Risk of Revision and Reoperation after ACL Reconstruction. Comparison of Quadriceps Tendon, Patellar Tendon, and Hamstring Autografts Stratified by Patient Gender and Age: A cohort study of 27,715 Patients

Justin Yang, Christopher Robert Lehman, Heather Ann Prentice, Chelsea E Reyes, Colin M Mansfield, Gregory B Maletis

INTRODUCTION:

Many different graft choices exist for anterior cruciate ligament reconstruction (ACLR) with potential for variable outcomes based on graft type. The purpose of this study was to evaluate risk for subsequent surgical outcomes, including revision and reoperation, for a cohort of primary ACLR patients according to autograft selection stratified by patient gender and age.

METHODS:

Data from a US healthcare system's ACLR registry was used to conduct a cohort study. 27,715 primary isolated autograft ACLR patients were identified (2012-2023); those with prior procedures in the same knee were excluded. The exposure of interest autograft type: quadriceps tendon (QT), bone-patellar tendon-bone (PT), and hamstring tendons (HT). Multivariable Cox proportional hazard regression models were used to evaluate the risk for aseptic revision and risk for aseptic ipsilateral reoperation according to autograft selection. Age, body mass index, race/ethnicity, American Society of Anesthesiologist's classification, activity at the time of injury, prior contralateral ACLR, cartilage injury, lateral meniscus injury, medial meniscus injury, femoral tunnel drilling technique, operative time, and operative year were considered as covariates in regression analysis; models also included a cluster term for operating surgeon to account for correlation of ACLR performed by the same surgeon. Hazard ratios (HR) and 95% confidence intervals are reported, a $p<0.05$ the threshold for statistical significance. Secondary analysis stratified by patients age at the time of their ACLR (<22 years and ≥22 years).

RESULTS:

The study sample comprised 27,715 ACLR. There were 10,955 females and 16,760 males who underwent primary isolated ACLR; procedures were performed by 319 surgeons at 58 hospitals.

In the female cohort, QT, PT, and HT autograft were used in 874 (8.0%), 4597 (42.0%), and 5484 (50.1%) ACLR, respectively. In adjusted models, no significant differences were observed in revision risk (HR=0.76, 95% CI=0.36-1.59, p=0.465) or reoperation risk (HR=0.83, 95% CI=0.57-1.23, p=0.355) when comparing QT to PT ACLR. However, QT ACLR had a lower revision risk (HR=0.44, 95% CI=0.24-0.83, p=0.011) compared to HT ACLR; no differences were observed for reoperation (HR=0.94, 95% CI=0.63-1.38, p=0.740). PT ACLR were noted to have a lower risk of revision (HR=0.57, 95% CI=0.44-0.73, p<0.001) compared to PT and no difference in reoperation risk (HR=1.09, 95% CI=0.93-1.28, p=0.282); a higher risk of reoperation for stiffness was observed with PT to HT ACLR (HR=1.48, 95% CI=1.11-1.98, p=0.008). Age-stratified results for female ACLR patients are presented in **Table 1**.

There were 1297 (7.7%) QT, 7560 (45.1%) PT, and 7903 (47.2%) HT ACLR performed in male patients. No differences in revision or reoperation risk were observed when comparing QT ACLR to PT (revision: HR=0.94, 95% CI=0.57-1.54, p=0.801; reoperation: HR=1.14, 95% CI=0.72-1.81, p=0.579) or HT (revision: HR=0.72, 95% CI=0.49-1.07, p=0.101; reoperation: HR=1.31, 95% CI=0.88-1.97, p=0.187). Similar to female patients, PT ACLR associated with a lower revision risk (HR=0.79, 95% CI=0.65-0.97, p=0.027) but higher reoperation for stiffness risk (HR=1.59, 95% CI=1.15-2.20, p=0.005) compared to HT ACLR and no difference was observed in reoperation risk (HR=1.14, 95% CI=0.96-1.35, p=0.128). Age-stratified results for male ACLR patients are presented in **Table 2**.

DISCUSSION AND CONCLUSION: In female patients, HT ACLR is associated with a 2.3 and 1.8x higher risk revision when compared to QT and PT ACLR, respectively. In male patients, a HT ACLR is associated with a 1.3x higher revision risk compared to PT. No differences in risk of revision were noted between QT and PT ACLR. Surgeons should consider this data when discussing risks and benefits of the different graft options for ACLR, especially with their female patients.

Table 1. Adjusted association between autograft selection and surgical interventions following primary ACLR in female patients.

Cohort	Surgical intervention	HR (95% CI)	P
Overall	*Quad tendon vs BPTB (N=5,471)*		
	Revision	0.76 (0.36-1.59)	0.465
	Ipsilateral reoperation	0.83 (0.57-1.23)	0.355
	Reoperation for stiffness	0.83 (0.44-1.57)	0.556
	Meniscus-related reoperation	0.73 (0.37-1.45)	0.372
	Cartilage-related reoperation	1.66 (0.48-5.73)	0.426
	Quad tendon vs hamstring (N=6,358)		
	Revision	**0.44 (0.24-0.83)**	**0.011**
	Ipsilateral reoperation	0.94 (0.63-1.38)	0.740
	Reoperation for stiffness	1.28 (0.71-2.31)	0.420
	Meniscus-related reoperation	0.69 (0.38-1.24)	0.211
	Cartilage-related reoperation	1.95 (0.65-5.83)	0.235
	BPTB vs hamstring (N=10,081)		
	Revision	**0.57 (0.44-0.73)**	**<0.001**
	Ipsilateral reoperation	1.09 (0.93-1.28)	0.282
	Reoperation for stiffness	**1.48 (1.11-1.98)**	**0.008**
	Meniscus-related reoperation	0.91 (0.74-1.12)	0.356
	Cartilage-related reoperation	1.20 (0.79-1.83)	0.385
<22 years	*Quad tendon vs BPTB (N=3,710)*		
	Revision	0.77 (0.33-1.83)	0.557
	Ipsilateral reoperation	0.71 (0.46-1.10)	0.121
	Reoperation for stiffness	0.81 (0.40-1.64)	0.560
	Meniscus-related reoperation	0.57 (0.26-1.23)	0.148
	Quad tendon vs hamstring (N=3,199)		
	Revision	**0.45 (0.22-0.92)**	**0.029**
	Ipsilateral reoperation	0.84 (0.54-1.29)	0.422
	Reoperation for stiffness	1.47 (0.74-2.94)	0.271
	Meniscus-related reoperation	0.60 (0.30-1.21)	0.152
	BPTB vs hamstring (N=5,983)		
	Revision	**0.57 (0.43-0.75)**	**<0.001**
	Ipsilateral reoperation	1.09 (0.89-1.33)	0.397
	Reoperation for stiffness	**1.58 (1.11-2.25)**	**0.012**
	Meniscus-related reoperation	0.91 (0.71-1.17)	0.450
	Cartilage-related reoperation	1.29 (0.77-2.17)	0.327
≥22 years	*Quad tendon vs BPTB (N=1,761)*		
	Ipsilateral reoperation	1.14 (0.67-1.95)	0.622
	Reoperation for stiffness	0.82 (0.33-2.07)	0.679
	Meniscus-related reoperation	1.34 (0.44-4.14)	0.608
	Cartilage-related reoperation	2.37 (0.47-11.20)	0.296
	Quad tendon vs hamstring (N=3,159)		
	Ipsilateral reoperation	1.08 (0.65-1.79)	0.766
	Reoperation for stiffness	1.06 (0.49-2.27)	0.886
	Meniscus-related reoperation	0.94 (0.36-2.48)	0.905
	Cartilage-related reoperation	2.14 (0.51-9.02)	0.302
	BPTB vs hamstring (N=4,098)		
	Revision	0.69 (0.31-1.52)	0.356
	Ipsilateral reoperation	1.11 (0.82-1.49)	0.507
	Reoperation for stiffness	1.33 (0.84-2.12)	0.229
	Meniscus-related reoperation	0.93 (0.60-1.45)	0.758
	Cartilage-related reoperation	1.08 (0.54-2.14)	0.829

Table 2. Adjusted association between autograft selection and surgical interventions following primary ACLR in male patients.

Cohort	Surgical intervention	HR (95% CI)	P
Overall	*Quad tendon vs BPTB (N=8,857)*		
	Revision	0.94 (0.57-1.54)	0.801
	Ipsilateral reoperation	1.14 (0.72-1.81)	0.579
	Reoperation for stiffness	1.13 (0.42-2.99)	0.811
	Meniscus-related reoperation	0.97 (0.60-1.59)	0.908
	Cartilage-related reoperation	1.65 (0.73-3.71)	0.230
	Quad tendon vs hamstring (N=9,700)		
	Revision	0.72 (0.49-1.07)	0.101
	Ipsilateral reoperation	1.31 (0.88-1.97)	0.187
	Reoperation for stiffness	1.62 (0.68-3.82)	0.274
	Meniscus-related reoperation	0.90 (0.59-1.39)	0.646
	Cartilage-related reoperation	1.99 (0.99-3.98)	0.052
	BPTB vs hamstring (N=15,463)		
	Revision	**0.79 (0.65-0.97)**	**0.027**
	Ipsilateral reoperation	1.14 (0.96-1.35)	0.128
	Reoperation for stiffness	**1.59 (1.15-2.20)**	**0.005**
	Meniscus-related reoperation	0.95 (0.78-1.15)	0.578
	Cartilage-related reoperation	1.11 (0.76-1.60)	0.597
<22 years	*Quad tendon vs BPTB (N=4,045)*		
	Revision	0.97 (0.55-1.72)	0.924
	Ipsilateral reoperation	1.34 (0.79-2.25)	0.279
	Reoperation for stiffness	2.36 (0.87-6.44)	0.093
	Meniscus-related reoperation	1.07 (0.53-2.17)	0.847
	Cartilage-related reoperation	3.97 (0.99-1.60)	0.053
	Quad tendon vs hamstring (N=3,727)		
	Revision	0.72 (0.45-1.15)	0.168
	Ipsilateral reoperation	1.00 (0.59-1.70)	0.989
	Reoperation for stiffness	**3.12 (1.00-9.72)**	**0.049**
	Meniscus-related reoperation	0.69 (0.37-1.31)	0.259
	Cartilage-related reoperation	**3.65 (1.28-10.44)**	**0.016**
	BPTB vs hamstring (N=6,300)		
	Revision	0.83 (0.66-1.04)	0.100
	Ipsilateral reoperation	0.87 (0.69-1.11)	0.278
	Reoperation for stiffness	1.58 (0.88-2.82)	0.122
	Meniscus-related reoperation	0.81 (0.62-1.05)	0.106
	Cartilage-related reoperation	0.75 (0.40-1.42)	0.383
≥22 years	*Quad tendon vs BPTB (N=4,812)*		
	Revision	0.76 (0.31-1.88)	0.550
	Ipsilateral reoperation	1.04 (0.61-1.75)	0.897
	Reoperation for stiffness	0.79 (0.25-2.55)	0.696
	Meniscus-related reoperation	0.87 (0.43-1.75)	0.688
	Cartilage-related reoperation	1.09 (0.43-2.75)	0.857
	Quad tendon vs hamstring (N=5,973)		
	Revision	0.67 (0.36-1.26)	0.216
	Ipsilateral reoperation	**1.59 (1.06-2.40)**	**0.026**
	Reoperation for stiffness	1.24 (0.48-3.18)	0.662
	Meniscus-related reoperation	1.17 (0.67-2.05)	0.581
	Cartilage-related reoperation	1.33 (0.56-3.18)	0.519
	BPTB vs hamstring (N=9,163)		
	Revision	0.74 (0.1-1.06)	0.096
	Ipsilateral reoperation	**1.39 (1.12-1.73)**	**0.002**
	Reoperation for stiffness	**1.56 (1.10-2.21)**	**0.012**
	Meniscus-related reoperation	1.14 (0.86-1.52)	0.372
	Cartilage-related reoperation	1.34 (0.89-2.02)	0.159