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Variance in Anterior Cruciate Ligament Reconstruction Graft Selection Based on Patient Demographics and Location within the MOON Cohort

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Abstract

The purpose of this study is to determine if any regional or age-related patterns exist in graft choice for patients undergoing primary anterior cruciate ligament reconstruction (ACLR) within a large multicenter consortium. A retrospective cohort study was performed using data collected from the Multicenter Orthopaedic Outcomes Network (MOON) on patients having undergone primary ACLR. Patients were stratified by age group (under 20 years, 20–29 years, 30–39 years, 40–49 years, 50+ years) and four demographic regions (Midwest, Southeast, Northeast, and West). A total of 2149 patients (1288 males, 861 females) were included. At least 70% of the patients were treated by a single surgeon in three of the four demographic regions. There were no clinically significant differences in body mass index (BMI), and no statistically significant differences in Marx Activity Rating Scale ($p > 0.05$) between regions within any particular age group. There were significant differences in the proportion of autografts versus allografts used for primary ACLR between regions in every age group ($p < 0.01$). There were also significant differences in autograft ($p < 0.001$) and allograft ($p < 0.001$) harvest location based on demographic region. The Southeast and Northeast were more likely to use bone-patellar tendon-bone (BPTB) autograft while the West and Midwest were likely to use hamstring autograft. Within our consortium, regional patterns exist both in autograft versus allograft use in patients undergoing primary ACLR, as well as harvest location of autografts and allografts. Given the similarities in average patient BMI and activity level between regions, as well as the single surgeon influence in three of the four regions, the regional patterns in graft use are likely due to surgeon preference.

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Keywords

anterior cruciate ligament reconstruction; allograft; autograft; demographics

Introduction

Previous studies have examined regional patterns of orthopaedic surgical procedures within the United States (US), including superior labrum from anterior to posterior (SLAP) repairs[1], biceps tenodesis[2], surgical treatment of lumbar spine pathology[3], and others.[4–8] However, no study has analyzed the demographic trends of graft choice for patients undergoing primary anterior cruciate ligament reconstruction (ACLR).

In young, active patients undergoing primary ACLR, several studies have demonstrated a significantly lower graft rupture rate with autografts compared to allografts and therefore autografts are used much more frequently among patients in this age group.[9–11] In some demographic regions within the US, older patients are also very active, though it is unknown if ACLR graft choice for these patients more similarly reflects that of young patients.

It is unknown if patient lifestyle based on climate and age demographics appear to play a major role in graft choice or if treatment decision-making is solely made with an evidence-based approach or surgeon preference. The purpose of this study is to determine if any regional or age-related patterns exist in graft choice for patients undergoing primary ACLR within a United States-based, large multicenter consortium. The authors hypothesized that patients in generally more active regions of the United States are more likely to undergo primary ACLR with an autograft at older ages.

Materials and Methods

Study Design and Setting

A retrospective cohort analysis was performed using data collected from the Multicenter Orthopaedic Outcomes Network (MOON) for patients undergoing primary ACLR. The data collection methods by this group have been previously reported.[12] MOON is a multicenter cohort that consists of participants from 7 academic centers (Cleveland Clinic, Cleveland, OH; The Ohio State University, Columbus, OH; University of Iowa, Iowa City, IA; Washington University, St. Louis, MO: Vanderbilt University, Nashville, TN; Hospital for Special Surgery, New York, NY; University of Colorado, Aurora, CO).

Participants

Institutional Review Board approval was obtained at participating institutions. Patients undergoing unilateral primary ACLR between January 1, 2002 and December 31, 2008 were included. These dates were chosen as the MOON ACL protocol subsequently changed to limit enrollment to only young athletes. Starting in 2009, only the highest enrolling MOON sites continued to enroll and the inclusion criteria changed in order to fulfill a National Institutes of Health (NIH) grant aim to look at progression of osteoarthritis in young athletes. For the purposes of this study, participants undergoing revision ACLR, bilateral

ACLR, concomitant medial or lateral collateral ligament reconstruction, or primary ACLR with a hybrid graft were excluded.

Variables

Patients were stratified by age group at the time of surgery (under 20 years, 20–29 years, 30–39 years, 40–49 years, 50+ years) and demographic region (Midwest, West, Southeast, and Northeast). The Midwest region was represented by the Cleveland Clinic, Ohio State University, University of Iowa, and Washington University in St. Louis with a total of 10 surgeons enrolling patients. The West region was represented by the University of Colorado with a total of 3 surgeons enrolling patients. The Southeast region was represented by Vanderbilt University with a total of 4 surgeons enrolling patients. The Northeast region was represented by Hospital for Special Surgery in New York with 1 surgeon enrolling patients. Variables extracted from each patient included patient age at the time of surgery, graft type (autograft or allograft), graft harvest location (bone-patellar tendon-bone, hamstring, tibialis, Achilles tendon, peroneus), body mass index (BMI), and Marx Activity Rating Scale. Anterior tibialis and posterior tibialis grafts were grouped together into a “tibialis” group. Peroneus longus and peroneus brevis grafts were grouped together into a “peroneus” group.

Statistical Analysis

Chi-square tests were performed to determine significant differences in the proportion of autograft versus allograft use by age and demographic region, autograft type by demographic region, and allograft type by demographic region. One-way analysis of variance (ANOVA) tests were performed to determine significant differences in age, BMI, and Marx Activity Rating Scale between demographic regions.

Results

A total of 2149 patients (1288 males, 861 females) met inclusion/exclusion criteria. The mean age at the time of surgery was 30.9 ± 10 years. At least 70% of the patients were treated by a single surgeon in three of the four regions. The Midwest region had the most patients enrolled (n = 1453) (Table 1).

There was a significant difference ($p < 0.001$) in average BMI between demographic regions (Table 2). Unsurprisingly, the patients in the West region had the lowest BMI (24.7 kg/m^2) versus the Midwest and the Southeast regions, whose ACLR populations had the highest BMI (average 26.4 kg/m^2 at each site). BMI was further compared between regions within each age group (Table 3), although statistical significance was only reached in the 20–29 and 30–39 age groups (and not deemed to be of clinical significance). There were no significant differences in Marx Activity Rating Scale between demographic regions within any particular age group (Table 4).

Patients were stratified based on age group, demographic region, and graft type (Table 5). The proportion of autografts versus allografts was significantly different across the four regions within every age group ($p < 0.01$), with the Midwest sites using a relatively high percentage of autografts in patients aged 40–49 years and over 50 years.

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There was a significant difference ($p < 0.001$) in allograft harvest location based on demographic region, with the Midwest and West sites most commonly using tibialis allografts and the Southeast and Northeast sites frequently using BPTB allografts (Table 6). Tibialis tendons were the most commonly used allograft overall.

There was a significant difference ($p < 0.001$) between autograft type and demographic region, with the Midwest and West sites using a high percentage of hamstring tendon autografts and the Southeast and Northeast sites using a high percentage of BPTB autografts (Table 7). BPTB was the most commonly used autograft overall.

Discussion

The results of this study suggest that regional patterns exist both in autograft versus allograft use in patients undergoing ACLR, as well as harvest location of autografts and allografts within our consortium sites. However, these regional patterns are likely due to surgeon influence rather than patient activity level. For young, active patients undergoing primary ACLR, superior outcomes have been demonstrated with autografts in multiple studies.[10,11,13,14] However, the use of fresh frozen allografts in multiple Level I and II studies[15–25] and two Level III studies[26,27] have been shown to demonstrate comparable clinical outcomes to autografts.

A meta-analysis of 5,182 patients conducted by Kraeutler et al[13] demonstrated that patients receiving BPTB autografts had lower rates of graft rupture, lower levels of knee laxity, improved single-legged hop test results, and generally higher patient satisfaction following primary ACLR. In a separate study by Barrett et al[14], a higher failure rate was found with the use of nonirradiated, fresh-frozen BPTB allografts in active patients under 40 years compared with low activity patients receiving allografts and all patients receiving autografts. Additionally, there have been several studies examining factors affecting patient selection of graft type in ACLR, with surgeon recommendation being the primary influencer in each of these studies.[28–30] The authors of the present study hypothesized that, in regions with generally more active populations such as Colorado (the West region in this study), a relatively high percentage of older patients undergo ACLR with autograft. However, no clinically significant differences were found in terms of BMI or Marx Activity Rating Scale between similarly-aged patients in the four demographic regions of this study. Therefore, the difference in decision to utilize autograft versus allograft in patients undergoing primary ACLR is likely not related to activity level, but simply due to surgeon preference. This is further evidenced by the fact that at least 70% of the patients were treated by a single surgeon in three of the four regions in this study.

Previous studies have reported objective and patient-reported outcome scores based on graft type in patients undergoing primary ACLR. In a meta-analysis comparing BPTB autograft to hamstring autograft, Freedman et al[31] demonstrated a significantly lower rate of graft failure, improved static knee stability, and increased patient satisfaction among patients receiving BPTB autograft. However, an increased rate of anterior knee pain was found in the BPTB group.[31] A study by Xie et al[32] demonstrated comparable clinical results between

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BPTB and hamstring autografts. This study also showed higher patellofemoral arthritis rates as well as increased anterior knee pain within the BPTB group.[32]

In terms of allograft types, O'Brien et al[33] compared patient-reported outcomes and graft-rupture rates of BPTB allografts and tibialis anterior allografts in patients younger than 30 years. This study found no statistically significant difference in patient-reported outcomes and graft rupture rates at a minimum of one-year (short-term) follow-up.[33] Using an ACLR registry, Tejwani et al[34] examined outcomes after primary ACLR with allograft in 5,968 patients and found an association between higher graft rupture rate and irradiation greater than 1.8 Mrad, BioCleanse graft processing, younger patient age, male patients, and BPTB allografts. However, in young active patients, fresh frozen allograft tissue for ACLR has been shown to provide long-term knee stabilization and functioning and help avoid graft harvest site morbidity.[35]

Given the abundance of outcome data available based on ACL graft type, it is interesting that the current study found significant differences in graft type based on demographic region. However, with limited surgeons representing each region, the results more accurately demonstrate variations between individual surgeon graft choice preference. In terms of allograft type, these regional patterns may simply be explained by healthcare settings in which particular hospitals or surgery centers may use the same type of allograft for the majority of ACL reconstruction procedures. The cost of allograft tissue used in ACLR is not compensated by the savings realized from shorter operating and recovery room times. Nonetheless, in a hospital outpatient setting, reimbursement has been shown to cover the expense of the allograft, offsetting the additional expenditure.[36] The regional associations based on autograft harvest location may again simply be due to surgeon preference, though autograft preference may also be related to a surgeon's training. Performing simply a database review and comparison can produce limitations such as the possibility that the surgeons are more likely to practice in the same region of the United States where they trained, and it is possible that orthopaedic surgeons are trained more commonly to perform ACLR with BPTB autograft in the Northeast and Southeast, and with hamstring autograft in the Midwest and Western United States.

The strengths of this study include the large sample size and prospective data collection. The limitations of this study should also be noted. First, some regions had low sample sizes of patients within particular age groups. In addition, the Northeast, Southeast, and West regions were represented by only one healthcare setting each. Therefore, the results of this study do not necessarily represent the graft type trends within these regions. Furthermore, the small number of surgeons enrolling patients may decrease reliability of our results. Finally, due to changes in data collection methods and involved MOON Group sites, it was necessary only to include data from 2002 to 2008 and thus the results of this study do not necessarily reflect current trends.

Conclusions

This study suggests a regional pattern within our multicenter consortium sites between autograft versus allograft use for patients undergoing primary anterior cruciate ligament

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reconstruction. The similarities in BMI and activity level between regions, as well as the single surgeon influence in three of the four regions, support that the regional patterns in graft use are likely due to surgeon preference. Furthermore, autograft and allograft harvest locations differ based on demographic region. Further studies should seek to determine if the graft patterns demonstrated in this study have persisted in more recent years.

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Table 1

Participating surgeon characteristics

% represents the percentage of all patients enrolled within the same demographic region.

Demographic Region	Clinical Site	Surgeon No.	Patients (%)
Midwest (n=1453)	Cleveland Clinic (n=415)	1	96 (6.6%)
		2	11 (0.8%)
		3	308 (21.2%)
	The Ohio State University (n=606)	1	102 (7.0%)
		2	504 (34.7%)
	University of Iowa (n=137)	1	86 (5.9%)
		2	51 (3.5%)
	Washington University, St. Louis (n=295)	1	25 (1.7%)
		2	48 (3.3%)
		3	222 (15.3%)
West (n=108)	University of Colorado (n=108)	1	76 (70.6%)
		2	11 (10.1%)
		3	21 (19.3%)
Southeast (n=450)	Vanderbilt University (n=450)	1	40 (8.9%)
		2	33 (7.3%)
		3	18 (4.0%)
		4	359 (80.0%)
Northeast (n=138)	Hospital for Special Surgery (n=138)	1	138 (100%)

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Table 2

Patients characteristics by demographic region

Data are reported as a mean ± standard deviation. M/F = male/female ratio

Demographic region	Midwest	West	Southeast	Northeast	p-value
M/F	876/577	59/49	268/182	85/53	0.68
Age, years	30.8 ± 10.2	31.4 ± 11.0	30.1 ± 10.2	33.1 ± 9.7	0.03
BMI, kg/m^2	26.4 ± 4.9	24.7 ± 3.6	26.4 ± 5.2	25.1 ± 4.1	< 0.001
Marx Activity Rating Scale	10.1 ± 5.4	10.7 ± 4.6	10.4 ± 5.3	9.8 ± 5.0	0.37

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Table 3

Patient BMI by age and demographic region

Data are reported as a mean ± standard deviation.

Age (years)	Midwest	West	Southeast	Northeast	p-value
< 20 (n=304)	24.2 ± 4.0	25.7 ± 4.7	24.8 ± 4.8	23.6 ± 2.3	0.39
20–29 (n=808)	26.2 ± 5.0	24.6 ± 3.1	25.8 ± 4.2	24.3 ± 4.0	0.013
30–39 (n=553)	27.7 ± 5.1	24.1 ± 3.5	27.9 ± 6.4	26.0 ± 4.6	< 0.01
40–49 (n=378)	26.8 ± 4.7	24.3 ± 3.5	27.0 ± 5.0	25.6 ± 4.2	0.07
50+ (n=107)	26.8 ± 4.2	26.1 ± 3.5	26.0 ± 4.2	24.8 ± 2.6	0.47

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Table 4

Marx Activity Rating Scale by age and demographic region

Data are reported as a mean ± standard deviation.

Age (years)	Midwest	West	Southeast	Northeast	p-value
< 20 (n=304)	13.8 ± 3.9	13.1 ± 4.6	13.5 ± 4.7	14.5 ± 2.2	0.74
20–29 (n=808)	11.1 ± 4.8	11.7 ± 4.2	10.8 ± 4.9	10.5 ± 4.7	0.58
30–39 (n=553)	8.9 ± 5.1	10.3 ± 2.6	9.5 ± 5.0	8.6 ± 5.1	0.39
40–49 (n=378)	7.9 ± 5.5	9.0 ± 4.8	8.4 ± 5.1	9.9 ± 4.5	0.24
50+ (n=107)	5.8 ± 5.1	7.4 ± 5.7	7.0 ± 6.1	5.6 ± 5.5	0.70

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Table 5

Graft use for ACLR stratified by demographic region and age

Percentages represent the proportion of autograft versus allograft within each demographic region and age group.

Age (years)	Midwest (n=1453)		West (n=108)		Southeast (n=450)		Northeast (n=138)		p-value
	Allograft (n=298)	Autograft (n=1155)	Allograft (n=41)	Autograft (n=67)	Allograft (n=124)	Autograft (n=326)	Allograft (n=33)	Autograft (n=105)	
< 20 (n=304)	25 (12%)	176 (88%)	0 (0%)	14 (100%)	7 (9%)	69 (91%)	0 (0%)	13 (100%)	0.25
20–29 (n=808)	86 (16%)	466 (84%)	15 (32%)	32 (68%)	23 (14%)	142 (86%)	2 (5%)	42 (95%)	< 0.01
30–39 (n=553)	93 (25%)	283 (75%)	11 (61%)	7 (39%)	34 (29%)	82 (71%)	10 (23%)	33 (77%)	< 0.01
40–49 (n=377)	62 (24%)	194 (76%)	10 (50%)	10 (50%)	46 (63%)	27 (37%)	13 (46%)	15 (54%)	< 0.001
50+ (n=107)	32 (47%)	36 (53%)	5 (56%)	4 (44%)	14 (70%)	6 (30%)	8 (80%)	2 (20%)	< 0.001

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Table 6

Allograft type by demographic region

Percentages represent the proportion of graft types within each demographic region. A significant difference was found in allograft type based on demographic region ($p < 0.001$). BPTB = bone-patellar tendon-bone

Allograft type	Midwest (n=298)	West (n=41)	Southeast (n=124)	Northeast (n=33)
Tibialis (n=309)	271 (90.9%)	36 (87.8%)	2 (1.6%)	0
BPTB (n=143)	13 (4.4%)	2 (4.8%)	110 (88.7%)	18 (54.5%)
Achilles tendon (n=37)	10 (3.4%)	0	12 (9.7%)	15 (45.5%)
Hamstring tendon (n=5)	4 (1.3%)	1 (2.4%)	0	0
Peroneus (n=2)	0	2 (4.8%)	0	0

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Table 7

Autograft type by demographic region

Percentages represent the proportion of graft types within each demographic region. A significant difference was found in autograft type based on demographic region ($p < 0.001$). BPTB = bone-patellar tendon-bone

Autograft type	Midwest (n=1155)	West (n=67)	Southeast (n=326)	Northeast (n=105)
BPTB (n=842)	448 (38.5%)	25 (37.3%)	294 (90.2%)	75 (71.4%)
Hamstring tendon (n=809)	705 (61.0%)	42 (62.7%)	32 (9.8%)	30 (28.6%)
Quadriceps tendon (n=2)	2 (0.5%)	0	0	0