Preoperative Ultrasonography Is Unreliable in Predicting Hamstring Tendon Graft Diameter for ACL Reconstruction

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Background: Hamstring autograft size <8 mm has been shown to be a predictor for failure after anterior cruciate ligament (ACL) reconstruction. The ability to predict graft size preoperatively is helpful in counseling patients about the possible need for graft augmentation.

Purpose: To determine whether preoperative ultrasound (US) measurements of hamstring tendons can predict intraoperative graft diameter during ACL reconstruction.

Study Design: Cohort study (diagnosis); Level of evidence, 2.

Methods: Twenty patients undergoing unilateral isolated ACL reconstruction were prospectively enrolled in the study (10 males, 10 females; mean ± SD age, 22.8 ± 6.6 years; height, 175.1 ± 7.1 cm; weight, 81.4 ± 14.2 kg; body mass index, 26.5 ± 4.1 kg/m^2). Hamstrings were assessed by US, and double-looped semitendinosus-gracilis hamstring size was independently calculated with a freehand selection method on a nonmagnified US image by 2 orthopaedic surgeons. Intraoperative autograft size was determined with a standard graft-sizing tool. Intra- and interrater reliability was measured with intraclass correlation coefficients (ICCs) and standard error of the measure (SEM). A receiver operating characteristic curve was calculated to assess the ability of the US measurement to predict intraoperative measurements.

Results: The mean autograft diameter by US was 8.9 ± 0.98 mm, while the mean intraoperative hamstring graft size was 8.1 ± 0.89 mm. There was excellent intrarater ($ICC_{2,1}$ = 0.95, SEM = 0.32 mm) and interrater ($ICC_{2,1}$ = 0.88, SEM = 0.55 mm) reliability for US measurements. Receiver operating characteristic analysis showed that US did not consistently quantify graft size. Graft size did not significantly correlate with height, weight, or body mass index in our sample (P > .05).

Conclusion: These results suggest that preoperative US imaging of the hamstring tendons is unreliable in predicting intraoperative graft diameter.

Keywords: anterior cruciate ligament; autograft; hamstring graft; preoperative planning; ultrasound

Hamstring tendons are the most common autogenous graft source utilized for anterior cruciate ligament (ACL) reconstruction.[14] The semitendinosus and gracilis tendons are often doubled, but graft diameter can be variable.[12] The diameter of the hamstring graft has been correlated to failure rates, with recent studies demonstrating an increased risk of failure for graft diameters <8 mm.[7,8,10] Thus, accurate prediction of hamstring graft size would help surgeons counsel patients preoperatively and plan for alternative graft sources or allograft augmentation.

Previous studies have evaluated various methods and their accuracy in predicting hamstring graft size. Anthropometric data have been used to predict hamstring size, but there has been disagreement among studies.[2,3,6,13,15,16,18] Imaging modalities that have been studied to predict hamstring graft size include magnetic resonance imaging (MRI),[1,4,5,17] 3-dimensional computed tomography (3D CT),[19] and ultrasound (US).[4,5] Despite the low cost and ease of accessibility of US, there is a paucity of data on the use of US measurements to predict intraoperative graft size. To date, only 2 studies in the literature have evaluated US as a predictor of hamstring graft size; both studies espoused it as a reliable tool in predicting graft sizes despite only moderate correlations.[4,5]

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TABLE 1
Patient Demographics

Age, y, mean ± SD	22.8 ± 6.6
Sex, male:female, n	10:10
Body mass index, mean ± SD	26.5 ± 4.1

The purpose of the current study was to evaluate if preoperative US measurements of hamstring tendon size can predict intraoperative hamstring graft diameter during ACL reconstruction.

METHODS

Institutional review board approval was obtained for the study. Twenty patients scheduled for isolated ACL reconstruction with double-looped semitendinosus-gracilis hamstring autograft were prospectively enrolled. Exclusion criteria included partial ACL tears, tibial eminence fractures, multiligament knee injuries, revision ACL reconstruction, and previous hamstring injuries. Sex, age, height, weight, and body mass index (BMI) were recorded for each patient, and demographics are shown in Table 1.

Ultrasonography

The semitendinosus and gracilis tendons, as they pass around the medial femoral condyle, were assessed by ultrasonography (Fujifilm SonoSite) by 1 physical therapist trained and experienced in ultrasonography. This US was completed within 14 days of surgery. With the patient positioned prone, a bolster was placed under the knee to maintain 30° of flexion and to keep the knee relaxed. Doubled-combined hamstring size was independently calculated with a freehand selection method on a nonmagnified US image (ImageJ software; National Institutes of Health) by 2 blinded orthopaedic surgeons. Each surgeon completed 2 sessions of measurements separated by at least 3 days. During each session, 3 measurements were completed. The overall mean was taken and used for analysis. Figure 1 provides an example of hamstring ultrasonography and measurement. The hyperechoic region of each tendon was outlined with ImageJ software. Using the traced area, the software calculates a diameter multiple times and takes the mean because the area is not a perfect circle.

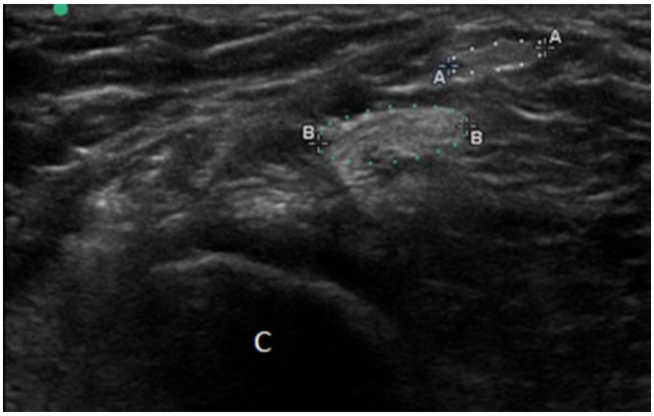

Figure 1. Ultrasonography of the hamstring tendons as they pass around the medial femoral condyle: gracilis tendon (*A*), semitendinosus tendon (*B*), and medial femoral condyle (*C*).

Hamstring Harvest

The autograft hamstring tendon harvests were performed by 3 surgeons. An approximately 2-cm incision was made near the pes anserinus. The sartorius fascia was opened, and the gracilis and semitendinosus tendons were separately harvested with a closed-loop tendon stripper after adhesions and other surrounding tissue were removed. After the tendons were harvested, they were prepared on a sterile back table. Any attached muscle and tissue were removed, and the tendons were doubled over. The diameter was measured by passing the pair of doubled tendons through a sizing block (Arthrex), which was available in 0.5-mm increments from 4.5 to 12.0 mm. The smallest diameter through which the doubled tendons could pass was considered the graft diameter. Measurement results between surgical and US evaluators were blinded from each other.

Statistical Analysis

Intra- and interrater reliability was measured by intraclass correlation coefficients (ICCs) and standard error of the measure (SEM). Pearson correlation coefficients were used to assess the relationship between US measurements and graft sizes, in addition to age, height, weight, BMI, and graft size. A receiver operating characteristic (ROC) curve was calculated to assess the ability of the US measurement to predict hamstring graft sizing. An area under the curve

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Ethical approval for this study was obtained from Greenville Health system (Institutional Review Board file No. Pro000014604).

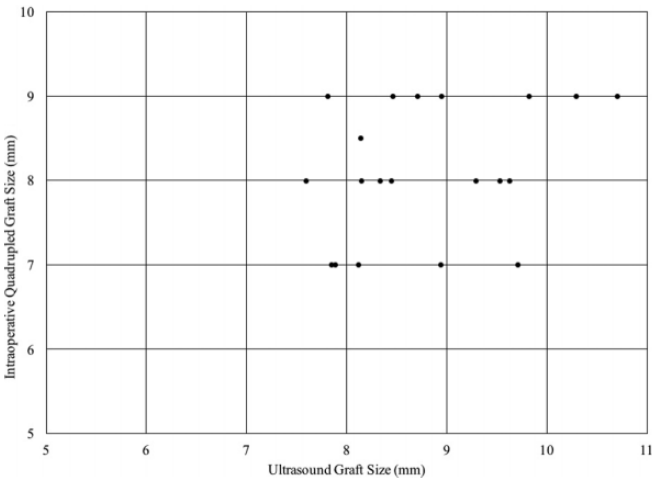

Figure 2. Intraoperative quadrupled graft measurements versus ultrasound graft measurements.

of >0.69 was considered statistically and clinically important, with a corresponding *P* value <.05.

RESULTS

The mean ± SD diameter of the doubled semitendinosus-gracilis hamstring graft by US was 8.9 ± 0.98 mm. There was excellent intrarater ($ICC_{2,1}$ = 0.95, SEM = 0.32 mm) and interrater ($ICC_{2,1}$ = 0.88, SEM = 0.55 mm) reliability and precision. The mean intraoperative hamstring graft size was 8.1 ± 0.89 mm. The frequencies of graft sizes were 7 mm (5 cases), 8 mm (8 cases), 8.5 mm (1 case), and 9 mm (6 cases). Figure 2 shows a scatter plot of intraoperative graft sizes versus US measurements. The Pearson correlation coefficient between intraoperative graft size measurements and US measurements was 0.38 (P = .09).

Of the 5 hamstring grafts that were <8.0 mm intraoperatively, US correctly predicted only 2 of these to be <8.0 mm. When US measured the tendons to be between 7.0 and 8.0 mm, it underpredicted the actual graft size in 25% of cases. When US measured the tendons to be between 8.0 and 9.0 mm, it overpredicted the actual graft size in 22.2% of cases. Similarly, it overpredicted graft size in 80% and 100% of cases for measurements between 9.0 and 10.0 mm and 10.0 and 11.0 mm, respectively.

An ROC curve was constructed, and the area under the curve was 0.34 (P = .25), with sensitivity of 8.3% for a graft size of 8.0 mm (Figure 3). Thus, ROC analysis revealed that US is not adequate in predicting grafts that will fall <8.0 mm. Graft size did not correlate with height, weight, or BMI in our sample, with correlation coefficients of <0.2 (P > .05).

DISCUSSION

This study is the first to demonstrate that US is not a reliable preoperative imaging modality to predict hamstring graft size in the setting of ACL reconstruction.

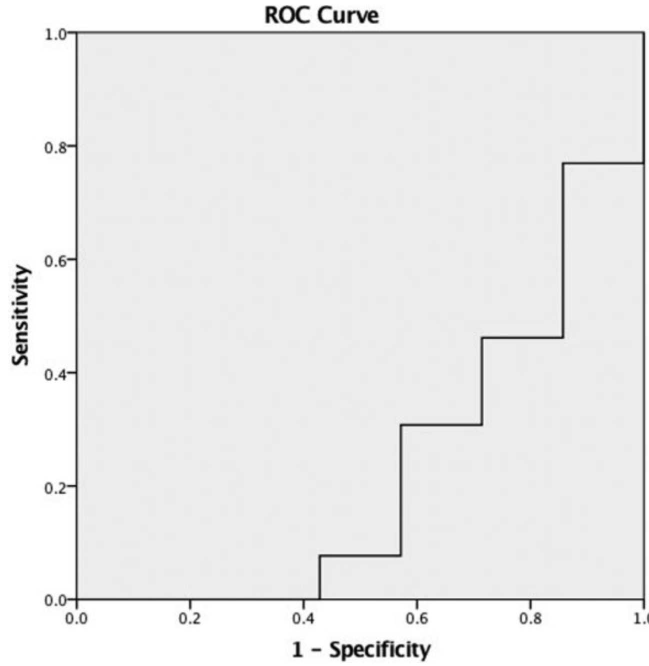

Figure 3. Receiver operating characteristic (ROC) curve for ultrasound as a predictor of hamstring graft size.

Hamstring graft size plays an important role in predicting ACL reconstruction failure; thus, the ability to accurately predict hamstring tendon graft size is important for preoperative planning.

To date, only 2 studies have explored the use of US to predict hamstring graft sizes.[4,5] In contrast to the current study, both these studies claimed US to be a reliable tool. Our study did not find a significant correlation between US measurements and intraoperative graft sizes. The correlation coefficient found in the current study was 0.38. This is lower than that reported by Erquicia et al[4] (0.51) and Galanis et al[5] (0.52). Although these studies stated that US is reliable, they both reported much higher correlation coefficients between MRI measurements and intraoperative graft sizes. Our mean intraoperative hamstring graft diameter was 8.1 mm, which is similar to those reported in the previous studies, 7.8 mm[4] and 8.1 mm.[5]

In our study, 2 blinded orthopedic surgeons performed repeated measurements for all patients, demonstrating excellent intrarater ($ICC_{2,1}$ = 0.95) and interrater ($ICC_{2,1}$ = 0.88) reliability. This is in contrast to the previous studies. In the study by Erquicia et al,[4] measurements were performed only once by 1 nonblinded surgeon; thus, no intra- or interrater reliability was calculated. In the study by Galanis et al,[5] measurements for only 5 of the 14 patients were repeated by 2 investigators, but the authors did report intra- and interobserver reliabilities of 0.83 and 0.80, respectively. Without complete intra- and interrater reliabilities, it is difficult to draw conclusions about the interobserver reliability of the US measurements of the previous studies.

It is unclear to what extent patient positioning and location of measurements during US scanning have on the ability to predict intraoperative graft sizes. In the current study, patients were positioned prone with the knee flexed to 30° and with use of a bolster to relax the leg. The tendons were assessed as they pass around the medial femoral condyle. In the study by Erquicia et al,[4] patients were positioned prone with the knee flexed to 90°. The tendons were scanned just proximal to the medial joint line. In the study by Galanis et al,[5] patients were positioned prone with the knee flexed to 30°, similar to the current study. Tendons were assessed near the widest point of the medial femoral epicondyle. It is possible that varying degrees of flexion and slightly different locations of tendon measurements may affect the ability to predict graft size.

Previous studies evaluated other imaging modalities to predict hamstring graft sizes, including MRI[1,4,5,17] and 3D CT.[18] Although MRI scans are routinely obtained in the setting of an ACL rupture, they often vary in quality and magnification, especially when obtained without standardized scanning protocols. In fact, the study by Erquicia et al[4] demonstrated differences in accuracy between MRI under 4× magnification and 2×. It would prove costly to repeat MRI for preoperative hamstring tendon evaluation. A previous study evaluated 3D CT to predict graft diameters,[19] but such a modality is also costly and may expose the patient to excess radiation.

In addition to imaging modalities, previous studies evaluated anthropometric data to help predict hamstring graft size. However, there are inconsistencies in the findings of these studies.[2,3,6,13,15,16,18] In the current study, we specifically examined BMI and its ability to predict graft size. We did not find any correlation between BMI and graft size. This lack of correlation with graft size is consistent with the findings of previous studies.[13,16]

In a recent study, Pennock et al[11] highlighted the importance of obtaining a preoperative prediction of hamstring graft size. In cases of smaller hamstring autografts, surgeons often augment with a soft tissue allograft to increase the diameter and thus theoretically reduce the failure rate. However, Pennock et al[11] found that the augmentation of smaller hamstring grafts does not reduce failure rates and may actually lead to higher retear rates.

This study has several limitations. There can certainly be variability among US operators owing to probe location and pressure applied. However, a study showed that accuracy and consistency are possible after minimal experience.[9] Second, our sample size was small, and a larger cohort may have strengthened the study. Nonetheless, our sample size was larger than those of previous studies published on the use of US to predict hamstring graft size, and our reliability within and between surgeons was good to excellent, suggesting that US image measurement error was not the differentiating factor driving our results.[5] It is unlikely that a complete shift in predictability would result from a larger sample size. Finally, the hamstring technique used here was a double-looped semitendinosus-gracilis autograft; thus, our findings may not apply to other grafting techniques. Nevertheless, this study demonstrates that preoperative US, as employed in this study, is not a reliable tool in predicting the diameter of an autograft hamstring graft. It was inconsistent with results, sometimes underestimating and at other times overestimating graft size. Further work should be performed to evaluate whether this modality can be optimized or to perhaps evaluate alternative imaging modalities or techniques to develop a reliable and accurate tool for preoperative prediction of hamstring graft size.

CONCLUSION

Our results suggest that preoperative US imaging of the hamstrings is not a reliable tool in predicting intraoperative hamstring graft diameter or the potential need for graft alternative or supplementation during ACL reconstruction.

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