Anatomy of the Adductor Magnus Origin

Implications for Proximal Hamstring Injuries

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Background: The adductor magnus (AM) has historically been a potential source of confusion in patients with suspected proximal hamstring avulsion injuries.

Purpose: To investigate the anatomic characteristics of the AM, including its osseous origin, anatomic dimensions, and relationship to the proximal hamstring tendons.

Study Design: Descriptive laboratory study.

Methods: Dissection of the AM origin was performed in 11 (8 cadavers) fresh-frozen hip-to-foot cadaveric hemipelvis specimens. The gross anatomy and architecture of the proximal hamstring and AM tendons were studied. After dissecting the hamstring tendons away from their origin, the dimension, shape, and orientation of the tendon footprints on the ischial tuberosity were determined.

Results: The AM was identified in all cadaveric specimens. The mean tendon thickness (anterior to posterior [AP]) was 5.7 ± 2.9 mm. The mean tendon width (medial to lateral [ML]) was 7.1 ± 2.2 mm. The mean tendon length was 13.1 ± 8.7 cm. The mean footprint height (AP dimension) was 12.1 ± 2.9 mm, and mean footprint width (ML dimension) was 17.3 ± 7.1 mm. The mean distance between the AM footprint and the most medial aspect of the conjoint tendon footprint was 8.5 ± 4.2 mm. Tendon measurements demonstrated a considerable degree of both intra- and interspecimen variability.

Conclusion: The AM tendon is consistently present just medial to the conjoint tendon at the ischial tuberosity, representing the lateral-most portion of the AM muscle. This study found wide variation in the dimensional characteristics of the AM tendon between specimens. Its shape and location can mimic the appearance of an intact hamstring (conjoint or semimembranosus) tendon intraoperatively or on diagnostic imaging, potentially misleading surgeons and radiologists. Therefore, detailed knowledge of the AM tendon anatomy, footprint anatomy, and its relationship to the hamstring muscle complex is paramount when planning surgical approach and technique.

Clinical Relevance: The reported data may aid surgeons in more accurate recognition, diagnosis, and repair of proximal hamstring avulsion injuries.

Keywords: anatomy; proximal hamstring; hamstring tendons; hamstring avulsion; hamstring repair; adductor magnus

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The hamstrings muscle complex is an important extensor of the hip and flexor of the knee and comprises 3 individual muscles: the biceps femoris (BF, long head and short head), semitendinosus (ST), and semimembranosus (SM).[2,3,34] With the exception of the short head of the biceps femoris, each of these muscles shares a common origin at the ischial tuberosity (Figure 1). The adductor magnus (AM) muscle is composed of a pubofemoral portion (innervated by the posterior branch of the obturator nerve) and an ischiocondylar portion, the latter of which also arises from the ischial tuberosity and shares a common innervation and action as the hamstring tendons. Because of this, the ischiocondylar portion is considered by some to be part of the hamstring muscle group.[24]
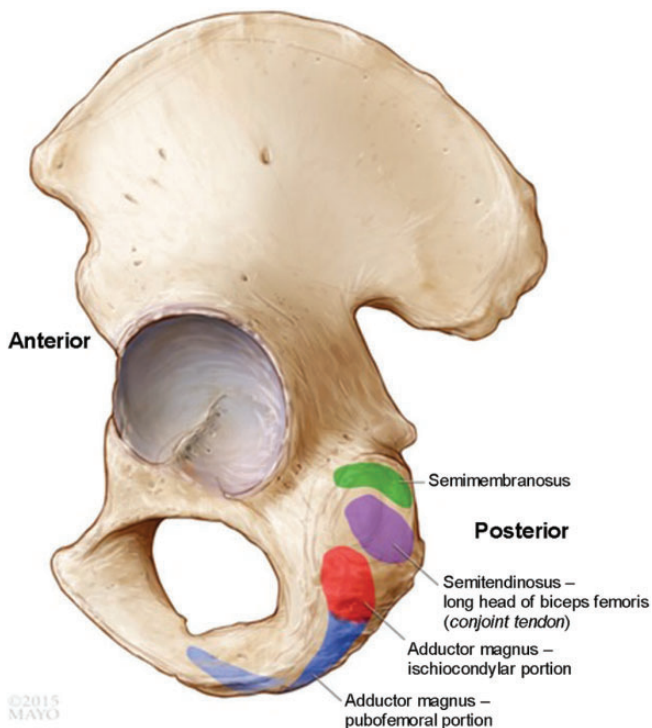
Figure 1. Lateral illustration of the ischial tuberosity demonstrates the relationship of the hamstring tendon and adductor magnus footprints. Note the difference in origin of the 2 components of the adductor magnus muscle and the medial location compared with the semimembranosus and conjoint tendons. Familiarity with this anatomy may aid surgeons in proper placement of anchors when repairing proximal hamstring injuries. Reprinted with permission from Broski et al.[5]

Figure 2. Coronal proton density–weighted magnetic resonance image through the ischial tuberosities demonstrating the normal origin of the adductor magnus (AM) ischiocondylar tendon (arrowheads), arising from the outer aspect of the inferior ischial tuberosity. The AM ischiocondylar tendon is found medially to the proximal semimembranosus (arrows) tendon. Note the close relationship and similar appearance of the 2 tendons on imaging.

The hamstring injury pattern most commonly seen in the adult population is a strain at the myotendinous junction, which can be successfully treated with rest and rehabilitation.[8,9,13,25] However, injury or complete avulsion of the proximal hamstrings tendon from its ischial origin is an increasingly recognized injury in the athletic population.[8,15] Forced flexion of the hip with ipsilateral knee extension has been implicated as the most common mechanism leading to these injuries.[10,23,29] It is often refractory to physical therapy and rehabilitation programs and frequently results in significant athletic morbidity. Previous studies have investigated the efficacy of conservative treatment of proximal hamstring avulsion injuries, and poor outcomes were reported.[11,12,14,16,28,29] Higher rates of persistent pain, nerve symptoms, decreased function, and inability to resume sport activities were reported by patients.[12,14,16,29] Therefore, patients with proximal hamstring avulsion are prime candidates for surgical repair, and early recognition is crucial in their management. Most authors recommend prompt surgical repair of acute hamstring avulsions to prevent further injury and impairment.¶
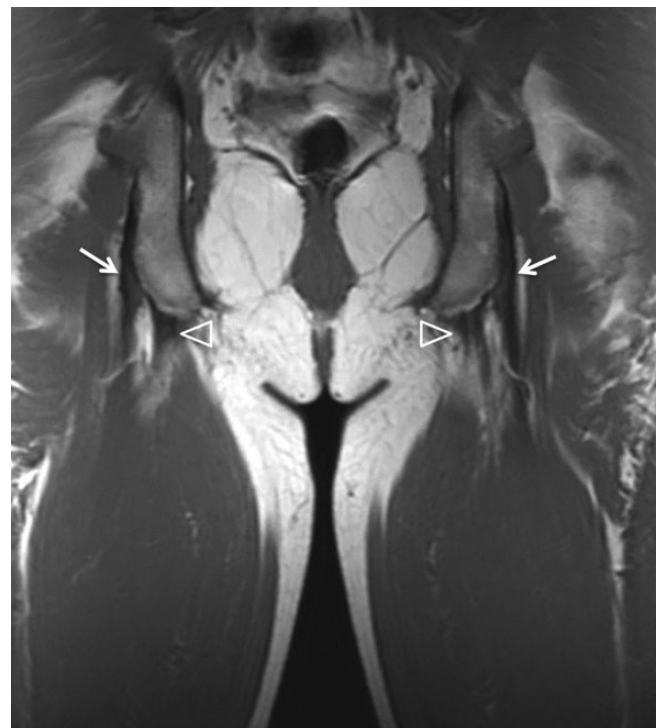
¶References 1, 4, 6, 7, 9, 10, 12, 17-19, 21, 22, 26, 29, 30, 32.

In a recent study by Broski et al,[5] the ischiocondylar portion of the AM was described as a possible source of diagnostic confusion when imaging complete proximal hamstring avulsion injuries with magnetic resonance imaging (MRI) as it may mimic an intact but attenuated semimembranosus tendon. This is especially true on coronal images where it may appear quite prominent (Figure 2). Because the AM is usually intact in cases of proximal hamstring avulsion, radiologists and surgeons run the risk of misdiagnosing patients with complete proximal hamstring avulsion and an intact AM as having only a partial proximal hamstring avulsion.[5] In addition to appearance on imaging, detailed knowledge of the regional anatomy and precise understanding of individual tendon footprint locations relative to one another may facilitate more accurate anatomic reconstruction in patients undergoing surgical repair.[25] Despite the increasing recognition and expanding literature on proximal hamstring injury repair and reconstruction, there are no prior anatomic studies detailing the gross anatomy of the AM and its relationship to the hamstring muscle complex. Therefore, the purposes of this study were to define the topographic anatomy and architecture of the AM origin on the ischial tuberosity, elucidate the remaining anatomic characteristics of
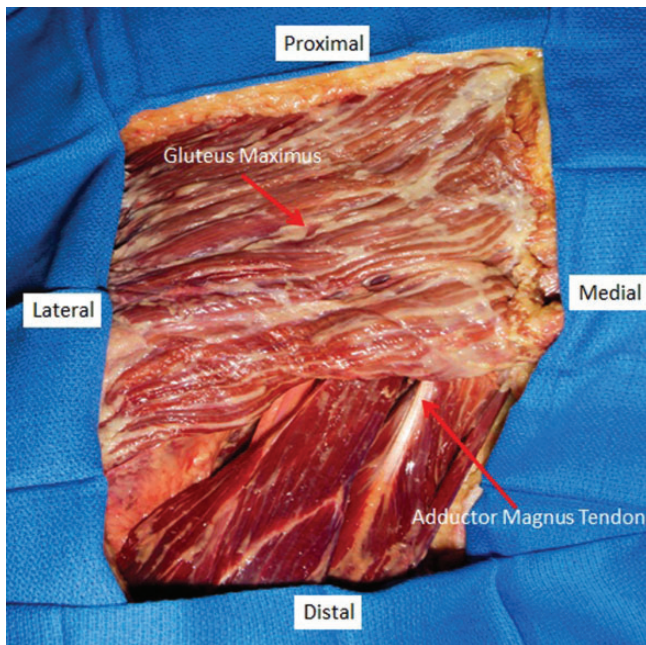
Figure 3. Gross anatomic findings after dissection of a left hip in the prone position. Gluteus maximus and common hamstring muscle group with overlying skin and subcutaneous adipose tissue were removed.

the AM, and explore the AM relationship to the hamstring muscle complex.

METHODS

Dissection of the AM origin was performed in 11 (8 cadavers) fresh-frozen hip-to-foot cadaveric hemipelvis specimens. The mean specimen age was 78.1 ± 6.3 years. Of the 11 specimens, 6 were male and 5 were female. Six specimens were left lower limbs and 5 right lower limbs. Dissection was performed in the prone position. The skin and subcutaneous tissues were first reflected to expose the gluteal muscles and hamstring musculature (Figure 3). Each of the 3 muscle bellies (ST, SM, BF) and the sciatic nerve were identified individually. The proximal hamstring tendons were isolated with blunt dissection and followed down to the level of their osseous origins (Figure 4). Once the AM ischiocondylar tendon was identified, its morphologic shape (flat, ovoid, or round) was recorded for each specimen (Figure 4). The tendon thickness (anteroposterior [AP] dimension), width (mediolateral [ML] dimension), and length (superoinferior dimension) were also measured using digital calipers. The medial distance from the semimembranosus tendon was also recorded. All measurements were made 1 cm distal to the AM ischial tuberosity origin.

With the sciatic nerve retracted laterally, the hamstrings and AM tendons were dissected away from the ischial tuberosity (Figures 5 and 6A). The AM tendon footprint was marked circumferentially with a surgical marker, and the height (AP dimension) and width (ML dimension) of the footprint measured (Figure 6B). The medial distances from
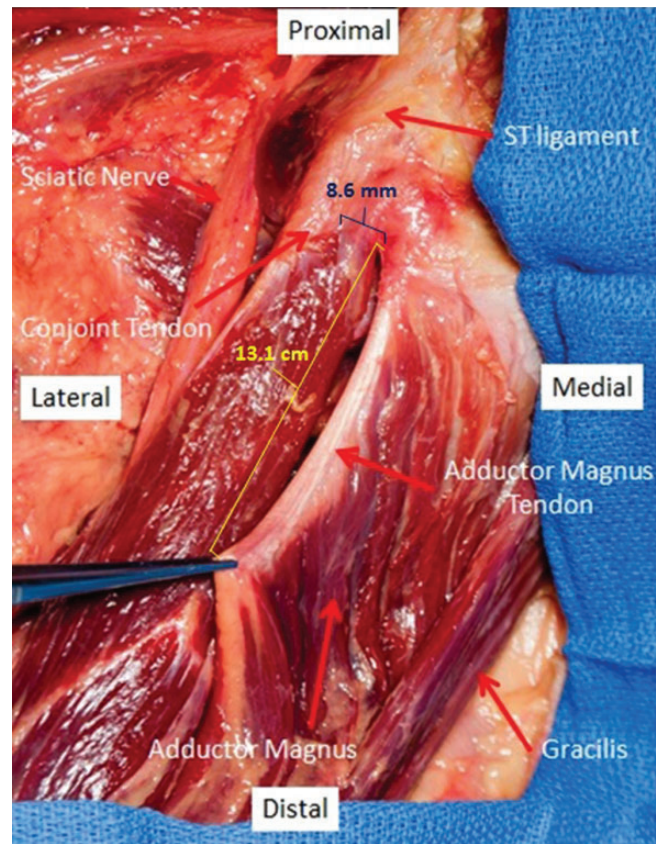

Figure 4. Gross anatomic findings after dissection. Adductor magnus (AM) tendon has been isolated and can be observed medial to the conjoint tendon. Yellow line, mean length of AM tendon; blue line, mean medial distance from the AM tendon to the semimembranosus tendon (located deep to conjoint tendon) at 1 cm distal to the ischial tuberosity.

the semimembranosus and conjoint tendon footprints were also recorded.

All measurements were collected using a digital caliper (Mitutoyo America Corp). Each measurement was taken 3 times by the same research investigator (S.M.B.), and a mean was calculated. Data were expressed as means and standard deviations for continuous variables and frequencies and percentages for discrete variables. All cadaveric specimens were obtained with permission from the Mayo Clinic Department of Anatomy in accordance with the Biospecimen Subcommittee policies for human specimen use in research. The study protocol was approved by our institution's ethics committee and received institutional review board approval.

RESULTS

Gross Anatomy and Morphology

All specimens demonstrated similar gross anatomy. No specimens were found to have any significant anatomic variation or abnormality. The semimembranosus tendon origin was located most proximoanterior and lateral on the ischial
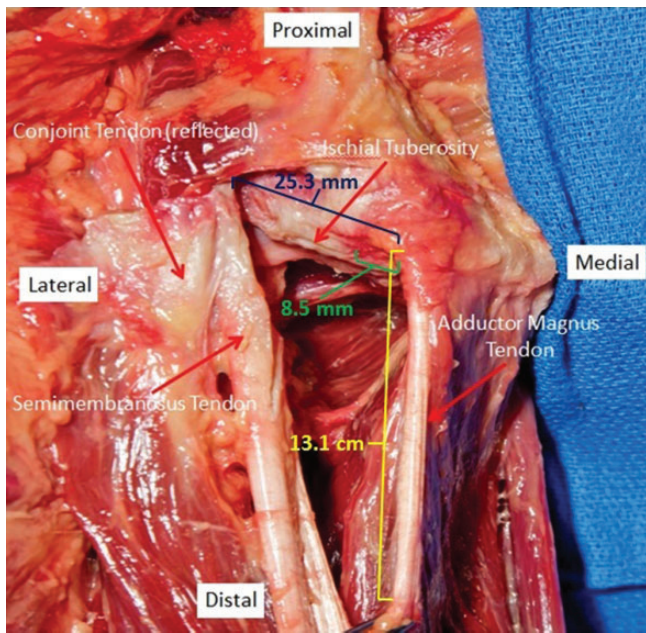
Figure 5. Gross anatomic findings after dissection. Reflection of conjoint tendon from ischial tuberosity revealing its footprint lateral to the adductor magnus (AM) but medial to the semimembranosus tendon. Yellow, mean length of AM tendon; green, mean medial distance from AM footprint and conjoint tendon footprint; blue, mean medial distance between the AM and semimembranosus footprints.

tuberosity. The semitendinosus and biceps femoris muscles merged to form the conjoint tendon, which originated posteroinferior and medial to the semimembranosus and superior and lateral to the AM ischiocondylar tendon. Therefore, the AM ischiocondylar origin was located inferior and medial to both the conjoint and semimembranosus tendons in all specimens (Figures 4 and 5). In each case, the AM ischiocondylar tendon was located lateral to the pubofemoral portion of the adductor magnus muscle. Of the 11 AM ischiocondylar tendons, 5 demonstrated ovoid and 6 were flat morphology.

Tendon Dimensional Characteristics

The mean tendon thickness (AP) was 5.7 ± 2.9 mm (range, 2.6-9.3 mm). The mean tendon width (ML) was 7.1 ± 2.2 mm (range, 3.0-11.8 mm). The mean tendon length was 13.1 ± 8.7 cm (range, 9.1-36.6 cm). One AM tendon had significantly greater length, measuring 36.6 cm, but the remaining AM tendons had measured lengths ranging from 9.1 to 12.5 cm. The mean medial distance from the semimembranosus tendon 1 cm below the tuberosity was 8.6 ± 2.5 mm (range, 4.1-12.3 mm).

Adductor Magnus Footprint Anatomic and Dimensional Characteristics

Mean AM ischial footprint height (AP) was 12.1 ± 2.9 mm (range, 8.9-17.8 mm). The mean width (ML) was $17.3 \pm$

7.1 mm (range, 6.5-27.5 mm). With all tendons reflected from their origins, the mean distance between the AM ischial footprint and the most medial aspect of the conjoint tendon footprint was 8.5 ± 4.2 mm (range, 1.1-15.8 mm). The mean medial distance between the AM ischial and semimembranosus footprints was 25.3 ± 7.7 mm (range, 13.0-43.0 mm).

DISCUSSION

This study demonstrates that the AM ischiocondylar tendon is a constant anatomic finding with variable anatomic characteristics. It has a well-defined osseous origin on the ischial tuberosity located medial to both the semimembranosus and conjoint tendons and may be a sizable structure in some individuals that has been described as a possible source of diagnostic confusion when imaging complete proximal hamstring avulsion injuries using MRI.[5]

The majority of hamstring injuries are strains at the myotendinous junction that respond well to conservative treatment. More recently, proximal hamstring avulsions have been recognized. Although such injuries are rare, the outcome of untreated hamstring avulsions is thought to be poor, especially in active patients. A detailed understanding of proximal hamstring anatomy as well as the AM ischiocondylar tendon is critical to accurate diagnosis and appropriate treatment of hamstring avulsion injuries.

Although proximal hamstring avulsions are relatively uncommon, they are heterogeneous and debilitating injuries. Cohen and Bradley[9] recommended nonoperative management of proximal hamstring injuries for 1- or 2-tendon avulsions with less than 2 cm of retraction. They hypothesized that nonoperative treatment is less successful for more substantial injuries, recommending acute surgical intervention for 2-tendon avulsions with more than 2 cm of retraction or complete 3-tendon tears regardless of the extent of retraction, and other authors have agreed with their recommendations.[16] Several studies have shown that acute surgical repair results in high patient satisfaction, earlier return to sport, and low rates of major complications.[4,6,10,30]

If precise guidelines are to be followed in selecting patients for surgery based on the number of tendons avulsed and degree of retraction, then accurate preoperative imaging based on a thorough understanding of the proximal hamstring anatomy, including the AM ischiocondylar tendon, is critical. A parallel imaging study performed by our group detailing the MRI appearance of the AM and involvement in cases of proximal hamstring avulsion has been undertaken. In a retrospective cohort of 66 patients, there were 17 cases of complete hamstring avulsion encountered. Of these 17 cases, the AM ischiocondylar tendon was intact in 13, partially torn in 3, and completely torn in 1 case. Given that the AM ischiocondylar portion can be a sizable tendon, originates from the ischial tuberosity in close proximity to the conjoint and semimembranosus tendons, and is usually intact in cases of hamstring avulsion, it may be mistaken for an intact hamstrings tendon on MRI.[5] If this is not recognized, patients who are truly
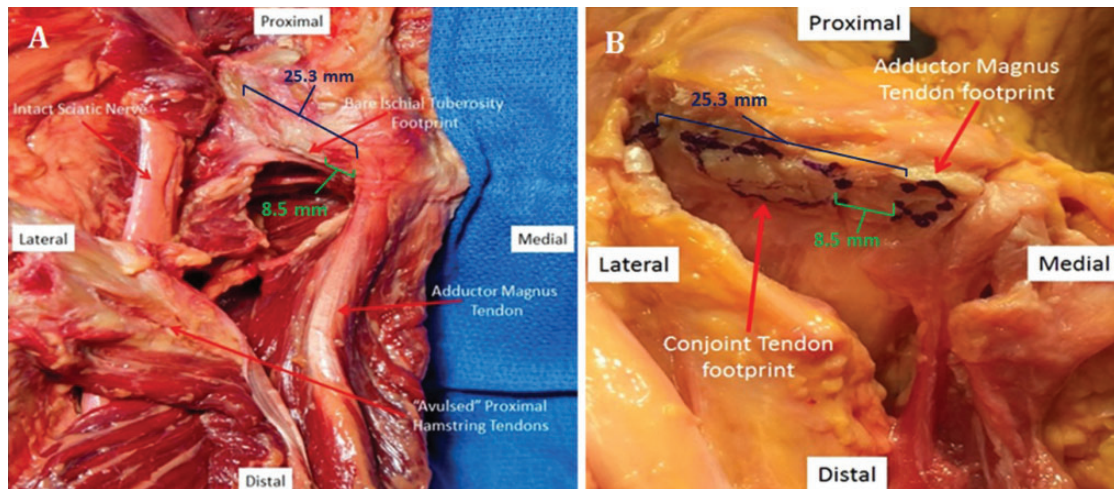
Figure 6. Gross anatomic findings after dissection. (A) Common hamstrings tendon (semitendinosus/semimembranosus/biceps femoris) dissected off from the ischial tuberosity revealing the dimensional characteristics of its footprint. (B) Circumferentially delineated common hamstring tendon footprint on ischial tuberosity observed laterally to the adductor magnus (AM) tendon footprint. Blue, mean medial distance between the AM and semimembranosus footprints; green, mean distance between the AM footprint and the most medial aspect of the conjoint tendon footprint.

surgical candidates may be relegated to conservative treatment, leading to poorer outcomes. We hope that a greater awareness of the AM tendon anatomy will decrease the possibility of misdiagnosis.

Detailed knowledge of the regional anatomy is particularly important for surgeons attempting to restore preoperative anatomy and reattach the avulsed hamstrings to their native footprints on the ischial tuberosity.[14] Unfortunately, current literature on the proximal hamstring anatomy is limited,[2,14,25,31,33,34] and there is some discrepancy regarding anatomic subtleties between authors.[1-3,9,20,25,27] A study by Feucht et al[14] documented the dimensional characteristics of the proximal hamstrings tendons and footprints, and their findings were largely concordant with previous reports.[25,31,33] Miller et al[25] also reported on tendon footprint locations and the relationship of the more lateral crescentic semimembranosus footprint and more medial oval semitendinosus/biceps femoris tendon footprint. In the present study, we observed a small degree of intra- and interspecimen variability in tendon footprint size and location; however, the findings are still largely in agreement with the current literature (see Figure 1).[14,25] Thus, the conjoint tendon footprint can be used as an excellent lateral intraoperative landmark, and with the information provided by this study, the AM ischial tendon may serve as a good medial landmark, being located on average 8.5 mm medial to the native conjoint tendon footprint. As described by Cohen et al,[10] discomfort while sitting is reported in up to 48% of patients after surgical repair, and it is largely believed to be associated with the surgical site dissection and buildup of scar tissue. While it has not been proven that anchor misplacement causes this symptom, it is possible it contributes in cases where structures have not been secured back to their natural anatomic location. In these instances, there is an increased risk for the development of unnatural folds in the tissue, which can lead to the

formation of abnormal pressure points that produce pain with sitting. Thus, this knowledge may facilitate current understanding and allow for accurate anchor placement that may decrease the incidence of sitting discomfort in patients after surgery.[10] Furthermore, in chronic injury, scar tissue can be so extensive as to obscure the sciatic nerve intraoperatively despite its size.[25] To avoid accidental injury, it is recommended to first identify the sciatic nerve in all surgical cases, which can be found 1.2 ± 0.2 cm from the ischial tuberosity's lateral aspect.[25] In these instances, the location of the AM ischiocondylar tendon can be utilized for accurate identification of the sciatic nerve's location. It serves as a medial landmark and the lesser trochanter a lateral landmark to locate the sciatic nerve to achieve neurolysis. Once the sciatic nerve has been safely isolated, the ruptured tendon can be identified, debrided, and tagged for repair.[10] In the surgical technique described by Cohen et al,[10] anatomic relationships are best restored by repairing the conjoined hamstring tendons together to the bone with a total of 5 bioabsorbable suture anchors placed in the configuration of an X on the ischial tuberosity. With regard to the findings of the present study, in the rare case where the AM ischiocondylar tendon is also torn, we suggest placing an additional anchor approximately 8.5 mm medial to the conjoined tendon footprint on the ischial tuberosity (see Figures 5 and 6). This will ensure proper restoration of the AM ischiocondylar tendon back to its natural anatomic location.

The present study has several limitations. All dissections were performed on fresh-frozen cadaveric specimens, and our measurements may vary from those obtained on surgical or embalmed specimens. There was a small sample size of specimens obtained for the study, which may have decreased the strength of our findings. The mean specimen age was 78.1 years, which is older than the average younger adult athlete who tends to present with proximal hamstring

avulsions. Therefore, there is likely anatomic variation due to myotendinous degeneration and atrophy that is part of the normal aging process. As also suggested by Feucht et al,[14] future investigations of the proximal hamstring anatomy might best be performed using younger specimens.

CONCLUSION

This study demonstrates that the AM ischiocondylar tendon is a constant anatomic finding with variable anatomic characteristics. It has a well-defined osseous origin on the ischial tuberosity located medial to both the semimembranosus and conjoint tendons and may be a sizable structure in some individuals. Because of this, an intact AM ischiocondylar tendon can be a source of diagnostic confusion in cases of complete proximal hamstring avulsion. Knowledge of this structure should prevent misdiagnosis on preoperative imaging, allow accurate selection of patients for conservative or operative management, and aid as an intraoperative landmark for accurate anatomic restoration during proximal hamstring repair.

ACKNOWLEDGMENT

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