Anatomical considerations in hamstring tendon harvesting for anterior cruciate ligament reconstruction

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Summary

Hamstring tendons are widely used for anterior cruciate ligament (ACL) reconstruction of the knee. Certain anatomical considerations must be taken into account when harvesting the hamstring tendons to be used in ACL reconstruction. These anatomical considerations are discussed in this review article.

Key words: hamstring, tendon, harvesting, ligament reconstruction, anterior cruciate ligament.

Introduction

Hamstring tendons are one of the most commonly used grafts in anterior cruciate ligament (ACL) reconstruction of the knee, either as an autograft or allograft. Hamstring tendon grafts when compared to patellar - bone - tendon - bone grafts allow harvesting through a minimal skin incision, minimal donor site morbidity, and less extensor mechanism dysfunction with equally successful long term clinical results[1-4]. However, certain anatomical considerations must be taken into account when harvesting the hamstring tendons.

Pes anserinus insertion

Semitendinosus, gracilis and sartorius, have a common insertion into the anterior-medial aspect of the tibia, the *pes anserinus*[5]. These muscles act as flexors of the knee but also provide tibial rotation and act as rotatory and valgus constraints to the knee. Semitendinosus and gracilis are used in ACL reconstruction. Gracilis originates from the inferior ramus of the pubis and is a long fusiform muscle, that gives rise to a cylindrical tendon, and is innervated by the obturator nerve. Semitendinosus originates from the ischial tuberosity, is a fusiform muscle that about halfway down the thigh gives rise to a tubular tendon, and is innervated by the tibial branch of the sciatic nerve. Sartorius originates form the anterior superior iliac spine, and its tendon becomes thin and flat, like a fascial layer[6]. Gracilis and semitendinosus lie between layers one (that includes the sartorius fascia) and two (that includes the medial collateral ligament) of the medial structures of the knee[7]. Although gracilis and semitendinosus are separate structures proximally, they converge prior to their insertion onto the tibia. The insertion of gracilis is superior to that of semitendinosus. The *pes anserinus* insertion is about 19 mm (range 10-25 mm) distal and 22.5 mm (range 13-30 mm) medial to the apex of the tibial tuberosity[8]. The convergence of Sartorius and gracilis is described as being 2.2+/- 0.7 cm distal and 4.5+/-0.6 cm medial to the tibial tuberosity[9]. The *pes anserinus* insertion is closely related to the infrapatellar branch of the saphenous nerve and to the main saphenous nerve itself (Fig. 1). The sartorius fascia must be incised in order to expose the underlying semitendinosus and gracilis tendons which can be seen closely attached to the sartorius fascia. It is also important to note that semitendinosus and gracilis are, unlike the medial collateral ligament, are not adherent to bone, except at their attachment, a characteristic which can help distinguish these structures (Fig. 2). Furthermore, once the converging attachment of gracilis and semitendinosus the tibia is identified, this must be traced

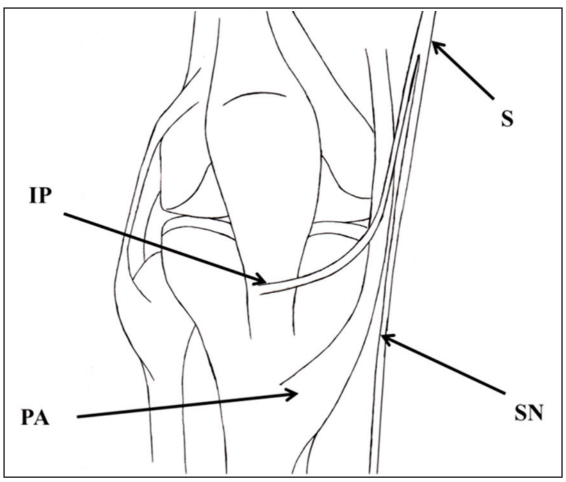

Figure 1. Anterior illustration of the right knee demonstrating the anatomical relationship between the PA: *Pes Anserinus*, S: Saphenous Nerve, SN: Sartorial nerve and the IP: Infrapatellar nerve.

more proximally to identify the two separate tendons prior to their convergence, and thus harvest them individually.

Graft Size

When using a patellar - bone - tendon - bone graft, the graft diameter can be reproducibly determined by the surgeon. However, when using hamstring tendons the graft diameter is predetermined by the natural diameter of the tendons of each individual and the surgeon has no influence on that. Hence it is possible to obtain a graft of too small diameter, which potentially could be associated with less mechanical resistance. Grafts greater than 7 mm in diameter are usually preferred. Graft length is also important, in order to allow adequate femoral and tibial fixation. It is estimated that a length of 9 cm for a looped graft (18 cm for un-looped) is needed, to give about 3 cm of intra-articular graft, 4.5 cm in the tibia and 2.5 cm in the femur. Again, the hamstring graft length that can be obtained is predetermined by each individuals natural anatomy.

Being able to predict graft length and diameter in each individual could allow preoperative planning particularly with regards the use of alternate grafts in those with anticipated short length or small diameter hamstrings. Several studies have investigated potential patient characteristics that could predict graft length and diameter. Chiang et al.[10] evaluated 100 patients who had double bundle ACL reconstruction with autologous hamstring tendons. Height and leg length were correlated with the lengths of gracilis and semitendinosus. Both tendons were longer in Caucasians as compared to Chinese. None of the anthropometric measures examined in that study were strong predictors of hamstring diameter. Along similar lines Tuman et al.[11] showed that the quadruple hamstring graft diameter was related to height, mass, age, and sex but not BMI. Height was the parameter mostly correlated with graft diameter, especially in females. In a study by Pinheiro et al.[12] involving 80 patients having ACL reconstruction with hamstring tendons in a quadruple graft, graft diameter was related to height, sex, leg and thigh length, weight and thigh diameter. Females had smaller grafts than males. Males taller than 1.85 m had an average graft diameter greater than the whole group and a greater proportion of 9 mm grafts. Ma et al.[13] found that males had significantly larger diameter hamstring grafts than females. Sex was related to graft diameter, but not age or weight. Height was a predictor of graft diameter in males. None of the parameters assessed predicted graft diameter in females. 42% of females had graft diameters of 7 mm or less. However, although correlations have been shown between certain anthropometric data and graft length/diameter it is not possible to accurately predict the diameter and length of a graft in a particular individual. Nevertheless there seems to be a consensus that females tend to have small diameter grafts, which may explain reports of postoperative graft laxity more often seen in females.

Previous studies have also examined the use of preoperative imaging in predicting graft length and cross sectional area in terms of three dimensional computed tomography (3-D CT) or Magnetic Resonance Imaging (MRI). There was a positive correlation between the total length of harvested semitendinosus tendon with the pre-operative length measured by 3-D CT scanning. However when the cross sectional area of semitendinosus tendon was examined there was no correlation between 3D-CT scan and intra-operative measurements[14]. Similarly MRI has been unable to accurately assess cross sectional area accurately in a particular individual[15].

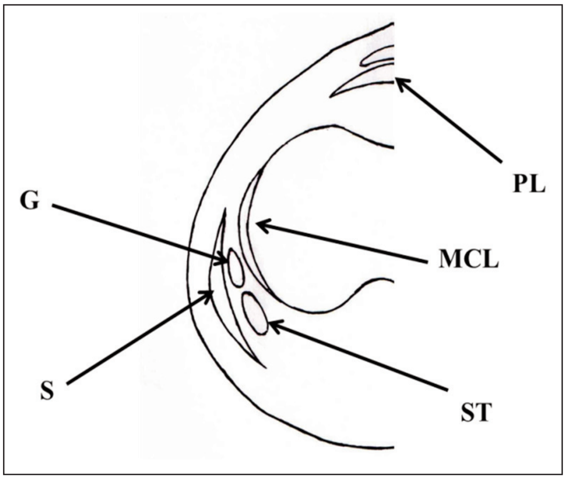

Figure 2. Cross-sectional illustration demonstrating the anatomical relationship of McL: Medial collateral ligament, G: gracilis, S: Sartorius, ST: Semitendinosus, PL: Patellar ligament.

It has also been suggested that the kind of tendon harvester used may influence the length of hamstring tendon obtained. Charalambous et al.[16] harvested 36 semitendinosus and gracilis tendons using either a closed stripper or a blade harvester in 18 cadaveric knees. The blade harvester gave longer lengths of usable tendon as compared to a closed stripper.

With the mainly caucasian population of the United Kingdom, graft length is not a major concern, however graft diameter can be. One must have the availability of using graft augmentation techniques such as the LARS (Ligament Augmentation & Reconstruction System), when faced with small diameter grafts. Such techniques have recently been reported to give good middle term functional results[17,18]. Alternatively, augmentation with a hamstring tendon from the opposite knee, or intra-operative conversion to a different graft may be essential.

Accessory insertions and fascial bands

Apart from the main hamstring tendon insertion to the *pes anserinus* there may be accessory tendon insertions, particularly for semitendinosus. In addition there are variable numbers of thick fascial bands that pass between semitendinosus and gracilis and also from these hamstring tendons to gastrocnemius, popliteal, pre-tibial and superficial fascia[19] (Fig. 3). Recognising these accessory insertions and fascial bands and dividing them is essential. If these are not recognised and divided they can divert the tendon stripper into the main tendon leading to premature tendon amputation and short graft.

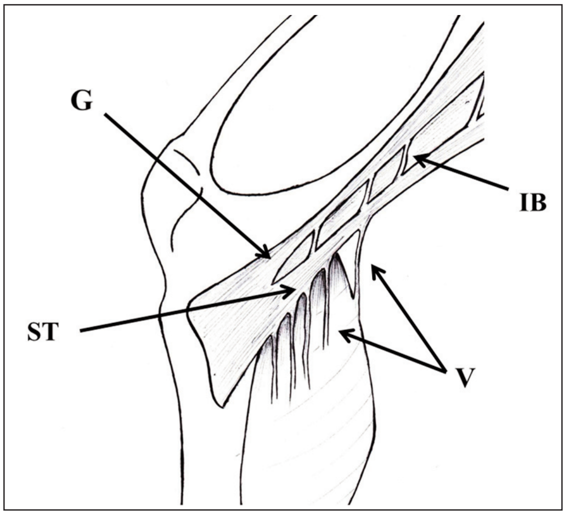

Figure 3. Simplified illustration or the medial aspect or the right knee demonstrating the anatomical relationship of Vincula to other structures in the knee. G: Gracilis, ST: Semitendinosus, IB: Interconnecting bands, V: Vincula.

Cadaveric studies by Candal-Couto and Deehan[19] and Tuncay[20] reported the existence of several accessory bands of gracilis and semitendinosus. Tuncay et al.[20] studied the anatomy of the fascial bands between semitendinosus and gastrocnemius in 23 cadaveric knees. They found that the mean width of the main band was 2.6 cm (1-4 cm) and the mean distance from the semitendinosus insertion to this fascial band was 7 cm (6-8 cm). However Candal-Coutoand Deehan[19] in another cadaveric study, found that accessory bands originated at greater than 10 cm from the tibial insertion of 8/10 semitendinosus and 2/10 gracilis tendons, contrary to the common belief that 10 cm proximal to the insertion of pes anserinus is a safe distance to avoid encountering such a band. This has been confirmed more recently by Yasin et al.[21] *in vivo*. They studied the number of accessory bands and their location in 25 patients undergoing ACL reconstruction using hamstring tendons. For gracilis the most common number of accessory bands was 2 (range 0-3). The average distance of the most proximal band from the common insertion was 5.14 cm with none of the gracilis accessory bands being more than 10 cm proximal to the tibial crest attachment. For semitendinosus tendons the most common number of accessory bands was 3 (range 1-4), the average distance of the most proximal band from the tibial crest insertion was 8.14 cm. However, 5 semitendinosus tendons had accessory bands located more than 10 cm proximal to the tibial crest attachment.
In a cadaveric study, Sanders et al.[22] described 3 zones with the knee in 90º flexion and the femur parallel to the floor. Zone A included the area anterior-superior to gracilis, zone B between gracilis and semitendinosus and zone C, posterior-inferior to semitendinosus. They described that proximally semitendinosus had variable slips inserting onto the crural fascia and gastrocnemius. Distally there were reproducible accessory tendon slips. In zone A, a membranous band originating from the medial epicondyle of the femur was found to insert on the intratendinous fascia of gracilis and semitendinosus. In zone B fibrous bands existed between the two tendons, reproducibly found at 2.5 cm, 5.5 cm and 6.5 cm form the distal tendon insertion. Zone C included the only true accessory insertional tendon from the semitendinosus at 5.1 cm which was preceded by a variable band at 3.8 cm.

Saphenous nerve

The saphenous nerve and its branches are closely related to the medial hamstring tendons and could potentially be damaged during hamstring tendon harvesting. Such nerve damage may occur during skin incision and dissecting beneath the skin or at deeper dissection and harvesting of the tendons. The saphenous nerve is a sensory nerve that supplies the intra-articular part of the knee and skin on the medial aspect of the knee, lower leg and ankle. It arises from the posterior division of the femoral nerve at the upper part of the thigh, traverses the adductor canal and divides into its two terminal branches, the infra-patellar and sartorial branch. The infra-patellar branch curves anteriorly to supply the anterior-medial aspect of the knee whereas the sartorial branch pierces the sartorial fascia to become subcutaneous. The sartorial branch continues distally alongside the great saphenous vein, giving sensation to the medial aspect of the lower leg[6]. The infrapatellar branch of the saphenous nerve may be described as posterior, penetrating, parallel and anterior according to its relationship to sartorius[23]. The posterior type (nerve emerges under the posterior border of Sartorius) is the most common, seen in 62% of cases. The infrapatellar branch passes between the inferior pole of the patella and the tibial tuberosity in 98.5% and distal to the tuberosity in 1.5% of cases. It passes as one branch in 25%, 2 branches in 62%, 3 branches in 10% and 4 branches in 1.5% of cases[24].
Sanders et al.[22] found that the saphenous nerve frequently run parallel and closely to gracilis on the deep surface of sartorius crossing gracilis from lateral to medial at 11.8 cm (range 7-13.2 cm) from its distal insertion. It then continued distally on the posterior-medial side of the tendon. The sartorial branch left the sartorius fascia at a mean of 7.2 cm (range 6.4 cm-9.3 cm) from the distal gracilis insertion to become subcutaneous, hence it was closely related to gracilis for 4.6 cm prior to leaving layer 1 of the knee.
In a review of 164 patients that had ACL reconstruction, Sanders et al.[22] reported a 19% rate of isolated infra-patellar nerve injury following hamstring harvesting through a 1.5-2 cm vertical incision over pes-anserinus. There was also a 23% isolated injury rate of the sartorial branch, and a 32% injury rate of both branches.
Luo et al.[25] examined the relationship between skin incision and injury of the infra-patellar branch during ACL reconstruction. A vertical incision was used in 35 and an oblique incision in 25 cases. 23 (65.7%) in the vertical incision and 6 (24%) in the oblique incision group had evidence of infra-patellar nerve injury. The skin area of altered sensation was greater in the vertical as compared to the oblique incision group. Four cases developed medial lower leg paraesthesia, suggestive of damage to the sartorial branch.

Papastergiou et al.[26] carried out a retrospective study of 230 ACL reconstructions using hamstring tendons. In one group harvesting was through a 3 cm vertical incision, and in a second group through a 3 cm horizontal incision. There was a 39.7% rate of sensory changes in the area innervated by the infrapatellar branch in the first group a 14.9% rate in the second group.

Boon et al.[27] tried to determine safe areas and angles for skin incisions for harvesting semitendinosus and gracilis by looking at 40 cadaveric knees. They reported that when the knee is placed in flexed position, a horizontal line was drawn on the plane of the tibial tuberosity. In the right knee the safe area was between 3.7 and 5.5 cm from the tibial tuberosity with a safe incision line at an angle of 51.6°. In left knee the safe area was between 3.6 and 4.9 cm from the tibial tuberosity with the safe incision line being at an angle of 52.5°. However such measurements may be difficult to reproduce intra-operatively.

Both the infra-patellar and sartorial branches of the saphenous nerve are at risk of damage during hamstring tendon harvesting. Careful dissection and harvesting, as well as a horizontal or oblique skin incision may reduce the injury rate. In addition placing the knee in 90° flexion with the hip externally rotated (by placing the leg in the figure of 4 position) may reduce the risk of damage to the saphenous nerve. Explaining this potential complication to the patient pre-operatively is essential.

Medial collateral ligament

The MCL lies deep to the semitendinosus and gracilis, closely adherent to bone. Care must be taken to avoid damaging this or mistaking it for a hamstring tendon. Its close adherence to bone is one way of distinguishing the MCL from the tendon.

Conclusions

In conclusion, hamstring tendons can give good functional results when used for ACL reconstruction with minimal donor site morbidity. However there are several anatomical issues which must be taken into account when performing hamstring tendon harvesting in order to minimise intraoperative as well as post-operative complications.

References

1. Beynnon BD, Johnson RJ, Fleming BC, Kannus P, Kaplan M, Samani J, Renström P. Anterior cruciate ligament replacement: comparison of bone-patellar tendon-bone grafts with two-strand hamstring grafts. A prospective randomized study. J Bone Joint Surg Am 2002; 84-A(9):1503-1513.
2. Corry IS, Webb JM, Clingeleffer AJ, Pinczewski LA. Arthroscopic reconstruction of the anterior cruciate ligament. A comparison of patellar tendon autograft and four-strand hamstring tendon autograft. Am J Sports Med 1999; 27(4):444-454.
3. Goldblatt JP, Fitzsimmons SE, Balk E, Richmond JC. Reconstruction of the anterior cruciate ligament: meta-analysis of patellar tendon versus hamstring tendon autograft. Arthroscopy 2005;21(7): 791-803.
4. Pinczewski LA, Lyman J, Salmon LJ, Russell VJ, Roe J, Linklater J. A 10-year comparison of anterior cruciate ligament reconstructions with hamstring tendon and patellar tendon autograft: a controlled, prospective trial. Am J Sports Med 2007;35(4): 564-574.
5. Mochizuki T, Akita K, Muneta T, Sato T. Pes anserinus: layered supportive structure on the medial side of the knee. Clin Anat 2004;17(1):50-54.
6. McMinn RMH. Last's Anatomy: Regional and Applied 9th Edition. Churchill Livingstone; November 1994.
7. Warren LF, Marshall JL. The supporting structures and layers on the medial side of the knee: an anatomical analysis. J Bone Joint Surg Am 1979; 61(1):56-62.
8. Pagnani MJ, Warner JJ, O'Brien SJ, Warren RF. Anatomic considerations in harvesting the semitendinosus and gracilis tendons and a technique of harvest. Am J Sports Med 1993; 21(4):565-571.
9. Tillett E, Madsen R, Rogers R, Nyland J. Localization of the semitendinosus-gracilis tendon bifurcation point relative to the tibial tuberosity: an aid to hamstring tendon harvest. Arthroscopy 2004; 20(1): 51-54.
10. Chiang ER, Ma HL, Wang ST, Hung SC, Liu CL, Chen TH. Hamstring graft sizes differ between Chinese and Caucasians. Knee Surg Sports Traumatol Arthrosc 2011; 25.
11. Tuman JM, Diduch DR, Rubino LJ, Baumfeld JA, Nguyen HS, Hart JM. Predictors for hamstring graft diameter in anterior cruciate ligament reconstruction. Am J Sports Med 2007; 35(11):1945-1949.
12. Pinheiro LF Jr, de Andrade MA, Teixeira LE, Bicalho LA, Lemos WG, Azeredo SA, da Silva LA, Gonzaga LG. Intra-operative four-stranded hamstring tendon graft diameter evaluation. Knee Surg Sports Traumatol Arthrosc 2011; 19(5):811-815.
13. Ma CB, Keifa E, Dunn W, Fu FH, Harner CD. Can pre-operative measures predict quadruple hamstring graft diameter? Knee 2010;17(1):81-83.
14. Yasumoto M, Deie M, Sunagawa T, Adachi N, Kobayashi K, Ochi M. Predictive value of preoperative 3-dimensional computer tomography measurement of semitendinosus tendon harvested for anterior cruciate ligament reconstruction. Arthroscopy 2006; 22(3):259-264.
15. Bickel BA, Fowler TT, Mowbray JG, Adler B, Klingele K, Phillips G. Preoperative magnetic resonance imaging cross-sectional area for the measurement of hamstring autograft diameter for reconstruction of the adolescent anterior cruciate ligament. Arthroscopy 2008; 24(12):1336-1341.
16. Charalambous CP, Alvi F, Phaltankar P, Gagey O. Hamstring tendon harvesting-Effect of harvester on tendon characteristics and soft tissue disruption; cadaver study. Knee 2009; 16(3):183-186.

17. Machotka Z, Scarborough I, Duncan W, Kumar S, Perraton L. Anterior cruciate ligament repair with LARS (ligament advanced reinforcement system): a systematic review. Sports Med Arthrosc Rehabil Ther Technol 2010; 7;2:29.
18. Hamido F, Misfer AK, Al Harran H, Khadrawe TA, Soliman A, Talaat A, Awad A, Khairat S. The use of the LARS artificial ligament to augment a short or undersized ACL hamstrings tendon graft. Knee 2011;18(6):373-378.
19. Candal-Couto JJ, Deehan DJ. The accessory bands of Gracilis and Semitendinosus: an anatomical study. Knee. 2003;10(4):325-328.
20. Tuncay I, Kucuker H, Uzun I, Karalezli N. The fascial band from semitendinosus to gastrocnemius: the critical point of hamstring harvesting: an anatomical study of 23 cadavers. Acta Orthop 2007;78(3):361-363.
21. Yasin MN, Charalambous CP, Mills SP, Phaltankar PM. Accessory bands of the hamstring tendons: A clinical anatomical study. Clin Anat 2010.
22. Sanders B, Rolf R, McClelland W, Xerogeanes J. Prevalence of saphenous nerve injury after autogenous hamstring harvest: an anatomic and clinical study of sartorial branch injury. Arthroscopy 2007;23(9):956-963.
23. Arthornthurasook A, Gaew-Im K. The sartorial nerve: its relationship to the medial aspect of the knee. Am J Sports Med 1990;18(1):41-42.
24. Kartus J, Ejerhed L, Eriksson BI, Karlsson J. The localization of the infrapatellar nerves in the anterior knee region with special emphasis on central third patellar tendon harvest: a dissection study on cadaver and amputated specimens. Arthroscopy 1999;15(6):577-586.
25. Luo H, Yu JK, Ao YF, Yu CL, Peng LB, Lin CY, Zhang JY, Fu X. Relationship between different skin incisions and the injury of the infrapatellar branch of the saphenous nerve during anterior cruciate ligament reconstruction. Chin Med J (Engl) 2007;120(13):1127-1130.
26. Papastergiou SG, Voulgaropoulos H, Mikalef P, Ziogas E, Pappis G, Giannakopoulos I. Injuries to the infrapatellar branch(es) of the saphenous nerve in anterior cruciate ligament reconstruction with four-strand hamstring tendon autograft: vertical versus horizontal incision for harvest. Knee Surg Sports Traumatol Arthrosc 2006;14(8):789-793.
27. Boon JM, Van Wyk MJ, Jordaan D. A safe area and angle for harvesting autogenous tendons for anterior cruciate ligament reconstruction. Surg Radiol Anat 2004;26(3):167-171.