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General Prediction Theory For Anterior Cruciate Ligament Graft Sizing

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Faculty Disclosure Information

No Disclosures.

Introduction

- Predicting hamstring graft size before anterior cruciate ligament (ACL) reconstruction is crucial
- Aids in anticipating and correcting inadequate graft diameter during procedures
- Helps avoid graft failure
- There is a higher risk of graft failure if the graft is lesser than 9 mm in diameter[1,2]

Most published models using MRI PACS are not feasible and practical:

1. Recruiting the help of a radiologist for measurement[1,2]
2. Usage of specialized 3D software or the freehand region of interest (lasso) tool that is not widely available on all MRI PACS systems[1,2]
3. Using 3T MRIs to predict the measurement – costly and not commonly performed[3]

1. Ashford, et al. 2018. "Predicted Quadriceps vs. Quadrupled Hamstring Tendon Graft Size Using 3-Dimensional MRI." The Knee 25 (6): 1100–1106.
2. Perez et al. 2020. "Preoperative Prediction of Autologous Hamstring Graft Diameter in Anterior Cruciate Ligament Reconstruction." Revista Espanola de Cirugia Ortopedica Y Traumatologia 64 (5): 310–17.
3. Hamada, et al. 1998. "Cross-Sectional Area Measurement of the Semitendinosus Tendon for Anterior Cruciate Ligament Reconstruction." Arthroscopy: The Journal of Arthroscopic & Related Surgery: Official Publication of the Arthroscopy Association of North America and the International Arthroscopy Association 14 (7): 696–701.

Aims of Study

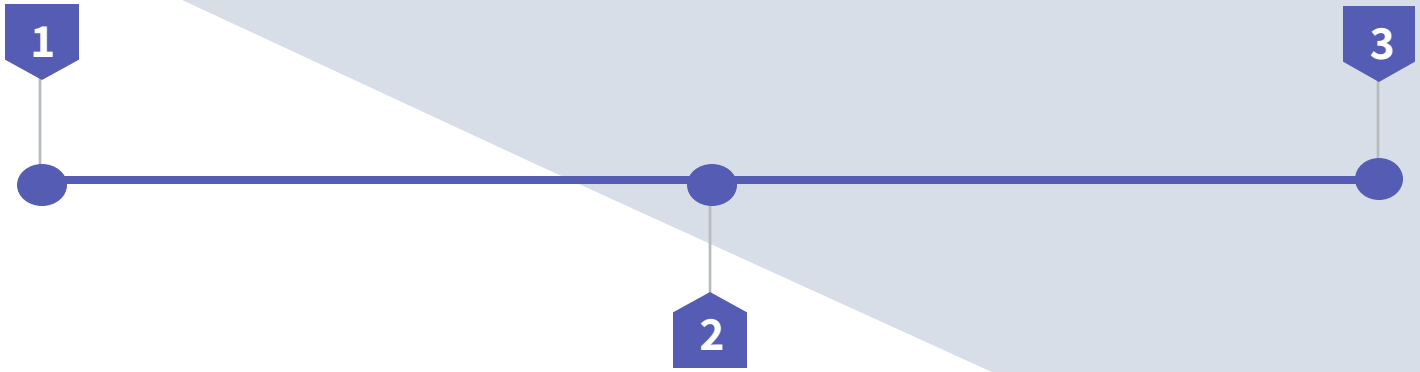
1. Develop a **General Prediction Theory**, based on a generalised algorithm
   - Predicts final ACL graft diameter for single and double tendon hamstring grafts consisting any number of folds
2. Evaluate our algorithm with a regression model adjusting for patient and surgical factors
3. Assess algorithm's sensitivity, specificity, and discriminative ability, defining adequate graft size as ≥9mm

Methodology

Retrospective review of 105 patients who underwent primary ACL reconstruction with single or double tendon grafts at a tertiary hospital between January 2023 and June 2024

Measurements were run through our **predicted graft diameter formula**

Data of the **actual graft sizes** used intraoperatively were extracted and compared to **predicted graft sizes**



Two independent and blinded evaluators with no prior radiology posting experience measured the cross-sectional lengths and breadths of both semitendinosus and gracilis grafts using standard MRI PACS for all included patients

How the ACL Hamstring Graft Sizes were Predicted

Figure 1: Sagittal T2-weighted images of the affected knee was first used to identify the axis of the pes tendons.

A and B represent 2 different patients with differing ACL axes.

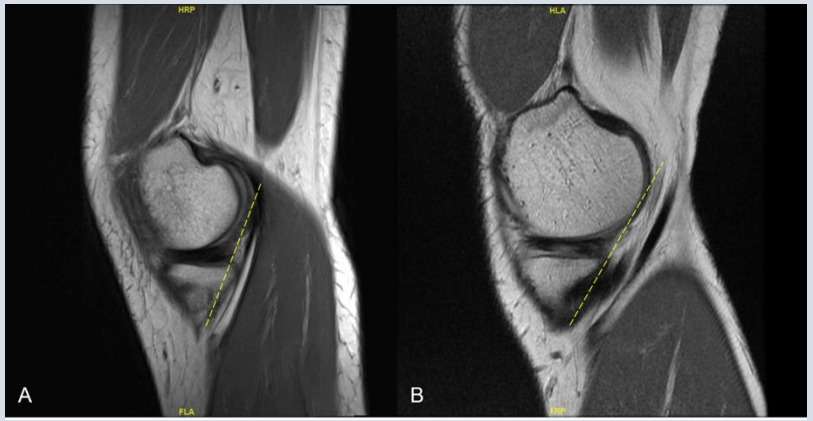


Figure 1

Figure 2: Sagittal cuts were scrolled laterally along the medial tibial plateau until a clear demarcation can be appreciated.

An annotation line parallel to the axis of the pes tendons was placed originating from the Liau ridge[4] on the posterior border of the subchondral surface of the tibial plateau and extending proximally by 30mm.

Figure 2

Figure 3: From the proximal aspect of the 30mm line, the closest axial MRI cut is used.

Cross-sectional lengths and breadths of the semitendinosus tendon and gracilis tendon were determined from 10x magnification.

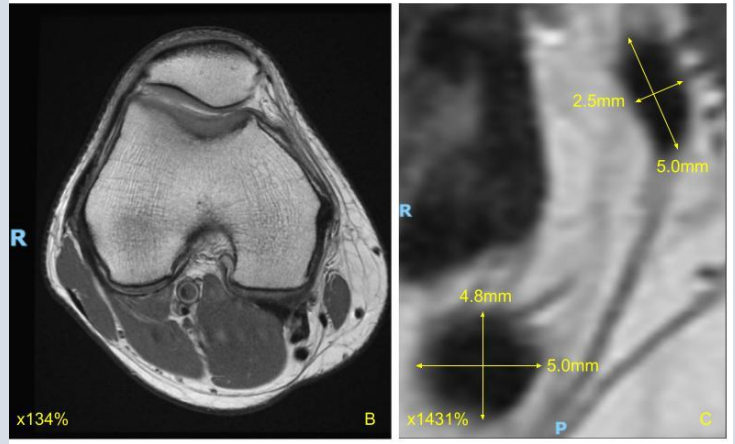


Figure 3

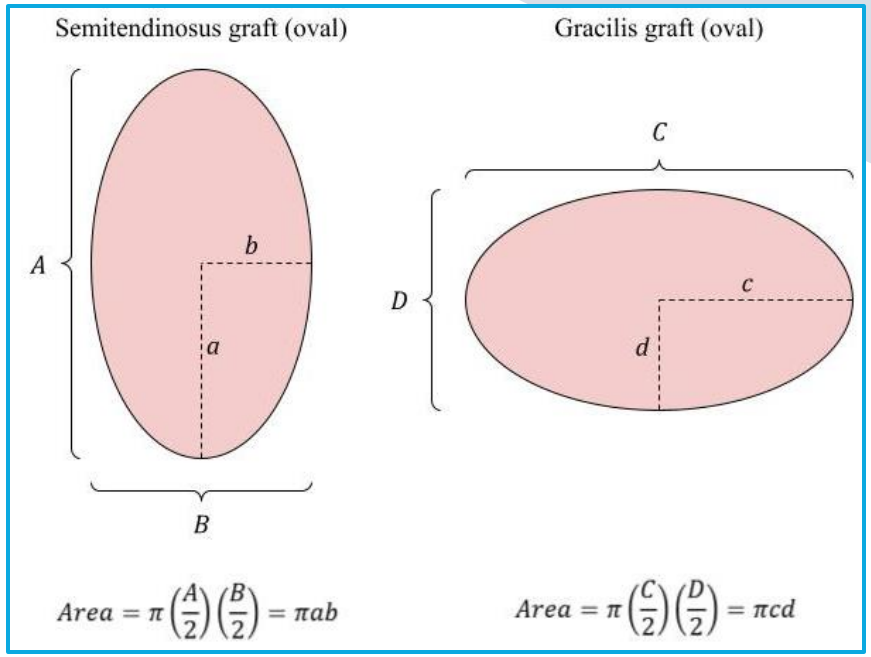
4. Liau ZQG, Ng MSP, Low SSE, Chin BZ, Hui JHP, Kagda FHY. A novel practical method to predict anterior cruciate ligament hamstring graft size using preoperative MRI. Knee Surg Relat Res. 2024 Apr 4;36(1):17. doi: 10.1186/s43019-024-00216-7. PMID: 38576029; PMCID: PMC10993534.

Mathematical Proof For ACL Graft Prediction Theory

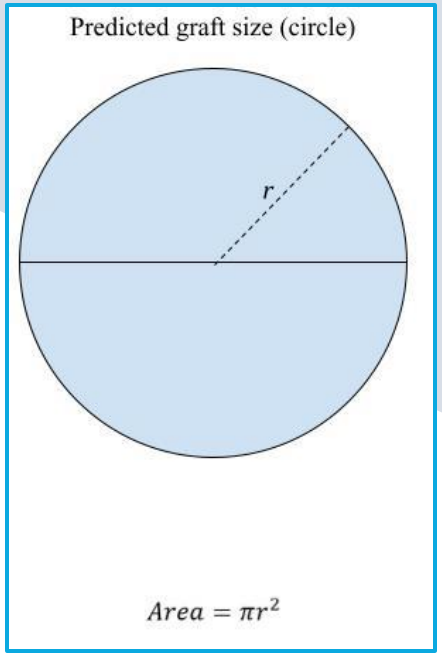
$$\pi r^2 = \text{Total area of predicted graft} = x(\text{semitendinosus area}) + y(\text{gracilis area}) = \pi\left(\frac{ABx + CDy}{4}\right)$$

$$r^2 = \frac{ABx + CDy}{4}$$

$$r = \left(\sqrt{\frac{ABx + CDy}{4}}\right)$$



Ovoid cross-sectional profiles of semitendinosus and gracilis tendons



Circular profile of predicted ACL graft

$\therefore$ Diameter of predicted graft size $(2r)$

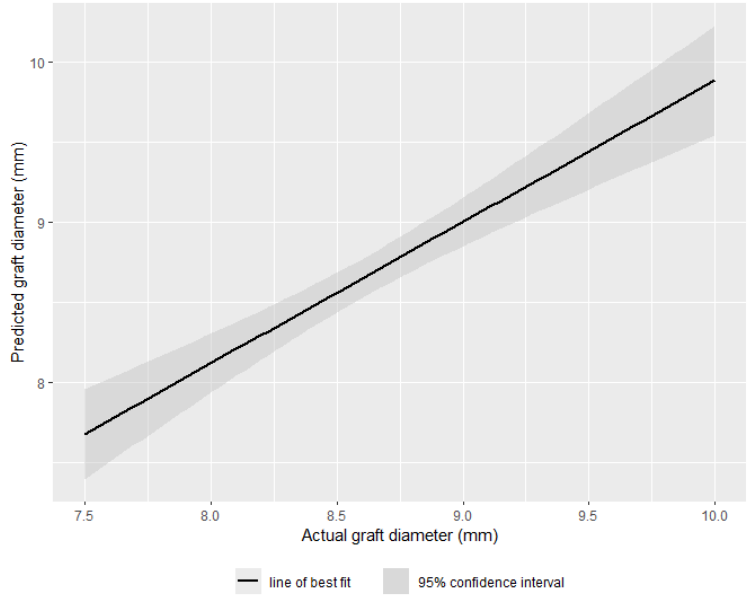
$$= 2\sqrt{\frac{ABx + CDy}{4}}$$

$$= \sqrt{(ABx + CDy)}$$

Results

Correlation between predicted and actual graft diameter

Pearson's correlation coefficient between the predicted and actual graft diameter of **105** patients was **0.602 (p < 0.01)**, which shows a **strong** positive correlation

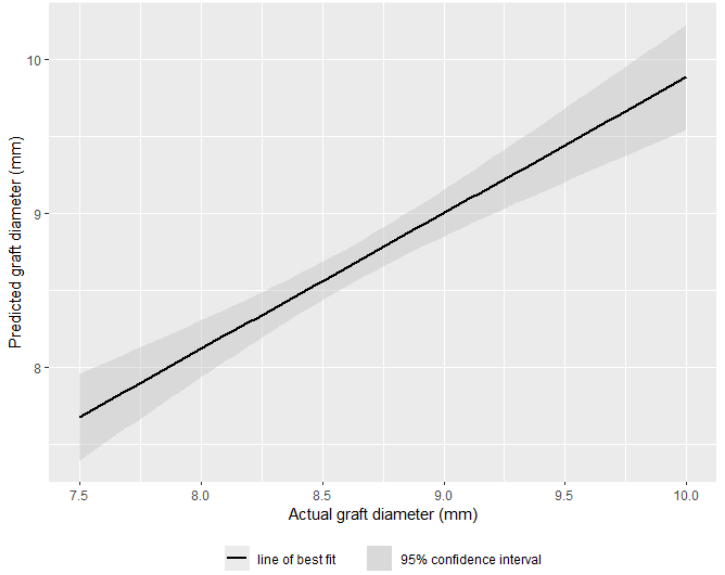


Univariate and Multivariate linear regression between predicted and actual graft diameter

Adjusted for age, gender, BMI, graft type (single vs double tendon)

Univariate linear regression

- Larger the predicted graft diameter, larger the actual graft diameter ($R^2 = 0.356$, $p < 0.01$)



Results

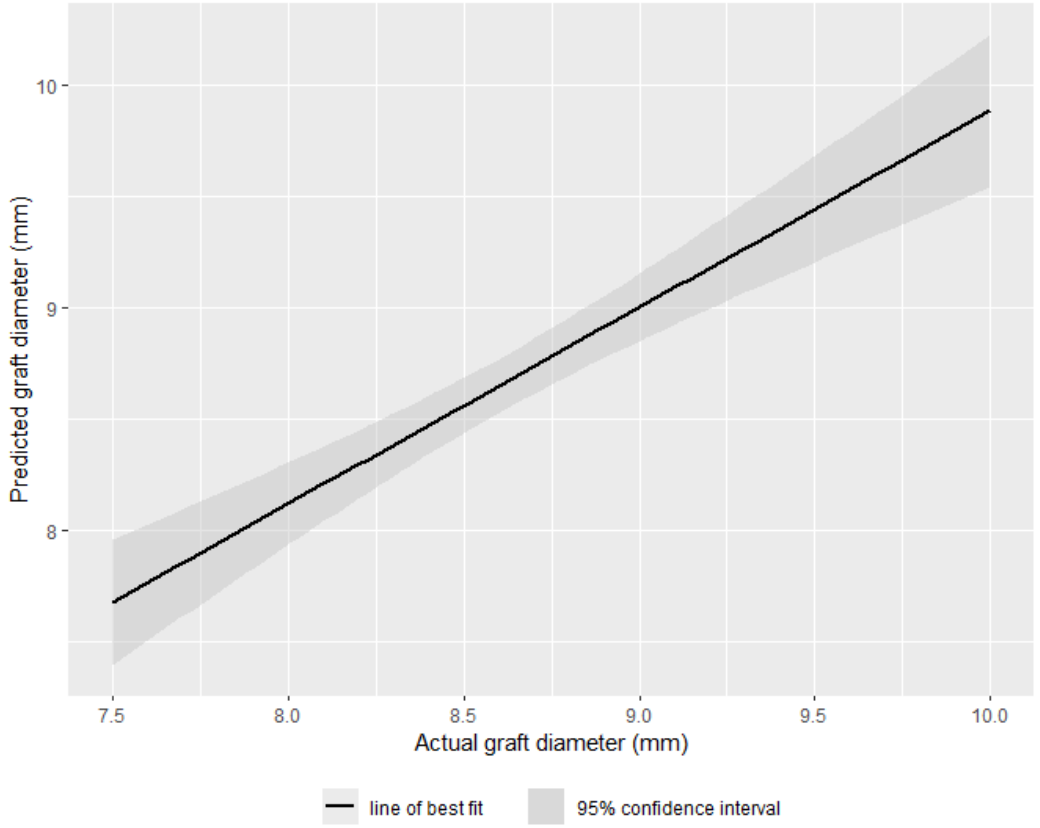
Univariate and Multivariate linear regression between predicted and actual graft diameter

Multivariate linear regression

Odds of having a bigger actual graft diameter is higher if patient is:

- **Male (p = 0.00160)**
- **Overweight (p = 0.0130)**
- **Single tendon graft (p = 0.000799)**

- Age does not influence actual graft diameter (p = 0.0850)



Results

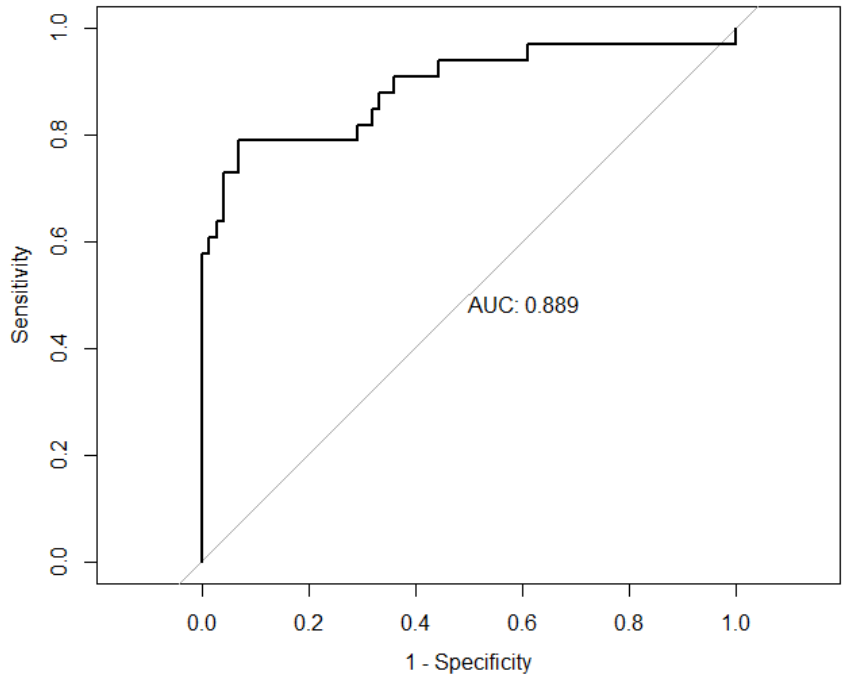
Specificity and sensitivity of our method

Our method yields a **high sensitivity of 95.8%** and a moderate specificity of **69.7%** if we define an adequate actual graft size as ≥9mm

Combined	Actual graft diameter (mm)	
Predicted graft diameter (mm)	< 9	≥ 9
< 9	69 (95.8% sens)	10
≥ 9	3	23 (69.7% spec)

Discriminatory ability of our method

An area under receiver-operating characteristic (ROC) curve plotted with the respective logistic regression models shows good discrimination **(AUC = 0.889)**



High percentage agreement = **82.9%**

Cohen's kappa = **0.578** ($p < 0.0001$)

Discussion

- Our method allows users to **determine the likely exact value of the axial graft diameter** compared to other methods which only provides a dichotomized outcome of whether a graft is sufficient [1,2]
- Our method yielded a **high sensitivity of 95.8%**
- Superior and comparable to reported studies
  - Hamada et al. – 74% sensitivity[3]
  - Erquicia et al. – 85.7% sensitivity[5]

Factors affecting graft size

- Odds of having a bigger actual graft diameter are higher if patient is
  - **Male** – larger muscle mass and tendon size
  - **Overweight** – increased body mass and hence, tendon size
  - **Single tendon graft** – involves harvesting thicker grafts

1. Ashford, et al. 2018. "Predicted Quadriceps vs. Quadrupled Hamstring Tendon Graft Size Using 3-Dimensional MRI." The Knee 25 (6): 1100–1106.
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5. Erquicia, et al. 2013. "How to Improve the Prediction of Quadrupled Semitendinosus and Gracilis Autograft Sizes with Magnetic Resonance Imaging and Ultrasonography." The American Journal of Sports Medicine 41 (8): 1857–63

Conclusion

- Our method does not require any specialized software
- Can be reliably done even by junior members of the surgical team
- Allows users to determine the likely exact value of the axial graft diameter with a high sensitivity of 95.8%
- Provides much more information about the magnitude of the difference compared to the ideal hamstring size
- Assists in discussing the appropriate graft options for the patient and better facilitates pre-operative planning

Limitations

1. Not considering the variation in **degree of knee flexion** when the MRI was taken
2. There may be the use of **3T MRIs** in clinical practice
3. Our **specificity is 69.7%**

References

1. Ashford, et al. 2018. “Predicted Quadriceps vs. Quadrupled Hamstring Tendon Graft Size Using 3-Dimensional MRI.” The Knee 25 (6): 1100–1106.
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