Origin of the Direct and Reflected Head of the Rectus Femoris: An Anatomic Study

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**Purpose:** This study aimed to define the footprint of the direct and reflected heads of the rectus femoris and the relation of the anterior inferior iliac spine (AIIS) to adjacent neurovascular (lateral circumflex femoral artery and femoral nerve), bony (anterior superior iliac spine [ASIS]), and tendinous structures (iliopsoas). **Methods:** Twelve fresh-frozen cadaveric hip joints from 6 cadavers, average age of 44.5 (±9.6) years, were carefully dissected of skin and fascia to expose the muscular, capsular, and bony structures of the anterior hip and pelvis. Using digital calipers, measurements were taken of the footprint of the rectus femoris on the AIIS, superior-lateral acetabulum and hip capsule, and adjacent anatomic structures. **Results:** The average dimensions of the footprint of the direct head of the rectus femoris were 13.4 mm (±1.7) × 26.0 mm (±4.1), whereas the dimensions of the reflected head footprint were 47.7 mm (±4.4) × 16.8 mm (±2.2). Important anatomic structures, including the femoral nerve, psoas tendon, and lateral circumflex femoral artery, were noted in proximity to the AIIS. The neurovascular structure closest to the AIIS was the femoral nerve (20.8 ± 3.4 mm). **Conclusions:** The rectus femoris direct and reflected heads originate over a broad area of the anterolateral pelvis and are in close proximity to critical neurovascular structures, and care must be taken to avoid them during hip arthroscopy. **Clinical Relevance:** A thorough knowledge of the anatomy of the proximal rectus femoris is valuable for any surgical exposure of the anterior hip joint, particularly arthroscopic subspine decompression and open femoroacetabular impingement (FAI) surgery.

Since the concept was popularized by Ganz et al.,1–3 femoroacetabular impingement (FAI) is increasingly treated by musculoskeletal physicians. FAI is a common cause of hip pain in active adolescents and adults and is proposed as an underlying factor in some types of hip osteoarthritis.4 Abnormal morphologic characteristics of the femur or acetabulum are believed to cause FAI. The bony conflict arises from either a prominence of the anterolateral head-neck junction of the femur (cam impingement) or relative overcoverage of the femoral head by the acetabulum (pincer impingement), or in many cases both. With repetitive motion of the hip, the cam or pincer lesions cause tears of the acetabular labrum and damage to the articular cartilage.5 In addition to cam and pincer impingement, anterior inferior iliac spine (AIIS) or subspine impingement has been recently proposed.6,7 This subtype involves collision between the AIIS and the distal aspects of the femoral neck or trochanter at high hip flexion angles. The anatomy of the AIIS has recently received increased attention in the literature, particularly in regard to spine/subspine decompression.8 However, the relationship between the tendons of the rectus femoris and important neurovascular structures has not been described and illustrated extensively. An improved understanding of AIIS anatomy would potentially help surgeons avoid destabilizing the rectus origin and avoid the creation of abdominal compartment syndrome resulting from overaggressive resection of the AIIS—a rare but potentially catastrophic complication of hip arthroscopy.

Options for treating FAI have increased in the past decade, particularly with the emergence of arthroscopic techniques.8 According to data from the American Board of Orthopaedic Surgery, between 1999 and 2009 there was an 18-fold increase in hip arthroscopy reported in case lists of candidates sitting for Part II of the American Board of Orthopaedic Surgery examination.9

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Further, between 2004 and 2009, a 365% increase in the rate of hip arthroscopy was observed. With the increase in the rate of hip arthroscopy observed in the United States, efforts to more clearly define the relevant anatomy involved in FAI are important. It is also important to note that the range of procedures performed by hip arthroscopists has expanded greatly since the introduction of hip arthroscopy. Rather than being a fairly limited tool used for a single indication such as debridement of degenerative labral tissue or removal of loose bodies, hip arthroscopy is now commonly used to perform complex labral repair, labral reconstruction, extensive capsulotomy and capsular closure, and resection of bony lesions, including cam, pincer, and prominent AIIS. Better understanding of the soft tissue and osseous anatomy is necessary both for improved treatment of the actual impingement lesions and for avoiding iatrogenic damage to surrounding structures within the operative field.

The purpose of this study was to define the footprint of the direct and reflected heads of the rectus femoris and define the relation of the AIIS to adjacent neurovascular (lateral circumflex femoral artery and femoral nerve), bony (ASIS), and tendinous structures (iliopsoas). We hypothesized that the direct and reflected tendons of the rectus femoris originate over a broad area of the anterior and lateral hip and pelvis and are closely situated to critical neurovascular structures.

Methods
Fresh-frozen cadaveric specimens were used for this descriptive anatomic study. The cadavers were provided by The Ohio State University Department of Orthopaedics. The specimens consisted of the entire pelvis (sectioned from the lower lumbar spine) with attached bilateral femurs (sectioned at the level of the mid to distal femur). All skin, soft tissue, and musculature of the pelvis, hip, and proximal thigh was otherwise in situ. We used 6 specimens, 2 from women and 4 from men, with an average age of 44.5 ± 9.9 years (range, 29 to 56 years). This allowed for examination of a total of 12 hips (6 right, 6 left). The frozen specimens were thawed at room temperature over 3 days. To maximize tissue quality, dissection work was completed over a 2-day period, and no additional freeze-thaw cycles were used.

A careful dissection of the anterior hip and pelvis was performed on each specimen (Fig 1). All dissection work and digital caliper measurements were made by the first author (J.M.R.), an orthopaedic hip preservation fellow. Skin and subcutaneous tissue were removed. Attention was directed over the anterior hip to the interval between the sartorius and tensor fascia lata muscles. This interval was opened to fully expose the rectus femoris muscle. The lateral circumflex femoral artery was noted and left in place where it passed deep to the rectus femoris. Proximally, the tendons of the sartorius and the direct and reflected heads of the rectus femoris were dissected to their origins on the anterior superior iliac spine (ASIS), AIIS, and superolateral margin of the acetabulum and adjacent joint capsule, respectively. Any overlying soft tissue was carefully removed to give a clear delineation of the extent of the tendon attachments. To give full visualization of the posterior extent of the reflected head of the rectus on the acetabulum, the tensor and gluteal musculature were dissected from their origins on the outer surface of the ilium. Additionally, the femoral nerve was identified as it passed over the pelvic brim anteromedially to the iliofemoral muscle. The tendon of the psoas muscle was also identified deep to the musculature as it passed over the pelvic brim.

Fig 1. Overview of anatomic area investigated in cadaveric dissections. (AIIS, anterior inferior iliac spine; ASIS, anterior superior iliac spine; Lat, lateral; Med, medial.)
Using digital calipers (accuracy of 0.025 mm; General Tools & Instruments, New York, NY), measurements were recorded for each of the following anatomic features:

1. Distance from the most medial to the most lateral aspect of attachment of the rectus femoris direct head on the AIIS (Fig 2A)
2. Distance from the most cranial to the most caudal aspect of attachment of the rectus femoris direct head on the AIIS (Fig 2B)
3. Distance from the anterior (defined as point at which direct and reflected tendons separate) to the most posterior aspect of the rectus femoris reflected head attachment to the superolateral acetabulum and joint capsule (Fig 3)
4. Distance from the most cranial to the most caudal aspect of origin of the rectus femoris reflected head on the superolateral acetabulum and joint capsule (Fig 4)
5. Distance from the superior aspect of the ASIS to the superior aspect of the AIIS (Fig 5)
6. Distance from the medial aspect of the AIIS to the lateral aspect of the femoral nerve at the level of the pelvic brim (Fig 6)
7. Distance from the medial aspect of the AIIS to the lateral aspect of the psoas tendon at the level of the pelvic brim (Fig 7)
8. Distance from the inferior aspect of the AIIS to the superior aspect of the lateral circumflex artery (Fig 8).

Each anatomic relation was measured 3 times by 1 examiner (JMR), and the mean values and standard deviations were calculated. Descriptive statistics were calculated for all data points for the entire group (Table 1). Intraobserver reliability was calculated for all continuous variable measurements using the intraclass correlation coefficient for single measures. PASW Statistics, student version 18.0.0 (SPSS, Chicago, IL) was used for all statistical calculations.
Results

The average dimensions of the rectus femoris direct head footprint were 13.4 (medial-lateral) × 26.0 mm (cranial-caudal). In contrast, the average dimensions of the reflected head footprint were 47.7 (anterior-posterior) × 16.8 mm (cranial-caudal). The footprint was slightly smaller in the female specimens (direct, 11.4 × 23.8 mm; reflected, 44.3 × 16.9 mm) than in the male specimens (direct, 14.4 × 27.1 mm; reflected, 49.4 × 16.8 mm).

The distance from the superior aspect of the ASIS to the superior aspect of the AIIS averaged 40.1 mm in all specimens. This distance was nearly identical in the male and female specimens.

The distance from the medial aspect of the AIIS to 2 important medial structures at the level of the pelvic brim—the femoral nerve and the psoas tendon—was also recorded. These structures were situated 20.8 mm (femoral nerve) and 19.3 mm (psoas tendon) medial from the AIIS. These distances were noted to be smaller in the female specimens compared with the male specimens.

Finally, the distance from the inferior aspect of the AIIS to the superior aspect of the lateral circumflex femoral artery at the level of its crossing deep to the rectus femoris muscle belly was recorded. This averaged 56.6 mm in all specimens.

Discussion

This study confirmed our hypothesis that the rectus femoris direct and reflected heads originate over a large area of the anterior and lateral pelvis and in close proximity to tendinous and neurovascular structures. The finding of a broad origin confirms the findings of a recent cadaveric and retrospective study by Hapa et al. and shows that a thorough knowledge of the anatomy of the proximal rectus femoris, and the femoral neurovascular bundle in particular, is valuable for any surgical exposure of the anterior hip joint, but is particularly relevant for hip preservation surgeons performing FAI surgery.

Recent evidence has suggested that in addition to the 2 most commonly described sources of osseous impingement (femoral head-neck junction cam and acetabular pincer), other extra-articular sources of impingement may exist, cause symptoms, and be successfully managed surgically with excellent early

Fig 4. Cranial-caudal extent of the reflected tendon of the rectus femoris (R) as it inserts along superolateral acetabular rim and joint capsule.

Fig 5. Distance from superior aspect of the anterior inferior iliac spine (AIIS) to superior aspect of the ASIS, indicated by white arrows. Sartorius (S) is reflected medially. Tensor and gluteal muscles are removed from outer surface of iliac wing. (R, rectus.)

High intraobserver reliability (≥0.90) was noted for all measured variables.
outcomes. These include the iliopsoas tendon (direct anterior labral tears)\textsuperscript{11} and impingement of the AIIS on the femoral neck or trochanter.\textsuperscript{4-8} AIIS or subspine impingement is an evolving concept that implicates prominence of the AIIS impinging on the distal anterior femoral neck at hip flexion angles greater than 90° as a potential cause of pain in some cases of FAI. The AIIS serves as the bony origin of the direct head of the rectus femoris, whereas the reflected head of the rectus femoris attaches along the superior lateral acetabulum and adjacent joint capsule. These structures are encountered during hip arthroscopy as well as during open surgical hip dislocations. The bony footprint of the direct head of the rectus femoris is of particular interest to the surgeon treating extra-articular (subspine or AIIS) impingement because correction of the bony impingement may require resecting a portion of the AIIS. In these cases, an awareness of the overall size and shape of the rectus footprint is important to avoid destabilizing the tendon from overly aggressive resection of the AIIS.\textsuperscript{6} The present study provides information about the average medial—lateral and cranial—caudal extent of the footprint of the direct head of the rectus, which may be useful to surgeons performing AIIS resection. Removal

**Fig 6.** Distance from medial aspect of the anterior inferior iliac spine (AIIS) to the lateral aspect of the femoral nerve (arrow) is indicated by the forceps. Rectus (R) remains attached to the AIIS. Sartorius (S) is reflected from the anterior superior iliac spine (ASIS) laterally.

**Fig 7.** Distance from medial aspect of the anterior inferior iliac spine (AIIS) to the lateral aspect of the psoas tendon, indicated by white arrows. Overlying iliopsoas muscle (red arrow) is reflected medially to visualize psoas tendon (green arrow). Sartorius (S) and rectus (R) are reflected laterally.

**Fig 8.** Distance from caudal aspect of the anterior inferior iliac spine (AIIS) to the lateral circumflex femoral artery, indicated by white arrows. Rectus (R) is reflected laterally.
of approximately 13 mm of bone medially-laterally and 13 mm cranially-caudally will, on average, eliminate approximately 50% of the bony attachment of the rectus direct head. However, it is important to note that AIIS morphologic characteristics may vary greatly, especially in the patient with a dysmorphic AIIS as a result of previous traction injury. Therefore, these results must be interpreted with consideration given to the unique anatomy of each patient.

This study also provides valuable insight into the relation of the AIIS and rectus tendon to the critical medial structures of the hip and pelvis, including the femoral neurovascular bundle. Our data indicate that in most cases the femoral nerve is approximately 2 cm medial from the AIIS, and the pelvic cavity is encountered immediately medial to the AIIS. This information prompts the surgeon to use caution to avoid entering the pelvis with aggressive resection of the AIIS or extension of a capsulotomy proximally and medially. In the setting of hip arthroscopy, aggressive dissection of the AIIS and adjacent joint capsule raises the possibility of creating an abdominal compartment syndrome from extravasation of arthroscopy fluid into the intra- or retroperitoneal spaces. Although few reports exist in the literature, the potential catastrophic consequences of abdominal compartment syndrome require the surgeon to be vigilant.12-15

**Limitations**

A strength of the current study is that the specimens were fresh frozen, resulting in better overall tissue quality and preservation of tissue planes. This allowed the structures to be more clearly delineated and likely improved the accuracy of the measurements. However, a potential limitation is that measurements of the tendon origins were based on careful gross dissection of the tendon-bone or tendon-capsule interface. The accuracy of the measurements could have been greater with a histologic analysis of the tendon-bone interface. A further analysis may have better defined the footprint of the reflected head of the rectus on the rim of the acetabulum and directly onto the hip capsule. In the current investigation, we were unable to determine a quantitative measurement of the percentage of the reflected head that originates directly from hip capsule versus acetabular rim.

The measurements recorded in this study—particularly of the rectus direct and reflected footprints—are 2-dimensional measurements of structures that have 3-dimensional shape. In particular, the footprint of the direct head on the AIIS follows rounded contours (medial-lateral and cranial-caudal) along the length of the inferior spine. This is also true of the reflected head footprint along its origin on the acetabulum from anterior to posterior. Therefore, the dimensions reported here should not be interpreted as calculations of the actual surface area of the tendon footprint. We did not delineate the measurement between the tendon proper and its sheath, although we recognize that this would be a more technically correct way to measure this area.

An additional limitation of the study is that a small number of specimens were available for examination. Although the specimens were relatively young (44.5 ± 9.9 years) compared with specimens typically available in anatomy laboratories, they were still older than many patients undergoing FAI surgery. Therefore, because of the small number and relatively older age of the specimens, the results presented here may not be completely representative of this anatomy in the typical FAI patient population. However, we believe that possible differences are not likely to be large and, as a result, these data provide useful information for the hip surgeon.

**Conclusions**

The rectus femoris direct and reflected heads originate over a broad area of the anterolateral pelvis and are in close proximity to critical neurovascular structures, and care must be taken to avoid them during hip arthroscopy.

**References**

5. Larson CM, Kelly BT, Stone RM. Making a case for anterior inferior iliac spine/subspine hip impingement:
Three representative case reports and proposed concept. Arthroscopy 2011;27:1732-1737.


7. Matsuda DK, Calipusan CP. Adolescent femoroacetabular impingement from malunion of the anteroinferior iliac spine apophysis treated with arthroscopic spinoplasty. Orthopedics 2012;35:e460-e463.


