oblique T2 fatsat	20	256 × 256	2 to 3	4 / 0.5	>2000	50-60	N/A	8
Sagittal T2 fatsat	20-22	256 × 256	2 to 3	4 / 0.5	>2000	50-60	N/A	8
Sagittal PD (optional)	20-22	256 × 256	2 to 3	4 / 0.5	>2000	20-30	N/A	8

Table 1: Non-contrast athletic pubalgia MRI for 1.5 Tesla, utilising a phased array torso coil centred over pubic symphysis. FOV=fields of view, NEX=number of excitations, TR=repitition time, TE=time to echo, TI=time to inversion, STIR=short tau inversion recovery, PD=proton density, N/A=not applicable.

ultimately predispose patients to ipsilateral lower extremity injuries at the hip, knee and ankle⁵.

IMAGING TECHNIQUE

Ultrasound is a very useful diagnostic tool for the assessment of true inguinal hernias, offering the potential for dynamic imaging e.g. during a valsalva manoeuvre. While musculoskeletal ultrasound techniques can accurately identify tendinopathies and muscle tears, the modality currently falls short in the identification of inflammatory and degenerative bony processes. MRI is currently considered the most useful imaging modality for athletic pubalgia, as we now know that the majority of lesions involve muscle, tendon and bone and MRI is optimal for simultaneous assessment of osseous and soft tissue structures⁶. An MRI protocol for evaluation of athletic pubalgia should include sequences covering the entire bony pelvis as well as higher resolution sequences dedicated to the pubic symphysis region. A relatively late model 1.5 Tesla MRI unit with a phased array, multichannel torso coil is an adequate setup to generate high quality images of the pelvic core. 3 Tesla scanners can offer advantages in signal and resolution over a larger field of view, but are also prone to

more imaging artifacts. Imaging is acquired in standard coronal, sagittal and axial planes, but coronal oblique imaging plane prescribed along the anterior margin of the iliac crest form a sagittal localiser sequence (along the arcuate line of the pelvis) is important for optimal assessment of the RA/AL aponeurosis and its attachment on the pubic tubercle. Large field of view sequences should cover from the umbilicus to the mid thigh, and smaller field of view sequences should be centred on the pubic symphysis, extending through the pubic rami bilaterally. Use of intravenous contrast has been proposed, but generally adds little in the identification and delineation of most athletic pubalgia lesions, and a non-contrast protocol at 1.5 Tesla can be considered standard (Table 1)⁷.

ATHLETIC PUBALGIA LESIONS ON MRI

An algorithm for assessment of the musculoskeletal core of the pelvis can begin at the midline pubic symphysis, and this joint is inherently impacted by many athletic pubalgia lesions. When evaluating the pubic symphysis, any subchondral bone marrow oedema, bony sclerosis, cystic changes or even marginal osteophyte formation can be termed osteitis pubis. However, this term alone is not enough to convey

observed pathology at MRI. Active osteitis pubis should include at least an element of subchondral bone marrow oedema spanning the joint anterior to posterior on an axial, fat-suppressed sequence⁸. This bone marrow oedema is often asymmetric and can extend into any of the pubic rami indicating osseous stress response being transferred toward the innominate bones, but should be distinguished from subenthesis marrow oedema at the pubic tubercle sometimes encountered in the setting of RA/AL injury without osteitis pubis at the symphysis. Osteitis pubis can be aggressive, with subchondral osseous resorption likely related to repetitive impaction at an unstable pubic symphysis. Osteitis pubis can also be chronic and indolent with bony productive change on radiographs, but no subchondral bone marrow oedema, a scenario often observed in women with previous history of pregnancy. When there is osteophyte formation at the symphysis in either active, acute on chronic or simply chronic osteitis pubis, a symphyseal effusion is sometimes present with an overall MRI appearance of osteoarthritis at the symphysis. All of these observations should be reported, as the constellation of MRI findings will help the imager to understand the state of the pubic symphysis joint, and its relation to

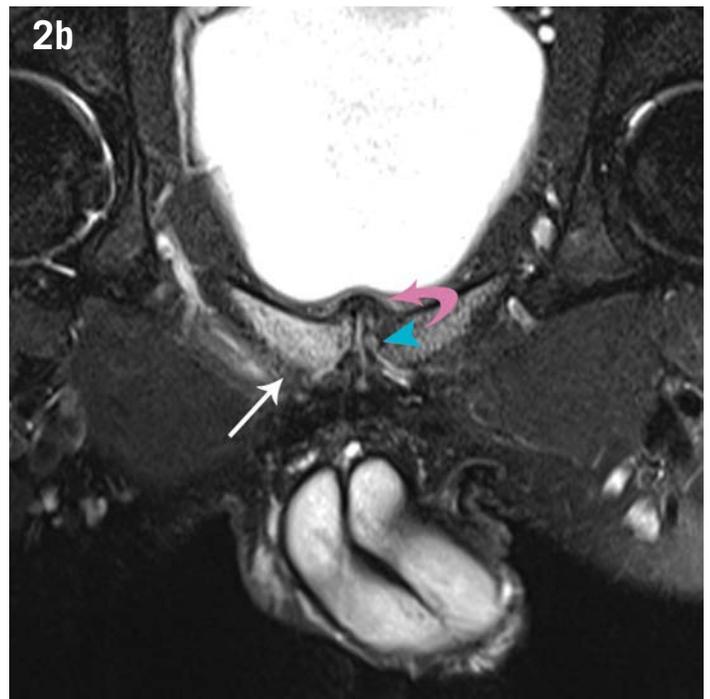
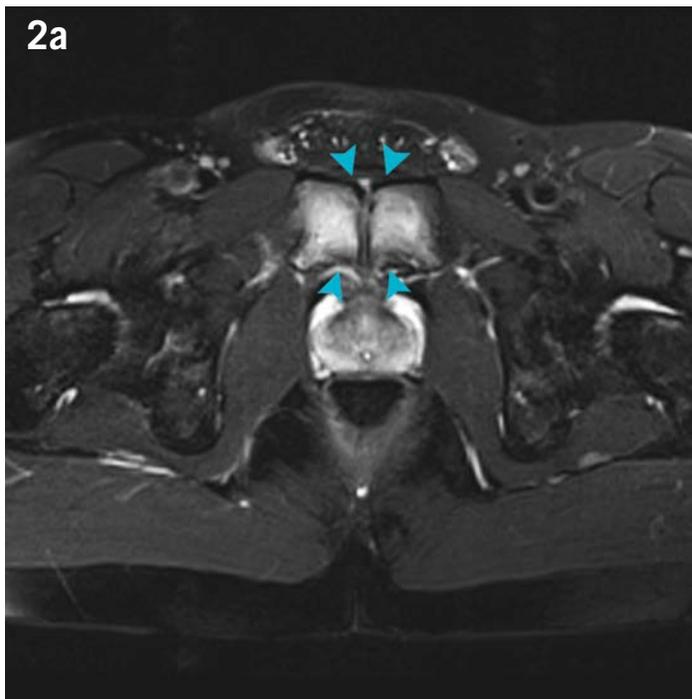


Figure 2: a) Acute osteitis pubis with extensive subchondral bone marrow oedema spanning the pubic symphysis anterior to posterior (blue arrowheads) on an axial T2-weighted fat-suppressed image in a female athlete 18 months postpartum. b) Acute on chronic osteitis pubis on a coronal oblique T2-weighted fat-suppressed image in a footballer with chronic right greater than left sided groin pain. There is bone marrow oedema (white arrow) indicating an acute component as well as subchondral cysts (blue arrowheads) and osteophytes (pink arrow) indicating chronicity.

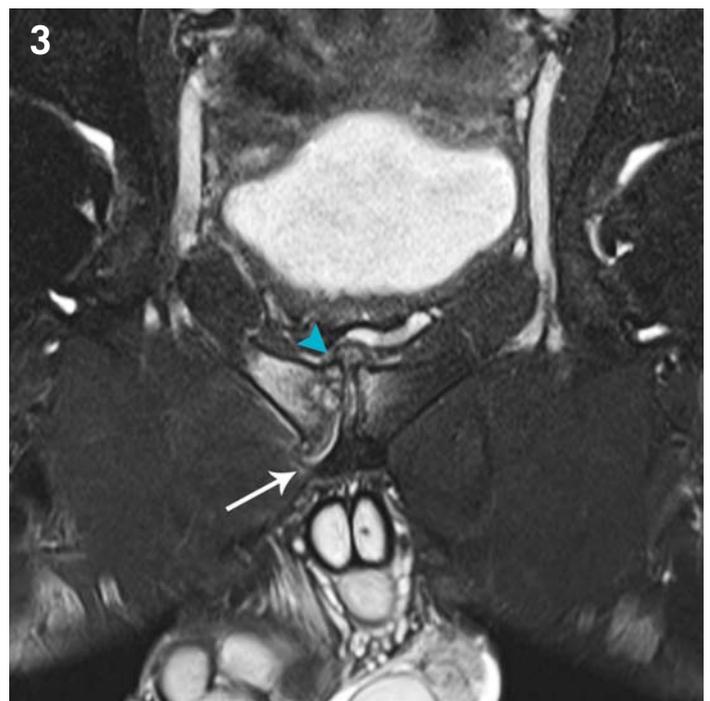


Figure 3: A T2-weighted fat-suppressed coronal oblique image from an athletic pubalgia MR protocol in a professional baseball player with right sided groin pain shows an MR secondary cleft (white arrow) with an inferolateral extension of the T2 hyperintense primary cleft, as well as acute on chronic osteitis pubis (blue arrowhead).

surrounding soft tissue lesions. Osteitis pubis and its various patterns is associated strongly with RA/AL aponeurosis lesions as well as midline pubic plate lesions, and more weakly with chronic ligamentous injury at the symphysis⁹. If there is suspicion for ligamentous instability at the pubic symphysis, weight-bearing ‘flamingo view’ radiographs can be obtained to assess for an unstable offset at the symphysis. Pain from osteitis pubis can often be treated effectively with therapeutic symphyseal injection, but the likelihood of recurrence exists without repair of the underlying destabilising lesion.

In fact, improvement of osteitis pubis on a postsurgical MRI has been used as an indicator of a positive surgical outcome (Figure 2)¹⁰.

The secondary cleft was initially described at fluoroscopic pubic symphysis injection as inferolateral extension of the vertical primary cleft within the pubic symphysis, and has been adapted to T2 hyperintense signal with the same curvilinear morphology on fluid sensitive MRI sequences. When unilateral, observation of a secondary cleft correlates strongly with the situs of unilateral or

asymmetric activity-related groin pain. Secondary clefts are commonly associated with asymmetric osteitis pubis, and have been proposed as indicative of an ipsilateral RA/AL aponeurosis lesion (Figure 3)¹¹.

MRI has shown us that some athletic pubalgia lesions originate at midline and propagate either unilaterally or bilaterally. These midline core muscle injuries have been termed midline rectus abdominis/adductor aponeurotic plate lesions, or more recently, midline pubic plate lesions. The point of this terminology is to distinguish these true midline injuries from those with

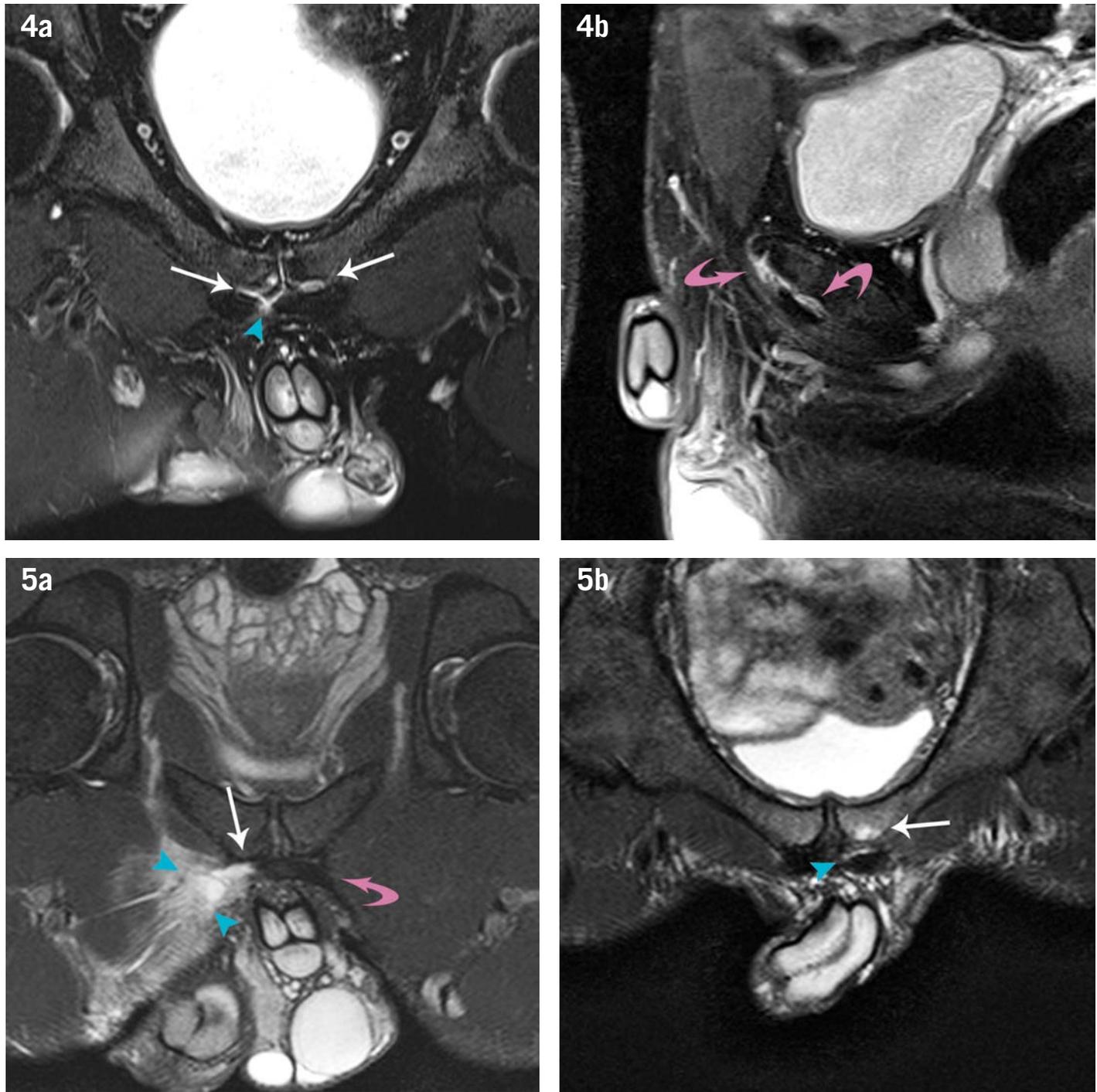


Figure 4: Coronal oblique (a) and sagittal (b) T2-weighted fat-suppressed images from an athletic pubalgia MR protocol in a footballer with right greater than left sided groin pain shows a midline pubic plate lesion. The plate is lifted from the pubic tubercles bilaterally (white arrows) with the disruption extending from the midline symphysis. As is often the case, this lesion extends preferentially caudal into the adductor tendons on the side of greater pain (blue arrowhead). At midline, there is an elongated tenoperiosteal detachment of the pubic plate from the symphyseal capsule and the adjacent pubic rami (pink arrows).

Figure 5: Two coronal oblique T2-weighted fat-suppressed images in different athletes with unilateral rectus abdominis/adductor aponeurosis lesions. a) A very large, high grade tear in an American football player with acute right sided groin pain. The aponeurosis has been avulsed from the pubic tubercle (white arrow) with oedema extending well into the adductor compartment (blue arrowheads). Note the normal aponeurosis on the left (pink arrow). b) A lower grade, more chronic RA/AL aponeurotic detachment in a lacrosse player, with subenthelial bone marrow oedema at the pubic tubercle (white arrow) and a T2 hyperintense gap between the aponeurosis and the pubic periosteum (blue arrowhead). RA/AL=rectus abdominis/adductor.

an origin unilaterally near the superficial inguinal ring, at the lateral edge of the rectus abdominis attachment on the pubic tubercle or at an adductor tendon origin. Midline pubic plate lesions often extend bilaterally but asymmetrically. In fact, it is common for a midline pubic plate lesion to extend into the rectus abdominis alone on one side but through the RA/AL aponeurosis and ultimately into the proximal adductor longus tendon on the other. These nuances should be reported at MRI as their delineation can contribute to appropriate treatment planning. On a sagittal MR image acquired at the midline pubic symphysis, there will often be a visible breach in the plate-like soft tissues superficial to the antero-inferior pubic symphysis with extension into its joint capsule. Coronal or coronal oblique MR images often show a confluent, bilateral secondary cleft, extending bilaterally. Sometimes the cleft extends all the way to the lateral edge of the RA/AL aponeurosis on one or both sides, suggesting a high grade lesion with complete aponeurotic detachment. Active osteitis pubis is very common in the setting of a midline pubic plate lesion. As for treatment, there is no clearly favoured therapy for midline pubic plate lesions, though surgical techniques aimed at repairing the propagation away from midline have been proposed with varying success (Figure 4)¹².

A unilateral rectus abdominis/adductor aponeurosis lesion is centred off

midline, and is the lesion most frequently encountered at MRI in athletes with a diagnosis of 'sports hernia'. Low grade and often chronic RA/AL aponeurosis lesions can manifest at MRI with simply asymmetric subenthesis bone marrow oedema at the pubic tubercle, indicating early aponeurotic detachment. Severe RA/AL aponeurosis lesions show a frank tear of adductor tendon origins from the aponeurosis with distal retraction into the thigh, a subsequently uncovered bony pubic tubercle, and soft tissue oedema extending proximal along or within a partially torn rectus abdominis muscle. With severe injuries, the pectineus and adductor longus tendons often avulse together, appearing as a hypointense, retracted tendon stump at MRI. When a RA/AL aponeurosis lesion extends to its lateral edge, the soft tissue injury can lead to a weakening of the posteromedial wall of the superficial inguinal ring on physical examination, a characteristic that has likely contributed to confusing terminology such as 'sportsman's hernia'¹³. With chronic RA/AL aponeurosis lesions, the rectus abdominis can atrophy, showing asymmetric decreased muscle bulk in cross section at the level of the pubic tubercle, a finding that can leave a more patulous superficial inguinal ring. In fact, true hernias are rare in this patient population, though they do occasionally occur and should be observed at MRI. RA/AL aponeurosis lesions are much more common in an athletic patient population

with activity-related groin pain however, and the RA/AL aponeurosis is positioned inferior and medial to the typical site of most mesh inguinal hernia repairs.

RA/AL aponeurosis lesions are also associated with osteitis pubis, though not as strongly as midline pubic plate lesions. There can be a unilateral secondary cleft, though its presence likely indicates extension of the RA/AL aponeurosis lesion to its medial edge. The pattern of adductor tendon involvement is variable at MRI, with instances of adductor longus hypertrophy, peritendinous oedema, interstitial tearing and complete avulsion¹⁴. Low grade, chronic RA/AL aponeurosis lesions can progress to high grade complete disruptions, and patients with a unilateral RA/AL aponeurosis lesion have a higher incidence of developing a contralateral RA/AL aponeurosis lesion compared to the general public¹⁵. Bilateral RA/AL aponeurosis lesions can be present simultaneously, but a midline pubic plate lesion with bilateral extension is more common. While many non-invasive and invasive therapies have been proposed for treatment of RA/AL aponeurosis lesions, very good outcomes have been published in the surgical literature with aponeurosis reconstruction or 'pelvic floor repair' (Figure 5)^{16,17}.

As understanding of the complex anatomy about the pubic symphysis has increased, the incidence of isolated adductor tendon lesions has seemingly decreased. While injuries isolated to the



Imagers should be able to recognise and describe variations of osteitis pubis, midline pubic plate lesions and rectus abdominis/adductor aponeurosis lesions with MRI



thigh adductor compartment certainly occur in athletes, pathology at the adductor origins is most often associated with either midline pubic plate lesions or RA/AL aponeurosis lesions. Still, the adductor tendon pathology encountered with these lesions is often symptomatic, and therapeutic measures can often be successfully centred on the adductors themselves. The adductor longus is the most commonly injured myotendinous unit in the adductor compartment, and tendinopathies range from acute osseous avulsion to calcific tendinosis, myotendinous strains and even focal, activity related compartment syndromes. With isolated adductor injury, it is important to modify an MRI protocol so as to cover the entirety of the lesion, as proximal tendon strains can cause haematomas and muscle oedema more distally in the same compartment¹⁸. All adductors are susceptible to myotendinous strains, and these should be localised, graded and clearly distinguished from proximal tendon

injuries seen in the lesions described above. Isolated adductor injuries generally respond well to conservative regimens including rest and physical therapy, though haematoma evacuation can facilitate healing in some cases (Figure 6).

REFERRED SOURCES OF GROIN PAIN

One of the great benefits of utilising MRI in the assessment of patients with athletic pubalgia is the modality's inherent sensitivity for a wide array of both musculoskeletal and visceral lesions. Unexpected lesions that might be contributors to symptomatology are not uncommon with MRI of the bony pelvis. This is the primary reason to include several large field of view sequences covering the entire bony and visceral pelvis in an athletic pubalgia MRI protocol, even when there is a strong suspicion that the inciting lesion is at the pubic symphysis. Hip flexor lesions including strains and tendinopathies of the iliopsoas, iliacus and sartorius can present as clinical athletic pubalgia. Bursitis in the pelvis, whether iliopsoas or external

oblique, can present with activity-induced groin pain. Benign and malignant soft tissue tumours in various locations around the pelvis can cause pain radiating to the groin, as can visceral pelvis sources such as endometriosis and inflammatory bowel disease. Osseous injuries including femoral neck stress fractures are not uncommon in this patient group, and primary osseous tumours such as osteoid osteoma are most common in an age group similar to an athletic pubalgia demographic. While true inguinal hernias are somewhat uncommon, scarring and fibrosis related to prior herniorrhaphy can cause athletic pubalgia. The majority of these lesions should be observed, or at least suspected, when reviewing an athletic pubalgia MRI (Figure 7)¹⁹.

The most common source of referred groin pain is internal derangement of the ipsilateral hip, and the literature suggests that concomitant athletic pubalgia lesions and hip lesions are a fairly common occurrence in athletes. It is the author's opinion that while an athletic pubalgia MRI

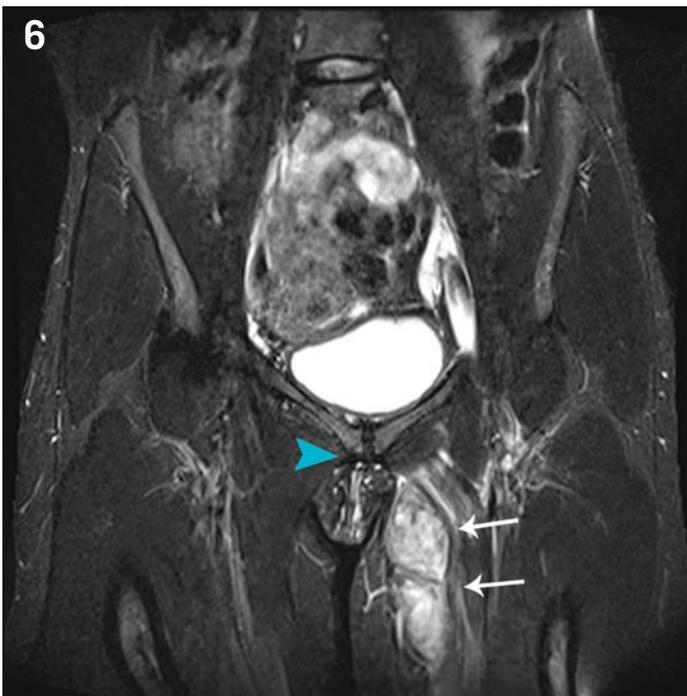


Figure 6: Coronal large field of view STIR image in a left-handed tennis player with a left groin injury 7 days earlier shows a normal RA/AL aponeurosis (arrowhead) and no osteitis pubis, but a large haematoma within the adductor longus muscle sheath at the level of its proximal myotendinous junction. This injury falls into the category of an isolated adductor injury. STIR=short tau inversion recovery, RA/AL=rectus abdominis/adductor.

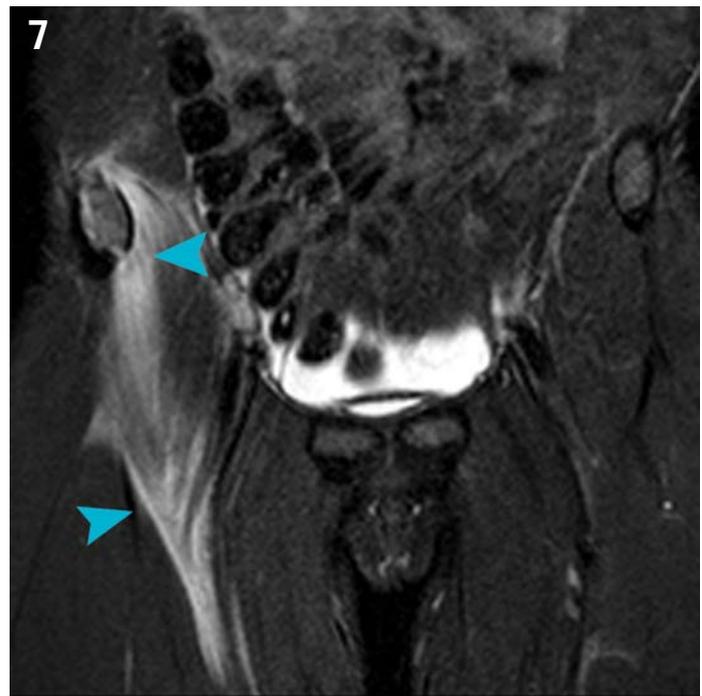


Figure 7: Coronal oblique T2-weighted fat-suppressed image from a right-footed footballer with an acute 'right groin strain' shows no lesion at the pubic symphysis but a high grade strain of the right sartorius with periosteal avulsion from the anterior superior iliac spine (arrowheads).

protocol can sometimes raise a suspicion of acetabular labrum tear or chondral lesion as a primary source of hip pain, the imaging study of choice for suspected internal derangement of the hip is a direct MR arthrogram with intra-articular anaesthetic injection. A physical examination performed before and after intra-articular anaesthetic administration can serve as a powerful diagnostic tool in directing treatment toward the hip or away from the hip in active patients with groin pain.

MRI is a powerful tool in the setting of suspected athletic pubalgia lesion or core muscle injury. A dedicated non-contrast athletic pubalgia protocol should provide both high sensitivity and specificity for common musculoskeletal lesions about the pubic symphysis, and should also provide at least survey assessment for potential athletic pubalgia confounders, including internal derangements of the hip. Musculoskeletal imagers should be able to recognise and describe variations of osteitis pubis, midline pubic plate lesions and rectus abdominis/adductor aponeurosis lesions with MRI and subsequently contribute to generation of an effective treatment plan.

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