European Journal of Radiology 118 (2019) 107–113

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Research article

MR imaging-anatomical-histological evaluation of the abdominal muscles, aponeurosis, and adductor tendon insertions on the pubic symphysis: a cadaver study

Michel De Maeseneer[a,*], Ramses Forsyth[b], Steven Provyn[c], Annemieke Milants[d], Leon Lenchik[e], Aron De Smet[e], Stefaan Marcelis[f], Maryam Shahabpour[a]

[a] Department of Radiology, Universitair Ziekenhuis Brussel, Brussels, Belgium
[b] Department of Pathology, Vrije Universiteit Brussel, Brussels, Belgium
[c] Department of Anatomy, Vrije Universiteit Brussel, Brussels, Belgium
[d] Department of Medical and Molecular Imaging, AZ, Nikolaas, Sint Niklaas, Belgium
[e] Department of Radiology, Wake Forest University Medical School, Winston Salem, NC, United States
[f] Department of Radiology, Sint Andries Ziekenhuis, Tielt, Belgium

ARTICLE INFO

Keywords:
Adductors, anatomy
Adductors, MR imaging
Adductor longus
Groin pain

ABSTRACT

Purpose: To perform an MR(magnetic resonance) imaging, anatomical, and histological evaluation of the abdominal muscles and adductor tendon insertions.

Method: Four fresh cadaveric pelvis specimens were imaged at 3 T with the following imaging parameters: TE (echo time)/TR (repetition time): 20, 4090, slice thickness: 2 mm, FOV: 270 × 90, matrix size: 512. Anatomical slices were obtained with a band saw and photographed. MR images and photographs were evaluated by an anatomist and radiologist. Selected 3 mm thick slices were placed in formalin and decalcified, cut, placed on large slides, and stained with hematoxylin eosin stain (HES).

Results: The main adductor tendon insertions are: the anterosuperior aspect of the pubic bone for the adductor longus, the anteroinferior aspect of the pubic bone - for the adductor brevis, and the inferior aspect of the pubic bone for the adductor magnus. On histology, the adductor longus tendon fibers inserted perpendicularly into the bone at a fibrocartilage enthesis and cross connected along the anterior pubic ligament into the controlateral tendon. The rectus abdominis-pyramidalis unit was covered by a thin anterior and posterior aponeurosis. The posterior aponeurosis inserted into the superior aspect of the anterior pubic ligament, whereas the anterior aponeurosis fused distally with the adductor longus tendons.

Conclusion: Our findings demonstrate the insertions of the adductor tendons, on the pubic ligament and pubic bone.Histologically, the adductor longus tendon fibers inserted perpendicularly into the bone through a fibrocartilage enthesis, and cross connected along the anterior pubic ligament into the contralateral tendon.

1. Introduction

The anatomy of the adductor tendon insertions on the pubic bone is not completely characterized [1–6]. Recent studies have provided additional insight into the complex anatomical relationships in this region [7]. Anatomical relationships are difficult to assess from dissection of embalmed cadaveric specimens because the tissues are distorted by the embalming process. The adductor longus tendon inserts onto the anterior pubic bone but the details of this insertion have not been fully described [8]. The tissues between the adductor longus tendons and covering the anterior aspect of the pubis have been termed the anterior pubic plate, aponeurotic plate, or anterior pubic ligament [9–12]. It is a commonly held belief that there is a thick aponeurotic or tendinous connection between the adductor longus and rectus abdominis. This tissue plane has been described as "aponeurotic plate'. [1–7] These observations were based on lower resolution images on which the precise nature of the abdominal wall to adductor tendon connections cannot be correctly appreciated. The insertions of the adductor brevis and magnus muscles have typically been reported as occurring on the pubic bone [8]. The relationship to the anterior pubic ligament has not been determined. Adductor tendinopathy and tear as well as pubic ligament tear (clefts) are important as they may lead to significant

* Corresponding author at: Department of Radiology, Laarbeeklaan 101, 1090, Jette, Belgium.
E-mail address: Michel.demaeseneer@uzbrussel.be (M. De Maeseneer).

https://doi.org/10.1016/j.ejrad.2019.06.029
Received 14 February 2019; Received in revised form 26 June 2019; Accepted 30 June 2019

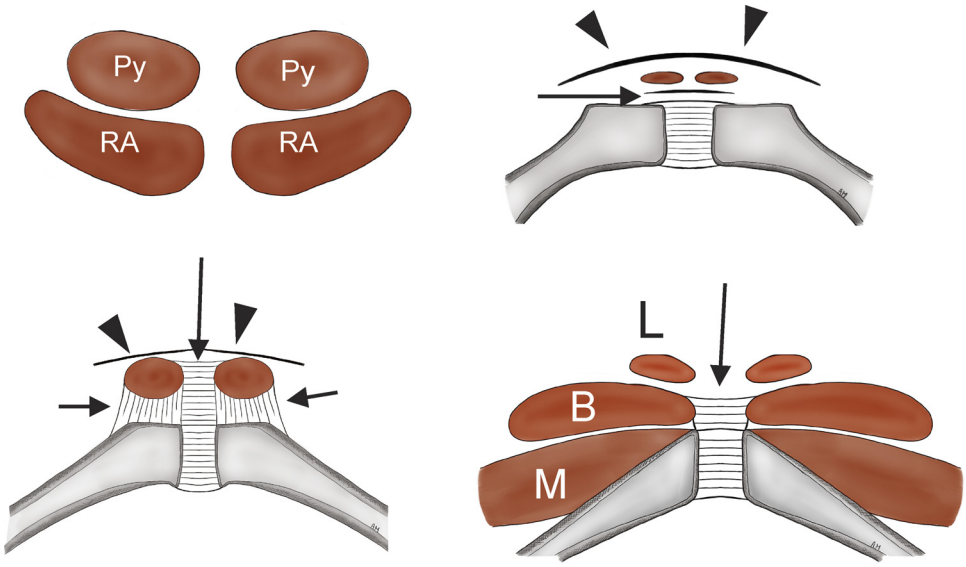

Fig. 1. Drawing of axial relationships of the rectus abdominis-pubic ligament-adductor longus. Left top (above pubic symphysis). Note pyramidalis muscles (Py) in front of rectus abdominis (RA). Right top (level of superior pubic bone –squared portion) Note small pyramidalis muscles (red) the only muscles in front of the pubic bone. The anterior (arrowheads) and posterior (long arrow) aponeurosis is depicted. Left bottom (superior pubic bone-triangular part) Note insertion of adductor longus tendons (red). Insertion continues into pubic bone (short arrows) but also cross connects (long arrow). Note anterior aponeurosis blending with adductor longus (arrowheads). Right bottom (anterior pubic symphysis) Note anterior pubic ligament (arrow). Adductor longus is seen in front (L), whereas adductor brevis inserts onto pubic ligament (B). Adductor magnus inserts on pubic bone (M).

disability in athletes [11–13]. In order to adequately interpret lesions of these structures and guide therapy a precise understanding of the anatomy of abdominal-adductor insertions on the pubic bone is a requisite.

We performed an MR imaging- anatomical correlation to (1) characterize the insertions of the adductor tendons on the pubic bone, (2) characterize the histology of the adductor insertions and the anterior pubic ligament, (3) characterize the connections between the rectus abdominis and pyramidalis muscle and the adductor longus tendons.

2. Materials and methods

2.1. Imaging of cadavers

Our study was approved by the ethical committee of the hospital. All regulations for body donations were respected using the specimens. Four cadaveric pelvis specimens were harvested immediately after death. The age of death of the cadavers was 57–66 years. Cadaveric specimens were deep frozen at - 30° After thawing for 20 h the specimens were imaged on a 3 T MR system (Siemens, Erlangen, Germany). It was ensured that MR images aligned with cadaver slices. The FOV was decreased compared to the FOV of a routine pelvic MR scan and a slice thickness of 2 mm was used. Proton density weighted imaging sequences were performed with the following imaging parameters: TE/ 20/ TR 4090; 2 mm slice thickness, FOV: 270 × 90, matrix size: 512.

2.2. Cadaver sectioning

After imaging the specimens were refrozen at a temperature of -30 °Celsius. While frozen the specimens were sliced with a band saw (Modena, Italy) into 3 mm thick slices. The slices were cleaned with lukewarm water, dried, and photographed. The photographs were correlated with MR images by consensus of an anatomist and MSK radiologist.

2.3. Analysis of MR and slices

To systematize analysis the images were examined at 4 transverse levels, 2 sagittal levels, and 2 coronal levels. These planes were defined by the senior investigator after analyzing images obtained in 25 symptomatic patients previously with the same imaging parameters, as well as studying dry bone specimens of 10 pelvises. The purpose for these preliminary observations was to define reference planes that would best demonstrate the anatomical details in the cadaveric correlation study. The adductor insertion sites were studied as well as the anterior pubic ligament. The nature of the connections between the abdominal muscles (rectus abdominis and piramidalis) to the adductor longus tendons was studied.

The levels chosen for the transverse plane were (1) above the pubic bone at the level of the rectus abdominis and pyramidalis muscles, (2) anterosuperior pubic bone, (3) anteroinferior pubic bone, (4) below the pubic bone. The levels chosen for the coronal plane were (1) anterosuperior pubic bone, (2) anteroinferior pubic bone. For the sagittal plane (1) midline section, (2) section 1 cm off the midline.

2.4. Histological study

Selected 3 mm thick slices were placed in formalin and decalcified in PC3 (VWR, Brooklyn, NY). After decalcification for 5 weeks the slices were cut with a microtome and placed on large slides. The slides were stained with hematoxylin eosin stain. The slides were digitally scanned, so that magnifications could be obtained. Histological data were analyzed by a senior pathologist subspecialized in clinical and investigative MSK pathology.

3. Results

The results are described at different craniocaudal and mediolateral levels as depicted in Figs. 1, 4 and 6 for better understanding.

3.1. Imaging and anatomical findings in the transverse plane (Fig. 1)

Most superiorly, above the pubic bone (level 1) (Fig. 2A) the rectus abdominis muscle bellies were visualized more posteriorly, whereas in the midline the small pyramidalis muscles were visualized. An anterior and posterior aponeurosis was seen covering these muscles.

Slightly lower in front of the superior pubic bone level 2) (Figs. 2B, 3 A) only the pyramidalis muscles could be seen in front of the pubic bone. The anterior and posterior aponeurotic tissue planes covering the muscle were well discerned at this level, measuring 1.5 mm in thickness and exhibiting low signal intensity compared to the intermediate signal intensity of the muscle bellies.

Slightly lower where the pubic bone obtains a triangular shape (, level 3) (Fig. 2C, 3 B) the anterior pubic ligament became visible as a 1 cm thick structure, with the adductor longus tendons attaching at the sides and in continuity with it. Both the pubic ligament and tendons demonstrated low signal intensity on MR. The posterior rectus abdominis-pyramidalis aponeurosis measured 1 mm in thickness and joined

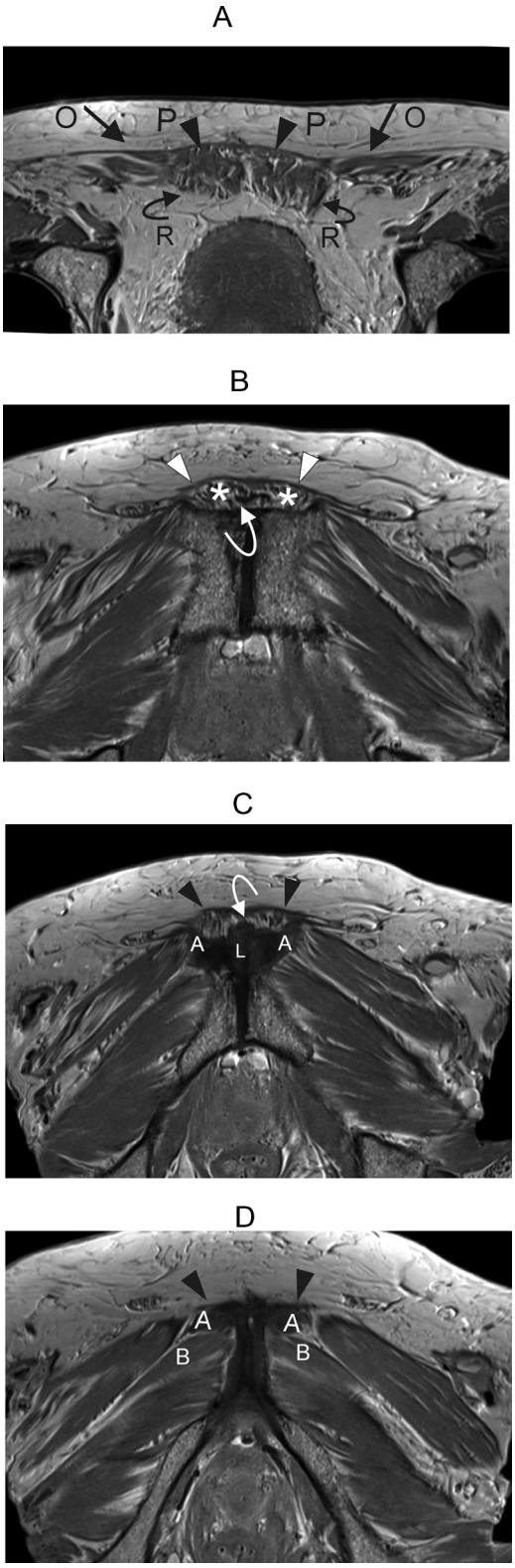

Fig. 2. A–D. (A) At level 1 the pyramidalis (P) are seen in front of the rectus abdominis (R). Note oblique muscles (O) more laterally. (B) At level 2 the pyramidalis muscles are seen in front of the pubic bone (asterisk). Note anterior (arrowheads) and posterior (arrow) aponeurosis. (C) At level 3 the adductor longus tendons (A) are seen to insert cross connecting via the anterior pubic ligament (L) Note insertion of anterior aponeurosis (curved arrow) and distal continuation of anterior aponeurosis (arrowheads). At level 4 the adductor longus tendons are seen (A) with anterior aponeurosis inserting on top (arrowheads).

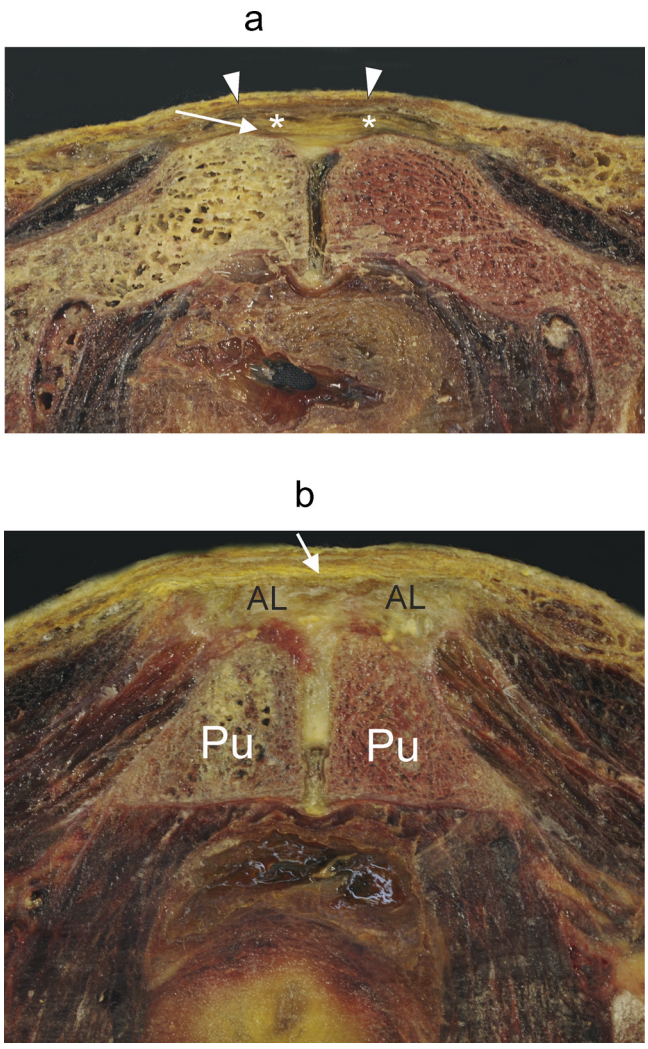

Fig. 3. A, B. (A) At level 2 the anterior (arrowheads) and posterior aponeurosis (arrow) are seen. Note pyramidalis muscles in between (asterisk). (B) At level 3 the bulk of the adductor longus tendons is seen (AL) inserting on the pubic bone and cross connecting via the anterior pubic ligament (arrow).

the most superior margin of the anterior pubic ligament. It did not extend more distally.

Just below the pubic bone (level 4) (Fig. 2D) the anterior pubic ligament became thinner, measuring 5 mm in thickness. The adductor longus tendons were now seen separately from the pubic ligament. The 1 mm thick anterior aponeurosis inserted onto the anterior aspect of the adductor longus tendons.

3.2. Imaging findings in the coronal plane

Anterosuperiorly (Fig. 4) the anterior pubic ligament was thickest, measuring 1 cm in thickness, with the adductor longus tendons inserting into the sides of the ligament.

More inferiorly (Fig. 5) the anterior pubic ligament was at its thinnest part, measuring 5 mm in thickness, with the main portion of the adductor brevis inserting into it. Still more inferiorly, the adductor magnus inserted on the pubic bone directly.

3.3. Histological findings

Histological slices (Fig. 4) in the coronal plane showed the adductor longus tendons inserting at the anterosuperior pubis into the anterior pubic ligament. The tendinous fibers gradually transformed into

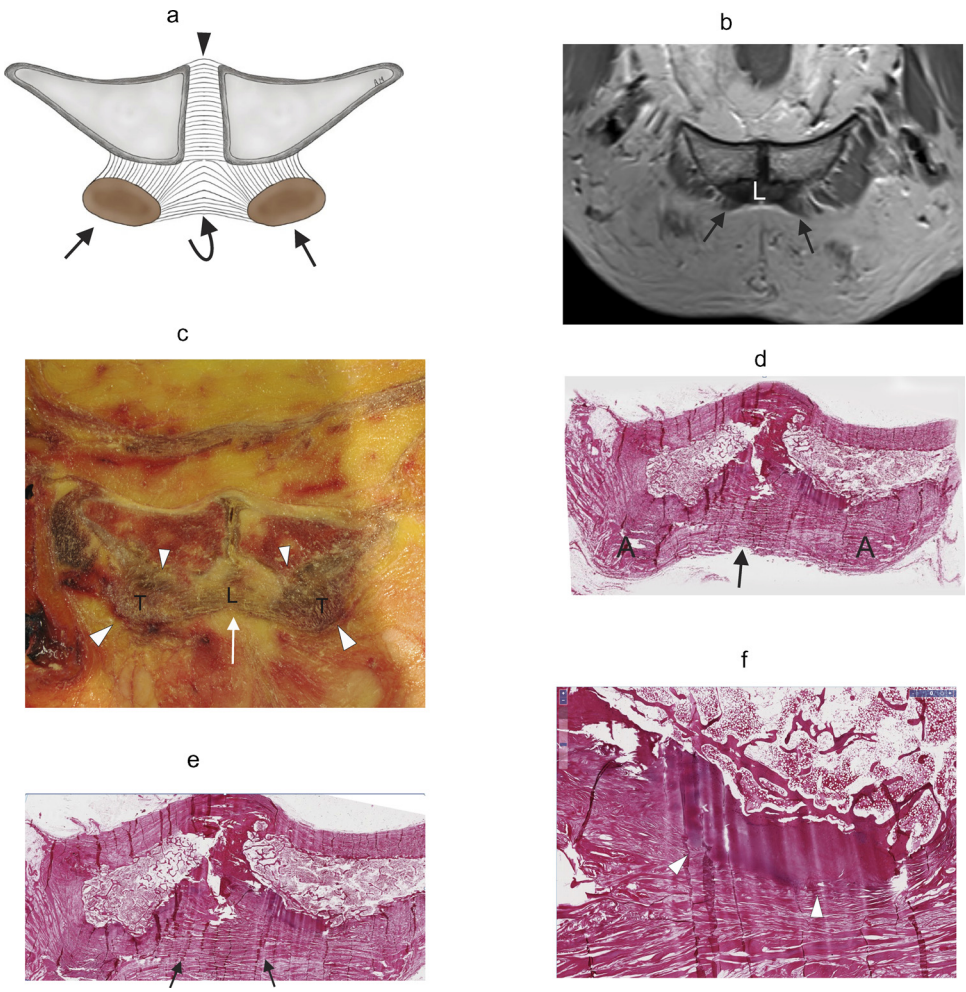

Fig. 4. A–C. (A) Drawing shows coronal relationships at the anterosuperior pubic symphysis. The adductor longus tendons (arrows) insert onto the pubic bone and cross connect (curved arrow). Note superior pubic ligament (arrowhead). (B) Coronal MR shows insertion of adductor longus tendons (arrows) on pubic bone and anterior pubic ligament (L). (C)Coronal anatomic slice shows insertions of adductor longus (T, large arrowheads) continuing to pubic bone (small arrowheads) Cross connections (arrow) via anterior pubic ligament (L) are seen.(D) Note insertions of adductor longus tendons (A) onto pubic bone. Arrow indicates anterior pubic ligament. (E) Higher magnification shows cross connections between adductor longus tendons (arrows). (F) Higher magnification shows cartilage enthesis at the bony insertion site of the adductor longus (arrowheads).

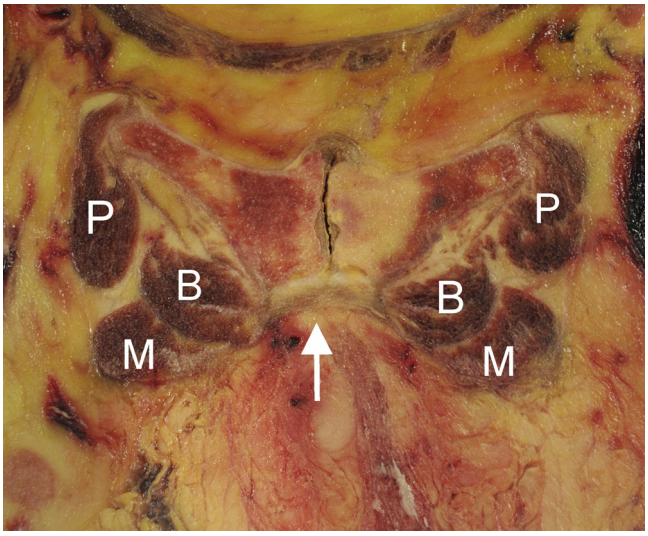

Fig. 5. Coronal anatomical slice more posteriorly. Note anterior pubic ligament (arrow) with insertions of adductor brevis muscles (B). The adductor magnus will insert more posterior on the pubic bone. P, pectineus.

ligament fibers and cross connected to the contralateral tendon. The tendinous fibers also continued perpendicular to the bone to insert into the bone. At the insertion site, a thin fibrocartilage enthesis was clearly visible.

3.4. Imaging findings in the sagittal plane (Fig. 6)

Right In the midline, the posterior aponeurosis was best visualized and inserted on to the most superior margin of the anterior pubic ligament.

One cm off the midline, the posterior aponeurosis was less well seen At this level the anterior aponeurosis, was well seen bilaterally measured 1.5 mm in thickness and connected the anterior borders of the rectus abdominis muscle with the adductor longus tendon.

4. Discussion

The adductor insertions have a major clinical importance. Injuries are extremely common in certain athletes, especially soccer players. These injuries can result in significant time off from play [11–13]. Various conservative and operative treatments have been proposed with variable success rates [14–17].

The anatomy of the adductor and abdominal muscle insertions on the pubic bone and the so called ‘anterior pubic plate’ or ‘pubic aponeurosis’ is not clearly described in the literature [7,8]. Recent anatomical studies have provided new insights into this anatomy. Schilders et al [7] studied the adductor insertions and pubic ligaments by dissection of fresh cadavers. Most previous descriptions were carried out in embalmed specimens. The anterior pubic ligament is referred to as the pubic plate, the pubic aponeurosis, or the fibrocartilaginous nodule, which does not agree with our findings. Our histologic findings show that the soft tissues anterior to the pubis correspond to ligament fibers that are in continuity with the adductor longus tendons at the anterosuperior aspect of the pubis. The tendinous fibers at this level show a

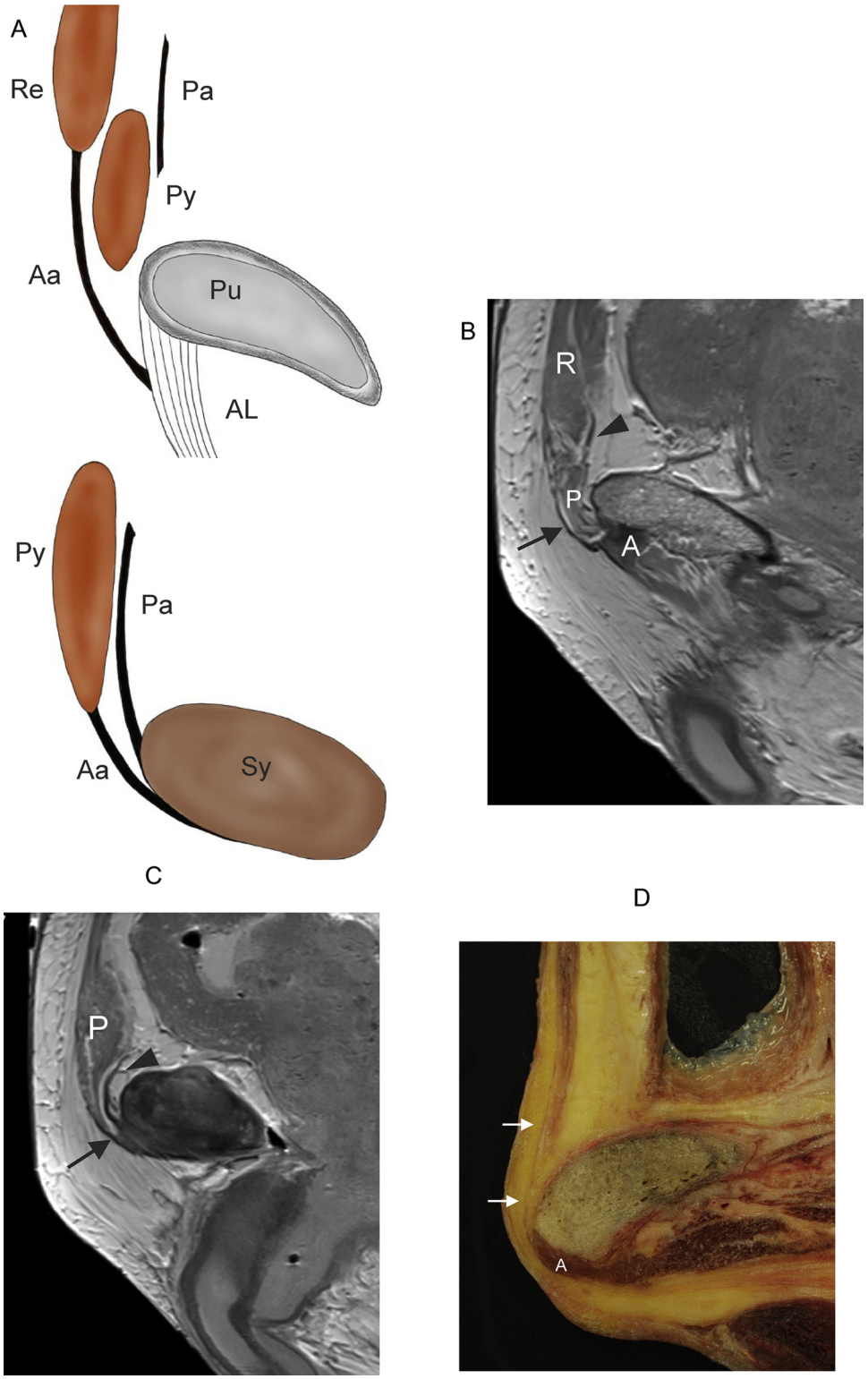

Fig. 6. Drawing of sagittal relationships. (A) Top image is 1 cm of midline. Note anterior aponeurosis (Aa) between the rectus abdominis (Re) and adductor longus (AL). The posterior aponeurosis is less well seen at this level (Pa). Note still small part of Pyramidalis (Py) seen posterior to rectus abdominis. Pu, pubic bone. (B)At the midline. Note pyramidalis muscle (Py) anterior to pubic symphysis (Sy) Anterior aponeurosis (Aa) continues more distally. Posterior aponeurosis (Pa-) blends with anterosuperior symphysis-pubic ligament. (B) MR of sagittal relationships. Section 1 cm off the midline. Note anterior aponeurosis (arrow) continuing from Rectus abdominis (R) to adductor longus (A). Posterior aponeurosis (arrowhead) is less well seen at this level. (C) Section in midline. Note anterior aponeurosis (arrow) continuing more distally to insert on anterior tissues, and posterior aponeurosis (arrowhead) inserting at anterosuperior symphysis. P, pyramidalis. (D) Sagittal anatomical slice 1 cm off midline. Note anterior aponeurosis (arrows) extending from rectus abdominis muscle to adductor longus tendon (A).

gradual transition into ligament fibers. The term ligament seems more appropriate than the previously used terms: plate, aponeurosis, or fibrocartilaginous nodule.

One major observation of our study was that the fibers of the adductor longus did not only attach into the pubic bone but also cross connected between the two adductor longus tendons across the midline and the anterior pubic ligament. This finding is previously unrecognized but it may explain why the clinical symptoms commonly occur bilaterally.

Fibers of the adductor longus also continue perpendicular to the bone and fan out to insert into the pubic bone. At the level of the bony insertion a thin fibrocartilage enthesis is found.

In the imaging literature the pubic plate has been described as an aponeurosis that forms the junction of the rectus abdominis and adductor longus tendon, and injuries have been referred to as common aponeurosis lesions [10,11]. Our findings and those of Schilders et al. suggest that such nomenclature may not be appropriate [7].

The rectus abdominis does not continue in front of the pubic bone

and does not show a direct thick connection to the adductor longus. In fact, only some muscle fibers of the pyramidalis are observed in front of the anterosuperior aspect of the pubic bone. The connection between the rectus abdominis-pyramidalis and adductor longus is only seen at the level of the anterior aponeurosis and is actually quite thin measuring 1.5 mm in thickness. The posterior aponeurosis of the rectus abdominis-pyramidalis blends with the superior aspect of the anterior pubic ligament, and is also quite thin. Robinson et al. in their work [10] refer to this aponeurosis as the rectus abdominis tendons. We feel their imaging and histological aspect corresponds more to an aponeurosis than to a true tendon.

Our study also showed that the adductor brevis inserted on the pubic ligament at the anteroinferior pubic bone, without a clearly identifiable tendon, and the adductor magnus on the inferior pubic rami.

All the structures that attach at the pubic bone are very intimately related and lesions may be combined. The inguinal ligament and the conjoint tendon (formerly falx inguinalis) insert on the pubic tubercle. Adequate closure of this space of Hesselbach between these two ligaments is deficient in abdominal wall weakness causing groin pain. These specific structures, however did not form the subject of our study. The relationship off the abdominal muscles to the pubic symphysis and adductor tendons has not been described in detail in previous works [7,8]. It is well known in traumatic and overuse injuries that injuries of the abdominal muscles and adductor longus may be combined. The adductor longus tendon itself presents different types of injuries. One of the lesions described in the MR imaging and arthrography literature is the 'secondary cleft'. Our observations confirm that this cleft is observed at the anterosuperior aspect of the pubic symphysis where the adductor longus tendons insert into the anterior pubic ligament. On imaging this cleft is close to the bone. Since our study did not include pathologic cases we could not determine whether this cleft occurs deep or superficial to the fibrocartilage enthesis, but we hypothesize it occurs superficial to it. Clefts may also occur in the substance of the tendon, as may partial or complete tears. Tears may also involve the musculotendinous junction of the adductor brevis. Other causes of non musculotendinous groin pain include bony causes such as stress fracture and pubic symphysis overuse changes. Our anatomical findings allow a better understanding of the tendon insertions and relationship with the abdominal muscles. Our findings also show the intimate connections between the abdominal wall, anterior pubic ligament, and adductor longus tendons, and this explains why abnormalities of these structures are often combined.

Our study has several limitations. First, because the number of specimens was limited we could not take into account anatomical variation. Also we did not have enough specimens to include mean values and SD (standard deviation) for measurements of thickness of structures. This could be the subject of a future work of an MR study in normal volunteers. This would be helpful as cadaveric studies of this area are very difficult in both embalmed and fresh specimens. We focused on certain details of the pubic insertions focusing less on other aspects such as the superior and posterior pubic ligaments, which could form the subject of a different study. Freezing and thawing of specimens may affect tissue characteristics on MR which may have influenced our observations, however we did not observe differences with observations in clinical patients. Aligning cadaveric slices and MR side by side may be difficult but this was solved by using the classic technique described by Hodler J et al. [18]. We cannot exclude that age related changes were present in the studied specimens. Histological studies did not reveal any evidence of such changes although the anatomic slices suggested some tendon calcification, which would have been removed by the decalcification procedure. We acknowledge that we reduced the FOV of our images to better delineate anatomical detail. This is necessary as the standard resolution is insufficient to observe the insertional details (personal observation). This however adds no imaging time on state of the art systems and in case of a clinical indication of adductor pathology can replace the lower resolution images. We did not obtain images in oblique planes, as we feel this is cumbersome in clinical practice and unnecessarily complicates image interpretation.

5. Conclusion

(1) Our study clarifies the precise insertion site of the different adductor tendons and this can be well depicted with MR.
(2) Histologically, the adductor longus tendon fibers inserted perpendicularly into the bone through a fibrocartilage enthesis, but a major finding was that they cross connected along the anterior pubic ligament into the contralateral tendon. This may explain why symptoms commonly are bilateral.
(3) Connections between the abdominal muscles and adductor longus do not correspond to a thick aponeurosis as typically thought but to thin anterior and posterior aponeurosis. This finding may have relevance for surgical treatments of this area.

Conflict of interest

The authors declare that they have no financial/personal conflicts of interest.

References

[1] C.A. Byrne, D.J. Bowden, E.C. Kavanagh, S.J. Eustace, Sports related groin pain secondary to symphysis pubis disorders: correlation between MRI findings and outcome after fluoroscopy guided injection of steroid and local anesthetic, AJR 209 (2017) 380–388.
[2] C. Petchprapa, J.T. Bencardino, Tendon injuries of the hip, Magn. Reson. Imaging Clin. N. Am. 21 (2013) 75–96.
[3] O.L. Santilli, N. Nardelli, H.A. Santilli, D.E. Tripoloni, Sports hernias: experience in a sports medicine center, Hernia 20 (February (1)) (2016) 77–84, https://doi.org/10.1007/s10029-015-1367-4 Epub 2015 Mar 18. PubMed PMID: 25784289.
[4] A. Chopra, P. Robinson, Imaging athletic groin pain, Radiol. Clin. North Am. 54 (September (5)) (2016) 865–873, https://doi.org/10.1016/j.rcl.2016.04.007 Review. PubMed PMID: 27545425.
[5] M. Bou Antoun, G. Reboul, M. Ronot, A. Crombe, N. Poussange, L. Pesquer, Imaging of inguinal-related groin pain in athletes, Br. J. Radiol. 91 (December (1092)) (2018) 20170856, , https://doi.org/10.1259/bjr.20170856 Epub 2018 Jul 25. Review. PubMed PMID: 29947268.
[6] W.K. Vasileff, M. Nekhline, P.A. Kolowich, G.B. Talpos, W.R. Eyler, M. van Holsbeeck, Inguinal hernia in athletes: role of dynamic ultrasound, Sports Health 9 (September/October (5)) (2017) 414–421, https://doi.org/10.1177/1941738117717009 Epub 2017 Jul 21. PubMed PMID: 28732177; PubMed Central PMCID: PMC5582701.
[7] E. Schilders, S. Bharam, E. Golan, A. Dimitrakopoulou, A. Mitchell, M. Spaepen, C. Beggs, C. Cooke, P. Holmich, The pyramidalis-adductor longus complex (PLAC) and its role with adductor injuries: a new anatomical concept, Knee Surg. Sports Traumatol. Arthrosc. 25 (December (12)) (2017) 3969–3977.
[8] J.A. Davis, M.D. Stringer, S.J. Woodley, New insights into the proximal tendons of adductor longus, adductor brevis and gracilis, Br. J. Sports Med. 46 (2012) 871–876.
[9] I. Becker, S.J. Woodley, M.D. Stringer, The adult human pubic symphysis: a systematic review, J. Anat. 217 (2010) 475–487.
[10] P. Robinson, F. Salehi, A. Grainger, M. Clemence, E. Schilders, P. O'Connor, Agur A.CAdaveric and MRI study of the musculotendinous contributions to the capsule of the symphysis pubis, AJR Am. J. Roentgenol. 188 (May (5)) (2007) W440–W445 PubMed PMID:17449740.
[11] C.A. Agten, R. Sutter, F.M. Buck, C.W.A. Pfirrmann, Hip imaging in athletes: sports imaging series, Radiology 280 (2) (2016) 351–369.
[12] T.M. Hegazi, J.A. Belair, E.J. McCarthy, J.B. Roedl, W.B. Morrison, Sports injuries about the hip: what the radiologist should know, RadiogGraphics 36 (2016) 1717–1745.
[13] ÉC. Falvey, E. King, S. Kinsella, A. Franklyn-Miller, Athletic groin pain (part 1): a prospective anatomical diagnosis of 382 patients–clinical findings, MRI findings and patient-reported outcome measures at baseline, Br. J. Sports Med. 50 (April (7)) (2016) 423–430, https://doi.org/10.1136/bjsports-2015-094912 Epub 2015 Nov 30. PubMed PMID: 26626272; PubMed Central PMCID: PMC4819645.
[14] C.A. Byrne, D.J. Bowden, A. Alkhayat, E.C. Kavanagh, S.J. Eustace, Sports-related groin pain secondary to symphysis pubis disorders: correlation between MRI findings and outcome after fluoroscopy-guided injection of steroid and local anesthetic, AJR Am. J. Roentgenol. 209 (August (2)) (2017) 380–388, https://doi.org/10.2214/AJR.16.17578 Epub 2017 Jun 13. PubMed PMID: 28609118.
[15] E. Ducouret, G. Reboul, F. Dalmay, C. Iosif, C. Mounayer, L. Pesquer, B. Dallaudiere, MRI in chronic groin pain: sequence diagnostic reliability compared to systematic surgical assessment, Skeletal Radiol. 47 (May (5)) (2018) 649–660, https://doi.org/10.1007/s00256-017-2824-1 Epub 2017 Nov 23. PubMed PMID: 29170813.

[16] E. Ostrom, A. Joseph, The use of musculoskeletal ultrasound for the diagnosis of groin and hip pain in athletes, Curr. Sports Med. Rep. 15 (March–April (2)) (2016) 86–90, https://doi.org/10.1249/JSR.0000000000000248 Review. PubMed PMID: 26963015.

[17] C. Kajetanek, O. Benoît, B. Granger, F. Menegaux, N. Chereau, H. Pascal-Mousselard, F. Khiami, Athletic pubalgia: return to play after targeted surgery, Orthop. Traumatol. Surg. Res. 104 (June (4)) (2018) 469–472, https://doi.org/10.1016/j.otsr.2018.01.012 Epub 2018 Mar 13. PubMed PMID: 29549038.

[18] J. Hodler, D. Trudell, Kang Hs, I. Kjellin, D. Resnick, Inexpensive technique for performing magnetic-resonace-pathologic correlation in cadavers, Invest. Radiol. 27 (1992) 323–325.