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ORIGINAL ARTICLE

The ligamentum capitis femoris: anatomic, magnetic resonance and computed tomography study

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ABSTRACT: *The objective of the study was to describe the normal anatomy of the ligamentum capitis femoris and to determine the neurovascular structures potentially at risk during its reconstruction.*
Ten cadaveric specimens of the ligamentum capitis femoris (LCF) were dissected and photographed. Magnetic resonance (MR) and Computed tomography (CT) arthrography evaluation of the anatomy of the LCF in 30 hips were performed to measure length of the ligament and to study the proximity of neurovascular structures.
The anatomical study showed that the LCF has a pyramidal structure and a banded appearance. The thickness of the medial wall of the acetabulum 3mm superior to the inferior acetabular boundary was found to be 6.7mm (4-9mm) at point 1 (anterior), 4.1mm (3-7mm) at point 2 (central), and 6.5mm (4-9mm) at point 3 (posterior). Central anchors or screws were found to lie within 1.7cm (1.6-1.9cm) of the external iliac vein and artery. Angulation of anchors in the anterior and posterior columns in the axial plane with respect to acetabular fossa floor (the Optimal Angulation Angle or OAA), is safer (0 to 45° the safest optimal angles). The sagittal angulation created by the safe pathway in the anterior and posterior columns with respect to the plane of the facies lunata in this area was also measured and termed the Optimal Angle of Penetration (OAP) with normal values being: 110° (102-123°) for the posterior column and 90° (85-94°) for the anterior column.
Our results suggest that reconstruction of the LCF can be safely performed if these guidelines are followed.

KEY WORDS: *Hip, Arthroscopy, Ligamentum capitis femoris*

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INTRODUCTION

The ligamentum teres may have a secondary stabilizing effect on the hip joint, especially in the presence of a deficient labrum or in developmental dysplasia (DDH) (1). Injuries to this ligament are sometimes treated by arthroscopic debridement of the tear. This may not to be sufficient for some athletes involved in sports such as martial arts, in which external rotatory and axial distraction forces are high. Repair or reconstruction should be considered in these patients (2, 3).

The developmental anatomy of the ligament has been described

(4), but its structure is not “round” (“teres”) and therefore we prefer the term ‘ligamentum capitis femoris’ (LCF). When considering reconstruction, anchors should be placed in areas of the acetabulum that provide the best bone stock for purchase, while minimizing the risk of damage to vital intrapelvic structures. The purpose of our study was to describe the neurovascular structures at risk when considering reconstruction of the LCF.

METHODS

Anatomic study

Observations that were made on ten (6 males and 4 females) fresh-frozen cadaveric adult hip joint specimens fixed in formalin at the Department of Pathology and Experimental Therapeutics (Unity of Human Anatomy), University of Barcelona, Spain. The mean age of subjects was 36 (range 30-40 years). Exclusion criteria were previous hip surgery, signs of significant congenital or developmental disease, and osteoarthritic change.

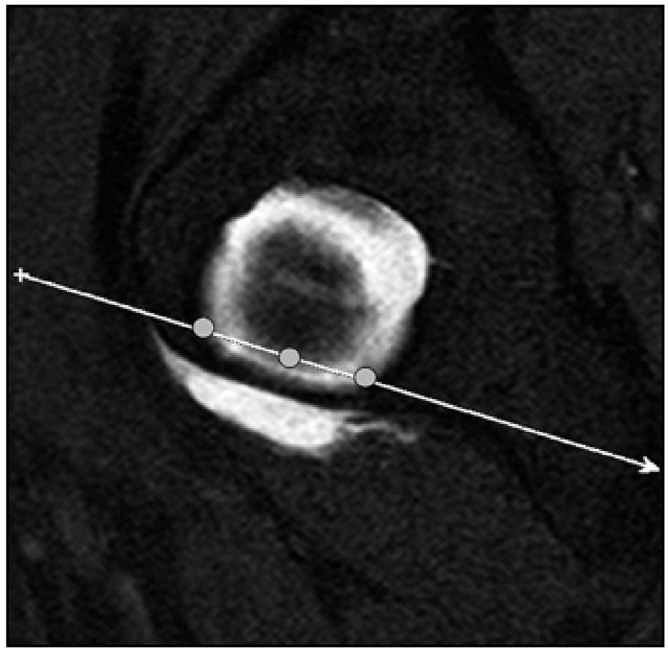

Fig. 1 - *Radiographic study, centred in the antero-inferior, the central-inferior and the postero-inferior cotyloid fossa 3mm above the rim, producing a cross-section of the inferior cotyloid fossa with the associated acetabular and posterior column segments.*

MR arthrography and CT arthrography studies

Thirty consecutive patients (20 males and 10 females) referred for the evaluation of groin pain were prospectively studied with magnetic resonance (MR) and compted tomographic (CT0 arthrography. The mean age was 35 (range 21-46 years).

Exclusion criteria were previous surgery, radiological signs of significant congenital or developmental disease and/ or inadequate hip distension.

We used a 1.5T MR system (Philips, Best, The Netherlands), with a phased array body coil, positioned for unilateral hip imaging. Fat saturated T1-weighted MR images (repetition time (TR) 450 , echo time (TE) 15msec, matrix 256X512, section thickness 3mm, interslice gap 0.3mm, number of signals per data line acquired 3, 16cm of field of view) were obtained in the coronal, axial and sagittal oblique planes, along the long axis of the femoral neck. A non fat saturated T1 weighted sequence using the same parameters was performed in the oblique sagittal plane. Coronal proton density (TR 1585msec, TE 35msec) was also performed with the same matrix and slice thickness, and spacing.

The CT study was performed using a 4-MDCT system (Aquilion, Toshiba, Otawara, Japan). Helical scanning was performed at 120kVp and 150mAs, and the collimation beam was 2.0mm. The field of view was 256mm, and the section thickness was 0.5mm. The imaging data were transferred digitally to a workstation (Vitrea 2, Vital Images) and coronal and sagittal reformations and 3D reconstructions of the hip joint were obtained.

Both imaging studies were analyzed at the inferior cotyloid fossa to determine the neurovascular structures at risk, safe drill insertion depth, the average thickness of the acetabulum, maximum bone depth for anchor or interference purchase, safe and unsafe areas for screw placement, the safest zone for surgery and the optimal angle of penetration.

Based on the anatomical data obtained in the cadaveric study (pelvic attachment of the ligamentum capitis femoris at the inferior margin of the acetabulum) we centered the study in the antero-inferior (1), the central-inferior (2) and the postero-inferior (3) cotyloid fossa 3mm above the rim, producing a cross-section of the inferior cotyloid fossa with the associated acetabular and posterior column segments (Fig.1).

Structures at risk of penetration by anchors include the

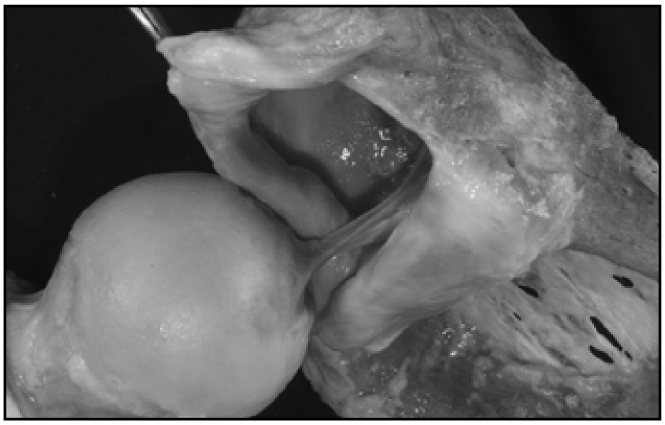

Fig. 2 - *Anatomic study. The ligamentum capitis femoris has a pyramidal structure with a cross sectional area smaller at its femoral insertion and a banded appearance that is composed of an anterior and posterior bundle with a serpentine course from its acetabular to its femoral attachment.*

external iliac vessels, the obturator nerve and vessels and the obturator internus muscle. The width and depth of the anterior column were also studied 3mm superior to the inferior margin of the acetabulum. The bony depth of the acetabulum was measured as well as the distance separating the inner cortex from the principal pelvic vessels. Images were also studied to determine the depth of the acetabulum to the inner table of the medial wall, and the thickness of the anterior and posterior columns. The angulation created by the safety zone line, or safe pathway, in the anterior and posterior column with respect to the plane of the facies lunata at this area, was measured and termed the Optimal Angle of Penetration (OAP). This represents the angulation in the sagittal plane necessary to provide a safe bone corridor for anchor or screw fixation placement.

RESULTS

Anatomic study

The horseshoe-shaped lunate surface of the acetabulum is readily recognized with the acetabular fossa occupying its infero-medial portion. The fat pad and synovium contained in the superior portion of the fossa can be quite vascular. The lowest portion of the fossa is lined by dense synovial tissue that encroaches upon and passes beneath the transverse ligament bridging the acetabular notch. The ligamentum capitis femoris arises inferiorly predominantly from the transverse ligament where it is trapezoid in shape. It becomes progressively round or oval in shape and somewhat bilobed in appearance on close inspection (Fig. 2).

The ligament passes from the fovea capitis, a small depressed bare spot located at the medial aspect of the femoral head, across the joint space downward and anteriorly. The insertion of the ligament into the fovea is slightly posterior and inferior to the true center of the head. Although an occasional capillary may be seen on the ligament, no substantial vasculature is visible macroscopically. Examination of the ligamentum demonstrates a strong pyramidal structure with a cross sectional area smaller at its femoral insertion with a banded appearance composed of an anterior and posterior bundle and a serpentine course. The broad origin is attached to both sides of the acetabular notch, with the ischial side or posterior band being larger and marginally broader. Here the attachment extends outside the bony cavity to the capsule of the hip and the periosteum of the ischium. The pelvic attachment at the inferior margin of the acetabulum resides mainly in the posterior portion of the cotyloid fossa. The broad acetabular origin attaching to both sides of the cotyloid notch and blending with the transverse acetabular ligament suggests that three different areas of fixation of a surgically reconstructed ligament may be appropriate. These are the antero-inferior cotyloid fossa, the postero-inferior cotyloid fossa and the central-inferior cotyloid fossa. As described previously (2, 5), the ligament is covered with synovial epithelium. The subsynovial layer consist of adipose tissue and blood vessels including the posterior division of the obturator artery (not patent on 33% of adults). The deepest layer is composed of a thick well-organized layer of collagen.

MR arthrography and CT arthrography

The normal ligamentum teres appears homogenous on MR imaging with low signal intensity on T1 and T2 weighted images. The normal length of the LCF was 32mm (28-35mm).

The normal range of values for thickness of the medial wall of the acetabulum at 3mm superior to the inferior acetabular boundary was analyzed. The thinnest part is the

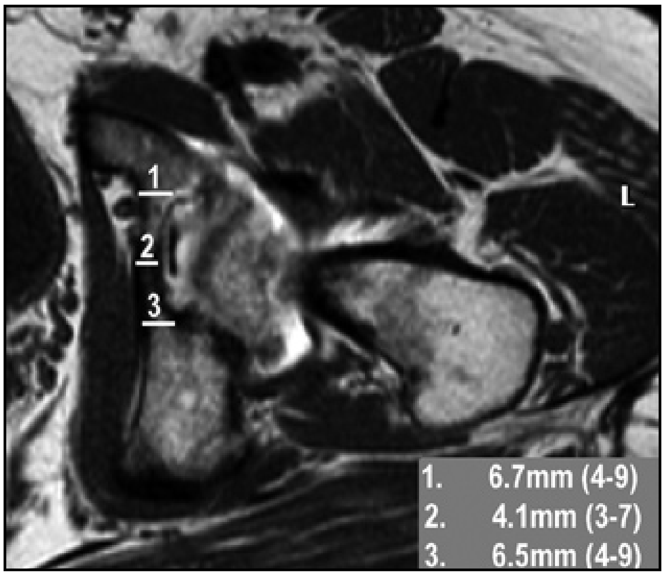

Fig. 3 - *MRI showing the thickness of the medial wall of the acetabulum at 3mm superior to the inferior acetabular boundary.*

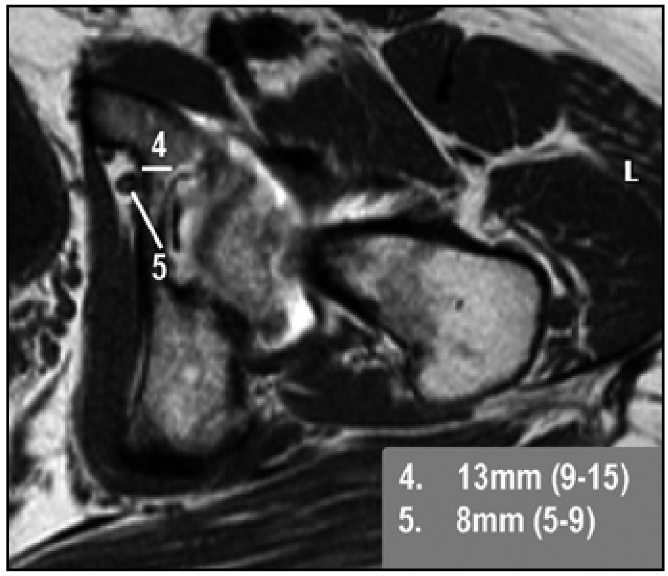

Fig. 4 - *MRI showing the obturator structures at risk at point anterior and central.*

middle zone of the central-inferior cotyloid fossa. Towards the anterior and posterior columns more bone stock can be found. The mean thickness was found to be 6.7mm (4-9mm) at point 1, 4.1mm (3-7mm) at point 2, and 6.5mm (4-9mm) at point 3 (Fig. 3).

Neurovascular structures at risk

The external iliac vessels and the obturator nerve, artery and vein are potentially at risk during anchor placement. Central anchors were found to lie within 1.7cm (1.6-1.9cm) of the external iliac vein and artery. The distance to the obturator structures was studied at anterior and central points (points 4 and 5 respectively). The structures were found to be 13mm (9-15mm) away at point 4, while at point 5 an extra of 8mm (5-9mm) was available (Fig.4).

Safe and unsafe acetabular locations

Surgical risk is greatest anteriorly and the safest zone for surgery is posterior. There is clearly adequate depth, cover and wall thickness for implantation of screws and anchors in the posterior and anterior columns. Perpendicular screws at point 1 and 3 have the greatest surgical risk. External angulation with respect to the axial plane of the acetabulum is safer, 0 to 45° being the safest optimal angles (optimal angulation angle - OAA) (Fig. 5).

The obturator internus muscle, which lies against the medial portion of the acetabulum, provided some interposition of tissue posteriorly and measured 1.2cm (0.6-1.5cm) in thickness. This protection was insufficient further anteriorly. Acetabular bone depth measurements revealed that the greatest depth for screw or anchor purchase was in the posterior column. The angulation created by the safe bone pathway in the anterior and posterior columns, with respect to the plane of the facies lunata at this area, was measured and termed as optimal angle of penetration (OAP). The values were 110° (102-123°) for the posterior column and 90° (85-94°) for the anterior column (Fig. 6).

DISCUSSION

Lesions of the LCF can be traumatic or degenerative in nature. The ruptured ligamentum can be a source of pain, locking and recurrent episodes of subluxation which may result in degenerative changes (6). Byrd analyzed 23 cases of traumatic injury to the LCF, 17 (74%) of which had occurred without accompanying dislocation of the hip (7).
There is emerging interest in reattaching or reconstructing the ligament to improve stability in DDH or following traumatic disruptions. In DDH, repair or reconstruction of the LCF to augment stability should be considered as an adjunct to open reduction (8). A recent study of high-performance runners noted hypertrophic change in the LCF during ar-

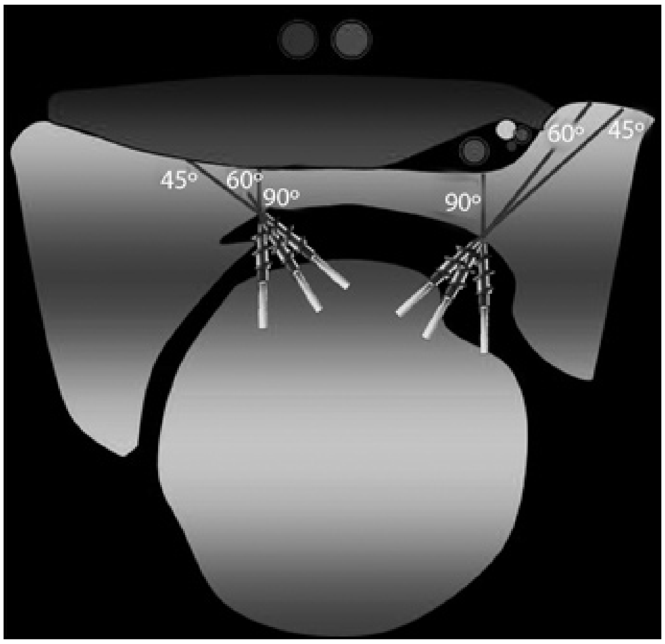

Fig. 5 - *Perpendicular screws at point 1 and 3 have greatest surgical risk than oblique. External angulation with respect to the axial plane of the acetabulum is safer being from 0 to 45° the safest optimal angles (Optimal Angulation Angle- OAA) External iliac vein and artey in the central portion. Obturator neurovascular structures near the anterior column.*

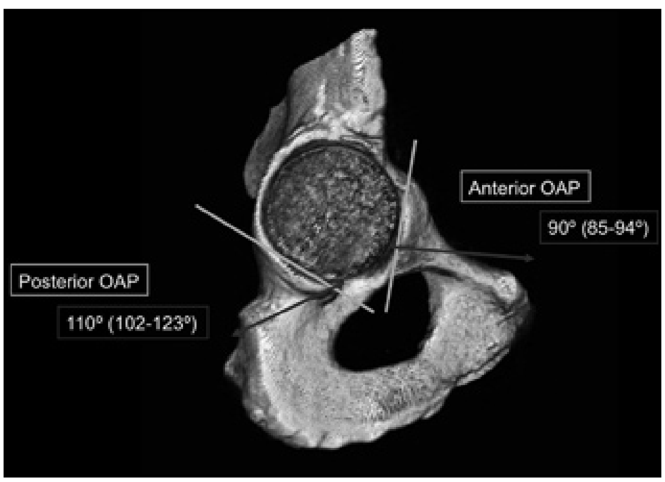

Fig. 6 - *Three dimensional reconstruction of the pelvis showing the Optimal Angles of Penetration (OAP) for safe anchor or screw pathway: 110° (102-123°) for the posterior column and 90° (85-94°) for the anterior column.*

throscopy, and also suggested a relationship with chronic instability (9). It is possible that the LCF has a role similar to that of the anterior cruciate ligament in the knee. The ultimate load to failure of this ligament in a porcine model is similar to that reported for the human anterior cruciate ligament (8). Reconstruction of the ligamentum has been carried out for recurrent instability of the hip with good short term results in individuals who participate in high-impact sports (football or hockey) or in sports that require excessive range of motion (ballet or martial arts) (10).

When contemplating reconstruction of this ligament, placement of anchors in the acetabulum is critical and technically demanding. Our study suggests that radiographic studies and three-dimensional reconstructions may assist preoperative planning to determine the anatomic course and proximity of the neurovascular structures, and to determinate the safe pathway for anchors in the anterior and posterior columns of the acetabulum. Screws and anchors located in the central inferior fossa longer than 3-4mm can potentially penetrate the inner wall and can endanger neurovascular structures.

The larger and broader posterior band of the ligament is (in our view) the more important during reconstruction. Nevertheless, in order to reproduce the mechanical properties of the ligament further studies are warranted. Our finding of wall thickness in the inferior fossa are similar to other studies (11, 12), but may not be representative of all hips because of anatomical variability (13). Patient weight also influences the safety of screw or anchor placement, because heavier patients are likely to have fat interposition. The concept of safe zones for transacetabular drill holes was developed by Wasielewski et al (14) and our study attempts to address the issue more specifically for arthroscopic surgeons.

There is sufficient thickness in the anterior and posterior columns to ensure secure fixation of anchors, the safer area being the posterior column. More anteriorly the region becomes closer to the obturator structures. The anterior part of central portion of the acetabulum appears to be inadequate since anchors or screws inserted perpendicular to the acetabular surface are directed towards the external iliac artery and vein and obturator structures. The danger to these structures is amplified by the lack of substantial bone stock and the sparse obturator internus muscle in this zone. Placement of anchors in the anterior part of the central region should be done with great care and avoided, if possible.

Two new surgically relevant angles angles must be considered as described above: The Optimal Angulation Angle (OAA) and the Optimal Angle of Penetration (OAP) which represent the orientation in the coronal and sagittal planes of the acetabulum. At present we are applying these techniques in cadavers, and we acknowledge that adjustment of drill direction can be problematic.

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