Estimating Lengths of Semitendinosus and Gracilis Tendons by Magnetic Resonance Imaging

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Purpose: To determine whether preoperative magnetic resonance imaging (MRI) can help predict the tendon-only length of the semitendinosus (ST) and the gracilis (G). **Methods:** The distance from the tibial insertion to the distal-most aspect of the musculotendinous junction (MTJ) of the ST and G was estimated on preoperative MRI scans of patients undergoing primary anterior cruciate ligament (ACL) reconstruction with single-bundle, quadruple-stranded hamstring autograft. This MRI tendon-only length, measured by a musculoskeletal radiologist blinded to surgical findings, was compared to the actual tendon-only length measured upon harvesting each tendon. **Results:** Among the 42 patients comprising the study population, there was very strong correlation between the estimates of tendon-only length made by MRI and surgical measurements for both the ST (Spearman coefficient = 0.83; $P < .0001$) and the G (Spearman coefficient = 0.82; $P < .0001$). The difference between MRI and surgical measurements did not exceed 3 cm for any of the 84 harvested hamstring tendons. Bland-Altman plots confirmed agreement between the 2 measurement methods. There was also strong correlation between the surgically measured tendon-only length of the ST and its G counterpart (Spearman coefficient = 0.68; $P < .0001$). **Conclusions:** MRI estimates of tendon-only length for both the ST and G very strongly correlate with operative measurements of these lengths; the discrepancy between these 2 measurement methods was found to not exceed 3 cm when the MTJ of these tendons is visible on MRI scans. **Level of Evidence:** Level III, comparative study.

Hamstring autografts continue to be widely used for anterior cruciate ligament (ACL) reconstruction surgery, and a very recent systematic review of higher quality investigations using independent femoral tunnel drilling techniques found outcome and failure rates to be comparable to bone-patellar tendon-bone autografts.[1] The standard technique for single-bundle ACL reconstruction is to use a quadruple-stranded graft, created by harvesting both the semitendinosus (ST) and gracilis (G) tendons and folding each over itself after any attached muscle fibers and other non-tendinous tissues are removed. Although there is some evidence that the diameter of the such grafts does not correlate with risk of clinical failure after single-bundle ACL reconstruction,[2] other clinical studies have linked higher failure rates with smaller diameter hamstring grafts.[3,4] Additionally, recent biomechanical testing showed a correlation between tensile strength and the diameter of quadrupled human hamstring grafts.[5]

Concern regarding the potential of a higher failure rate with use of thinner hamstring grafts has led some investigators to the practice of adding allograft tissue to increase the overall graft diameter when thickness of harvested tendons is deemed insufficient.[6] Others prefer to increase the number of times the harvested hamstring tendons are folded to obtain a thicker, albeit shorter, final graft.[5,7-9] But the ability to fold a tendon on itself more than once to increase graft thickness requires the harvested tendon to be long enough to allow that. Indeed, a recent description of the use of a 5-stranded graft for ACL reconstruction by tripling the ST indicated that harvested tendon needed to be at least 21 cm long to yield a graft of sufficient length.[7] Furthermore, some individuals simply have very short tendon lengths of the ST or G due to an abnormally distal musculotendinous junction (MTJ), which can preclude using the too short harvested tendon in the standard fashion, let alone folding it over more than

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The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received September 24, 2017; accepted March 16, 2018.

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0749-8063/171179/$36.00

https://doi.org/10.1016/j.arthro.2018.03.031

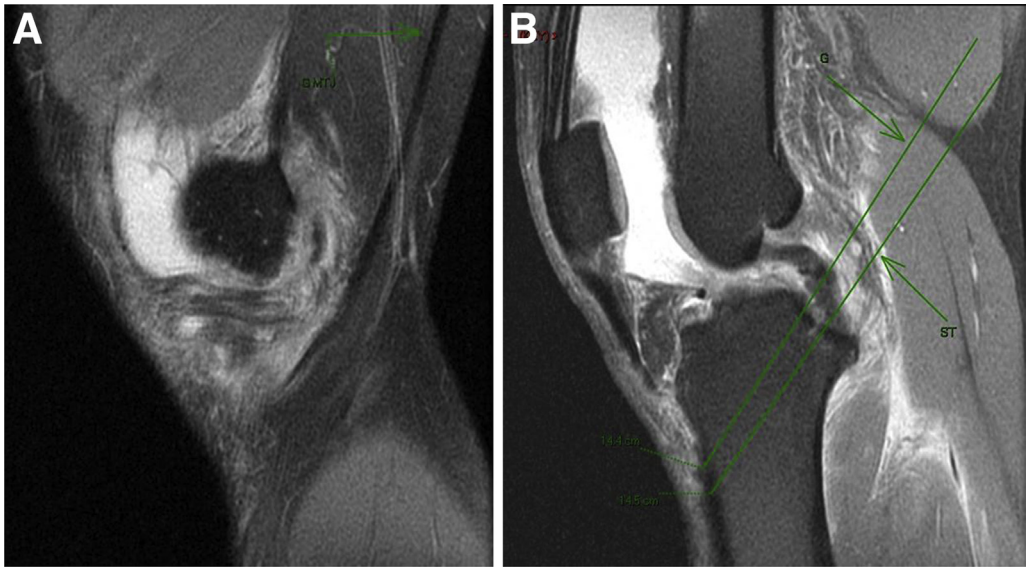

Fig 1. Select magnetic resonance images from the left knee of a 42-year-old male study subject showing (A) the distal-most aspect of the gracilis (G) musculotendinous junction (green arrow) and (B) the tendon-only length measurements for both the gracilis (14.4 cm) and the semitendinosus (ST; 14.5 cm). Upon harvesting, the corresponding lengths measured 14 cm for the G and 15 cm for the ST.

once in order to increase graft diameter.[10] Such information, if known reliably preoperatively, rather than being found only after hamstring harvesting, may influence graft selection decision making.

Although certain anthropometric measurements (especially patient height) have been consistently shown to correlate with the size of harvested hamstring tendons, depending upon these measurements is unreliable as the strengths of such correlations have been repeatedly shown to be moderate, at best.[10-16] Preoperative imaging has also previously been reported to have variable success in predicting adequacy of harvested hamstrings.[17-22] Recent investigation, however, has shown a fairly consistent relationship between the length of the ST and G distal to their respective MTJ and the ultimate harvested length of those tendons.[10] A strong correlation between MRI and surgical measurements would be more reliable than moderate or weaker correlations between various anthropometric measurements and harvested tendon size. The purpose of this study was to determine whether preoperative magnetic resonance imaging (MRI) can help predict the tendon-only length of the ST and the G. The hypothesis of the current investigation was that there would be agreement and strong correlation between the length of both the ST and G from the distal-most aspect of their respective MTJ to insertion (i.e. tendon-only length) measured on preoperative MRI and those same measurements obtained upon surgical harvesting.

Methods

From December of 2011 through December of 2015, all cases of primary, single-bundle ACL reconstructions using hamstring autograft by the senior author (O.A.I.) for which preoperative MRI was ordered by the operating surgeon were included. Patients requiring surgical treatment of ligaments in addition to the ACL were excluded, as those were reconstructed using allograft tendons. Also excluded were those presenting with an MRI obtained previously elsewhere in order to minimize variability of imaging technique/quality. All scans evaluated in this study were performed using a dedicated knee coil, either on a Siemens Magnetom Avanto 1.5 T 18-channel (Siemens, Munich, Germany), a Hitachi Oasis 1.2 T Open (Hitachi, Tokyo, Japan), or a General Electric Signa LX 1.5 T MRI instrument (General Electric, Chicago, IL).

A musculoskeletal-trained radiologist (R.S.S.), blinded to operative findings, performed measurements on the MRIs using a computerized imaging caliper tool (Carestream Vue PACS ver. 12.1.5.1156, Rochester, NY). Because the MTJs and tibial insertions were not visible on the same image slice, for each tendon the distal-most aspect of the MTJ (confirmed in at least 2 planes) was digitally marked and this point translated to a fat-suppressed, PD FSE sequence sagittal image depicting the tibial insertion, which was then also digitally marked. The straight-line distance between these 2 points was reported as the tendon-only length of each hamstring (Fig 1). These measurements were rounded to the nearest centimeter to mirror surgical measurement precision. Patients with MTJs outside the visualized field of the MRI were excluded from final analysis. Prior to measuring the study scans, the senior author and the radiologist together reviewed several MR scans of patients not included in the study to confirm measurement parameters.

At surgery, both the ST and G tendons were harvested through a 2-cm incision over the pes anserinus insertion. Blunt dissection between the pes tendons and the