Groin pain is a common problem facing athletes. It is usually due to three causes that are often combined, including:

- osteitis pubis (joint or symphysis damage);
- musculotendinous lesions of the rectus abdominus or the adductors;
- inguinal hernia arising from a secondary weakness of the posterior wall of the deep inguinal ring.

Adductor tendinopathy is one of the most frequent causes of pubalgia (groin pain) in athletes. It is suspected when unilateral or bilateral inguinal pain occurs during sports movements and gradually leads to reduced sports participation. Clinical examination is used to determine whether the cause is articular, musculotendinous, hernia-related or of combined origin.
X-ray assessment is essential to confirm the diagnosis and exclude bone or coxo-femoral joint injuries or disorders. Nonetheless, tendinopathies are diagnosed using ultrasound and above all magnetic resonance imaging (MRI), which rules out with certainty the numerous other possible causes [1–3].

The aim of this article is to review the complex anatomy of the pubic region and discuss the contribution of different imaging modalities to positively and differentially diagnosing adductor tendinopathy.

Anatomy

Proximal attachment of the adductors

Apart from the sartorius, the adductor muscles insert proximally into the pubic arch adjacent to the obturator internus muscle. The adductor longus inserts anteriorly via tendon fibers (40%) near to the pubic tubercle and to the pubic symphysis and posteriorly via muscular fibers (60%) [4,5]. According to the cadaver study conducted by Strauss et al., the tendon of the adductor longus is small in size; it measures only 11.6 mm long and 3.7 mm thick (Figs. 1 and 2) [6]. Its enthesis is fibrocartilaginous [5]. The adductor brevis and adductor magnus muscles are situated deep to the adductor longus with an essentially muscular proximal attachment (although a short central tendinous portion has also been described) [4,5]. The gracilis is the most medial muscle of the adductor group and attaches inferiorly to the adductor brevis and adductor longus on the anterior margin of the symphysis pubis and on the medial third of the inferior ramus of the pubis. The sartorius originates from the upper half of the iliac notch at a certain distance from the other adductor tendons. The pectineus attaches more proximally on the pubic crest supero-laterally to the tubercle of pubis [4].

Anatomical relations between the muscles of the adductor group

The deep insertion of the adductor longus on the articular capsule of the symphysis pubis shows some variants, with either a combination of tendon and muscle fibers or deep muscle fibers alone. It generally attaches to the tubercle of pubis via tendon fibers only [6,7].

The rectus abdominis and adductor longus attach in continuity via a single common sheath (RA–AL aponeurosis; Figs. 3 and 4). This common RA–AL aponeurosis blends with the underlying fibrocartilaginous disk and the capsule of the symphysis pubis. These anatomical findings explain why pain can radiate from the affected structure and spread down into the thigh or up into the abdomen [8–11]. In addition, the most superficial fibers decussate in continuity with the fibers of the oblique aponeurosis of the contralateral external oblique muscle.
The most superficial fibers of the gracilis decussate to blend with contralateral fibers, fibers from the rectus abdominis, the aponeurosis of external oblique muscle and vice-versa (Fig. 2). Finally, in 10% of patients the tendon fibers of the gracilis merge to those of the adductor longus to form a single tendon [6,7].

Clinical features
Clinical patterns
Groin pain of musculotendinous origin generally arises from the proximal insertion of the adductor longus. However, the clinician must distinguish between proximal tendon involvement at the enthesis where the tendon inserts into the periosteum and a more distal lesion at the musculotendinous junction. This is important because proximal tendon involvement may require surgical management whereas a distal lesion of the musculotendinous junction should be treated solely by physiotherapy [12].

Adductor longus tendinopathy is a mechanical enthesisopathy generally due to repetitive strain injuries. Classically, it presents as pain of the inner side of the top of the thigh, which radiates downwards, is negative for cough impulse, and increases when stretched against resistance, during sports movements and kicking. In some cases, only the tendon is involved but generally posterior wall deficiency (weakness of the posterior wall of the deep inguinal ring, inguinal hernia) or osteitis pubis is also detected. Imaging is therefore needed when medical treatment is unsatisfactory. The condition is typically bilateral due to the decussation of tendon fibers.

Acute adductor tendon rupture can be observed but is rare compared with musculotendinous junction involvement. In such cases of tendon rupture, adolescent

Figure 3. Schematic drawing of the adductor longus, rectus abdominis and gracilis showing the continuity of tendon fibers that decussate above the pubic symphysis.

Figure 4. Schematic drawing and MR imaging presentation of adductor anatomy in a sagittal plane through the ramus of the pubis (P). The adductor longus (AL) muscle attaches proximally via both muscular and tendon fibers. The insertions of the adductor brevis (AB) and adductor magnus (AM) consist of muscular fibers alone. The tendon of the adductor longus (AL) blends into the distal tendon of the rectus abdominis (RA) via a common aponeurosis.
athletes also have an antero-inferior pubic avulsion fracture [9].

Risk factors include a history of muscle injury and insufficient physical preparation. Groin pain in athletes is most frequently observed in sports requiring repetitive side-to-side ambulation and frequent forceful twisting of the trunk (football, rugby, handball, and hockey) [13].

Macroscopic and microscopic observations

Intraoperative exploration has associated various observations with tendinopathy: hyperemia, fibrosis, tears, calcifications and hematoma (Fig. 5). However, only superficial tears can be visualized and not those corresponding to secondary clefts.

Histopathological examination conducted for some patients confirmed that the enthesopathy was mechanical in origin. Typically, granuloma is observed with infiltration of inflammatory foreign body giant cells, neo-vascularization and a fibroblast repair response. Increased collagen tissue density has also been reported to be related to fibrotic lesions and hyalinized and calcified structures.

Related lesions

Chronic damage to the RA—AL aponeurosis may predispose to peritoneum wall deficiency because it lies adjacent to the attachment of the transversalis fascia in the inguinal region. This explains why the causes of adductor tendinopathy are so often combined and why early diagnosis enables successful management of the lesions. Acute lesions of the RA—AL aponeurosis have also been reported (tennis) with involvement spreading to the adductors and rectus abdominis muscles.

Adductor tendinopathy is less frequent than deficiencies of the posterior wall of the inguinal canal; however, these two forms of pubalgia are often associated. Out of 180 patients who received surgery for adductor tendinopathy in our center, 80% also showed associated posterior wall deficiency that required surgical treatment (unpublished data). During the same period, 500 patients received surgery for isolated posterior wall deficiency using the Shouldice’s repair technique. In the same way, adductor tendinopathy is often associated with osteitis pubis.

Adductor conditions can be further complicated by nerve involvement by obturator nerve entrapment, which results in hypoesthesia of the medial thigh region [12]. Lliohypogastric or lilioinguinal nerve pain can be important for differential diagnosis or be associated with adductor tendinopathy. Such nerve pain is difficult to diagnose using electromyography but readily responds to xylocain nerve blocks [14].

Imaging findings

Radiographs

It is essential to obtain antero-posterior radiographs of the weight-bearing pelvis to assess bone structure, the symphysis pubis, coxo-femoral joint space and detect a potential pelvic tilt in the coronal plane. Soft tissue analysis is indispensable to localize potential calcifications in the areas surrounding the symphysis pubis [2,15].

Ultrasound

Examination technique

Ultrasound is the first-line imaging modality owing to its greater availability and the spatial resolution offered by the latest generation of devices. The patient is examined with a linear transducer in supine position with the thigh abducted at 30°, externally rotated and the knee bent (Fig. 6). The frequency of the transducer should be adjusted to the patient’s anatomy. Adductor assessment proceeds clinically by identifying the bulk of the adductor longus on the antero-medial aspect of the thigh. It is helpful to first identify the central aponeurosis of the adductor longus and then follow it by moving the transducer proximally until the tendon is visualized. Longitudinal and axial images are obtained and then compared to the contralateral side [16].

Normal findings

In normal subjects, the tendon of the adductor longus lies between the anterior margin of the ramus of the pubis and the bodies of the adductor longus and adductor brevis muscles (Fig. 7). In athletes, cortical irregularities are often described and are associated with asymptomatic calcifications. Such irregularities can be sequelae of enthesopathy but can also be due to incomplete fusion of secondary ossification centers (observed up to age 26). Deep hypoechoic regions are also found and the superficial portion of the tendon can appear blurred due to the oblique fibers originating from the rectus abdominis and contralateral muscles. Anisotropy artifacts can be explained by the oblique course followed by the tendon in the sagittal plane. Sometimes the use of small ”golfclub” transducers can alleviate such artifacts. It is important to be familiar with these anatomical
variations because diagnosis can sometimes be challenging in the event of previous and/or chronic rearrangements.

Pathological findings
It is difficult to appreciate whether the enthesopathy is recent or not with certainty. Hyperemia can be detected using color Doppler but does not occur consistently. Cortical erosion is frequently observed but is non-specific and occurs in late phases [17]. Pain from pressure as the transducer is pressed over the region is clinically suggestive.

It can be difficult to distinguish between enthesopathic lesions or uncomplicated isolated tendinosis and normal anatomical variations in athletes. The most specific sign remains an intratendinous tear, which is usually observed on longitudinal images (Fig. 8). Such tears can correspond to the clefts (secondary or/and superior) described using MR imaging and reflect an extension of the common RA—AL aponeurosis and of the articular capsule (Fig. 9). They appear as anechoic tears on the deep side of the tendon adjacent to the periosteum. Such tears usually develop upwards through the RA—AL aponeurosis and can result in various degrees of tendon rupture.

In acute situations, rupture is confirmed if the body of the adductor longus muscle is found to be significantly retracted, i.e. in our experience retracted by more than 2 cm from its bony attachment (the average length of the adductor longus tendon is 11 mm), and if blood pooling is detected. The extent of the rupture depends on its spread posteriorly towards the muscular attachment; the rupture is therefore greater if the muscular insertion is affected.
Tendon rupture can be associated with an avulsion fracture, particularly in adolescents [18].

Related lesions
Examination of the symphysis pubis generally reveals erosive anomalies and osteophytic spurs although it is difficult to confirm the inflammatory nature of joint damage since signs of synovitis are rarely observed.

Signs of posterior wall deficiency and inguinal hernia are sought during dynamic maneuvers of the deep inguinal ring. The spermatic cord is used as an anatomical landmark and localized adjacent to where the epigastric arteries branch from the external iliac artery. The size of the hernia opening can be measured but lacks in specificity and reproducibility due to the absence of pathological threshold values [18]. It should also be recalled that inguinal hernias in athletes are direct inguinal hernias, i.e. with a sac protruding medially to the epigastric arteries, and that these small hernias can only be diagnosed using dynamic maneuvers.

MR imaging
Examination technique
MR imaging is indicated if ultrasound is inconclusive or for presurgical assessment. MR imaging is performed in a comfortable supine position to avoid movement artifacts with an empty bladder and a surface coil. MR examination should start with assessment of wide field-of-view (FOV) sequences to visualize the whole pelvis and first exclude various differential diagnoses (tumors, coxo-femoral disorders) [1,19]. Smaller FOV sequences and 40° oblique axial slices are then used to assess how the symphysis interacts with adjacent musculotendinous structures (Fig. 10) [1,8]. Injection of gadolinium-based contrast agent is not performed in routine except for postoperative assessment.

In healthy subjects, the tendon of the adductor longus is triangular in all three spatial planes and is hypointense on T1- and T2-weighted MR images [1].

Pathological findings
Adductor longus tendinopathy may result in a high signal intensity on T2-weighted MR images that is first peripheral then central without apparent fluid and enhanced following injection of gadolinium; it is associated with morphological abnormalities. In our experience, these morphological abnormalities, in particular hyperintense features on T2-weighted images, are very variable if recent tears or tendon rupture is not detected. This could be explained by the frequency of fibrotic lesions, microcalcifications and calcifications observed intraoperatively and after histopathological examination that do not necessarily produce high signal intensity on T2-weighted MR images. Comparison of MR images and surgical findings demonstrated that intratendinous abnormalities were sometimes minimal or absent on MR images and that an antero-inferior edema of cancellous bone was the only consistent sign of aponeurosis involvement (confirmed by

Figure 9. Adductor longus tendinopathy with a tear. Ultrasonography in the sagittal plane (a) and fat-suppressed T2-weighted MR image in the sagittal plane (b). A small partial tear is observed on the deep side of the tendon.

Figure 10. Localizer and fat-suppressed T2-weighted images in the axial oblique plane. Bone marrow edema (arrows) of the antero-inferior margin of the ramus of the pubic associated with bilateral enthesopathy of the adductor longus.
surgical findings). Monitoring these anomalies over time also showed that such lesions progressively developed to give the typical “secondary cleft” sign [8,15].

The typical “secondary cleft” sign reflects an extension of the lesion of the common RA—AL aponeurosis in depth towards the capsule, inferiorly towards the adductors and in continuity with the central physiological cleft (Fig. 11) [15,20].

In healthy subjects, the central physiological cleft is visualized as a vertical linear hyperintense signal on T2-weighted MR images. The second cleft appears as a linear oblique high signal intensity on T2-weighted MR images that extends infero-laterally from the central symphysal cleft. The secondary cleft is easier to detect on T2- or proton-density-weighted coronal images but can generally be seen in all the three anatomical planes. Tight correlation is observed between the location of pain and the secondary cleft sign, as well as between the anomalies detected by MR imaging and pubic symphysal arthrography (performed in some centers during treatment by cortisone injection) [21].

In the study by Cunningham et al. that compared 100 healthy soccer players and 100 soccer players with pubalgia, the secondary cleft sign was detected in 88% of pubalgia patients and was either isolated or associated with an edema adjacent to the bone marrow. None of the healthy players displayed the secondary cleft sign [22]. However, abnormalities of the symphysis pubis (erosive lesions and osteophytic spurs) were very frequently observed in both groups and only the bone marrow edema at the margin of the joint was considered as a significant pathological feature. This study showed that the secondary cleft sign is the most specific sign and should be sought first and foremost when examining a patient with pubalgia [22].

The superior cleft sign has been described recently as indicating a deep rupture of the RA—AL aponeurosis and is located superiorly to the secondary cleft; it lies parallel to the superior ramus of the pubis. This abnormal feature was described both by symphysography and MRI and was consistently correlated with the location of pain [23]. Finally, typical injuries to the rectus abdominis that are frequently confused with adductor complaints are located on the antero-inferior part of the pubic bone about 1 cm laterally from the symphysis.

The injection of gadolium-chelate can enhance former fibrous scar tissue that is not visible on T2-weighted MR images [17].

A study comparing MR imaging and surgical findings in 102 patients assessed the diagnosis performance of MR imaging in the diagnosis of adductor longus tendinopathy [8]. The sensitivity and specificity of MR imaging were 86 and 89%, respectively [8]. In patients with tendon rupture, blood pooling is detected in the space left by the retracted tendon (Fig. 12).

Figure 11. Secondary cleft sign. Fat-suppressed T2-weighted coronal MR image. Secondary cleft sign reflecting a hyperintense tendon tear at the tendon-bone junction.

Figure 12. Proximal rupture of the adductor longus. Fat-suppressed coronal (a) and sagittal (b, c) T2-weighted images showing blood pooling (white arrows) and tendon retraction (star). Note the continuity of the common RA—AL aponeurosis (arrowheads) with the tendon of the rectus abdominis.
Finally, MR imaging is useful to detect abnormal features suggestive of osteitis pubis and other common differential diagnoses (stress fractures, coxo-femoral injuries, etc.) but does not give clear indications on posterior wall structure [1,11].

Management

Medical treatment

As a precautionary measure, the pre-season training of professional athletes should focus on balancing muscle groups and appropriate muscle strengthening programs (rectus abdominis, obliques, transverses and adductors).

If diagnosed at an early stage, the condition is treated by physiotherapy based on the Toronto protocol. In cases of tendinopathy with hyperemia, peritendinous infiltration of cortisone derivatives can be proposed; however, such treatment is now frequently replaced by platelet-rich plasma (PRP) injections under ultrasound guidance (Fig. 13). Such injections are usually proposed prior to surgery in patients with documented tendon tears but now seem to be proposed more and more often during the early stages [24]. PRP injections accelerate recovery by enhancing tendon healing and are not associated with any specific risks [25]. They have a longer lasting effect than corticosteroids because PRP injection stimulates the production of fibroblasts and collagen [26,27].

Surgical management

Surgical management consists in tenotomy to release the adductor longus tendon (Fig. 14). During this procedure a small skin incision of approximately 3 cm is made just over the prominence of the adductor longus tendon. After dissection of the covering layers, the tendon component of the adductor longus is resected (sometimes with forceps in cases of long-term calcific tendinopathy); this does not have a functional impact in the long-term [28]. Complications (hematoma, infection) are very rare and postoperative care is generally simple. Mini-invasive surgical management has the advantage of fast recovery (return to running about 4 to 6 weeks after surgery), as well as low recurrence and complication rates [28].

When adductor tendinopathy is associated with inguinal hernia, posterior wall surgery using the modified Shouldice’s repair technique is usually performed. This consists in repairing the transversalis fascia (resection of fibrotic parts, suture) and sometimes even the aponeurosis of the external oblique [29]. In patients with excessive wall weakening, the conjoined tendon is sutured to the inguinal ligament. Bilateral surgery is often proposed [30]. Rarely managed alone, the treatment for osteitis pubis does not involve surgery.

Conclusion

Adductor muscle attachment differs from that of other muscles since only the adductor longus has a tendon, which is only about 1 cm long. Other adductor muscles attach proximally mostly via muscle fibers. Adductor muscle and tendon insertions can be visualized by ultrasound with the patient lying knee bent with the thigh abducted and externally rotated. Any abnormalities detected must always be
compared with the contralateral side because there are many normal anatomical variations. The most specific sign for tendinopathy is tendon tear. MR imaging is the gold standard imaging modality as it enables the clinician to detect lesions related to pubalgia (osteitis pubis, posterior wall deficiency) and helps rule out the many other possible causes.

**Disclosure of interest**

The authors declare that they have no conflicts of interest concerning this article.

**References**