Postoperative Anterior Cruciate Ligament Reconstruction Quadricep and Patella Tendon Rupture, Infection, and Lysis of Adhesions Decreased Despite Changing Graft Trends Over the Past Decade

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Purpose: To investigate recent trends in postoperative complications following anterior cruciate ligament (ACL) reconstruction.

Methods: Patients who underwent ACL reconstruction surgery were identified in a national insurance database and separated into 2 cohorts based on the date of their initial surgery comprising the years 2010 to 2012 and 2016 to 2018, respectively. Patients were matched 1:1 based on comorbidities and Elixhauser Comorbidity Index. All patients were assessed for postoperative complications within 18 months of surgery. Rate of complication was compared between cohorts.

Results: Overall, the all-cause complication rate was 2%. There were significantly more quadriceps tendon rupture, patella tendon rupture, lysis of adhesion, and infection in the early cohort. There were significantly more instances of deep vein thrombosis in the late cohort. We found no significant difference in manipulations under anesthesia between the 2 cohorts.

Conclusions: Patients who underwent surgery in the late cohort had lower rates of postoperative complications, except for deep vein thrombosis. The rate of postoperative quadriceps tendon rupture decreased despite considerable increase in the use of quadriceps tendon autograft.

Clinical Relevance: As there has been an increased use of quadriceps tendon autografts, but little is known about the postoperative complications after ACL reconstruction with these grafts. This information has the potential to improve patient outcomes.
same study, indices of stability such as side-to-side difference and presence of negative Lachman test were improved in the QT group. Recent systematic reviews have gone on to demonstrate no significant differences in patient-reported outcomes, stability indices, and graft failure rates in patients treated with QT compared with both BPTB and HT. In fact, QT was shown to have lower rates of anterior knee pain and donor-site pain than BPTB.

The purpose of this study was to investigate recent trends in postoperative complications following ACL reconstruction. Our null hypothesis was that there would be no significant difference in the rate of postoperative complications between the 2 cohorts despite a significant increase in QT use for ACL reconstruction since 2010.

Methods

Database

This retrospective study was conducted using PearlDiver, a national insurance claims database widely used in orthopaedic literature. PearlDiver comprises more than 93 million individual patient records spanning 2010 to 2020. These records are searchable using physician billing codes including International Classification of Diseases, Revisions 9 and 10 (ICD-9/ICD-10) diagnostic codes, Current Procedural Terminology (CPT) procedural codes, and drug codes.

Patient Selection

All patients who underwent an ACL reconstruction were identified in the database via CPT 29888 and sorted based on the date of their surgery into 2 cohorts: an early cohort comprising the years of 2010 to 2012 and a late cohort from 2016 to 2018. As we were interested in comparing their postoperative complications, all patients were required to be continuously active for 18 months in the database following the initial date of surgery.

We matched patient comorbidities 1:1 based on age, sex, tobacco use, obesity, diabetes, and Elixhauser Comorbidity Index between the 2 cohorts. Postoperative surgical complications included QT rupture, patella tendon rupture, manipulation under anesthesia, return to the operating room for lysis of adhesions, infection, and deep vein thrombosis (DVT). The surgical complications rates were defined using CPT and ICD-9 codes.

Statistical Analysis

We used Pearson χ² analysis to assess the univariate difference in rates of surgical complications between the early and late cohorts. The Student t-test was used to compare continuous variables. All tests were conducted at an alpha level of 0.05. For complication outcomes that were statistically significant, a multivariate logistic regression was used to account for potential confounding from the comorbidities and demographic factors of age, sex, tobacco use, obesity, and diabetes. The adjusted odds ratios (ORs) and confidence intervals (CIs) were determined from the multivariate analysis. Statistical analysis was done using the R statistical package available through PearlDiver.

Results

A total of 80,376 patients who underwent ACL reconstruction were identified, 46,024 of whom underwent surgery in the years 2010 to 2012, and 34,352 of whom underwent surgery in the years 2016 to 2018 with 18 months of follow-up. After matching patient comorbidities and Elixhauser Comorbidity Index 1:1, 27,057 patients remained in each cohort (Table 1). Overall, the all-cause complication rate was 2%. There was significantly more QT rupture, patella tendon rupture, lysis of adhesion, and infection in the early cohort (Table 2). However, there was significantly more DVTs in the late cohort. We found no significant difference in manipulations under anesthesia (MUA) between the 2 cohorts.

The univariate and multivariate logistic regression results are listed in Appendices 1 to 8, available at www.arthroscopyjournal.org. Univariate analysis demonstrated QT rupture to be independently associated with diabetes (OR 5.24; 95% CI 1.65-14.4). MUA was found to be independently associated with female sex (OR 2.3; 95% CI 1.86-2.85). Patella tendon rupture and lysis of adhesions were not found to be associated

Table 1. Patient Demographics

| Demographics | Early Cohort (n = 27,057) | Late Cohort (n = 27,057) | P Value |
|--------------|--------------------------|-------------------------|---------|
| Obesity      | 5,356 (19.8%)            | 5,356 (19.8%)           | 1       |
| Diabetes     | 2,163 (7.9%)             | 2,163 (7.9%)            | 1       |
| Tobacco      | 5,761 (21.3%)            | 5,761 (21.3%)           | 1       |
| >60 years old| 518 (1.9%)               | 518 (1.9%)              | 1       |
| Female       | 14,254 (52.7%)           | 14,254 (52.7%)          | 1       |

NOTE. n = 54,114. Patient demographics showing the percentage of patients with diagnosis of obesity, history of diabetes, history of tobacco use, age older than 60 years, and female sex in both the early (2010-2012) and late (2016-2018) cohorts.

Table 2. Complication Rates

| Outcomes              | Early Cohort (n = 27,057) | Late Cohort (n = 27,057) | P Value |
|-----------------------|---------------------------|-------------------------|---------|
| Quadriceps rupture    | 15 (0.1%)                 | 1 (0.003%)              | <.001   |
| Patella tendon rupture| 12 (0.04%)                | 1 (0.003%)              | .003    |
| Manipulation          | 198 (0.7%)                | 221 (0.8%)              | .178    |
| Adhesion lysis        | 22 (0.08%)                | 8 (0.03%)               | .013    |
| Infection             | 344 (1.3%)                | 191 (0.7%)              | .001    |
| DVT                   | 3 (0.01%)                 | 89 (0.3%)               | .001    |

NOTE. P values in bold indicate statistical significance. DVT, deep vein thrombosis.
with any patient comorbidities. Infection was found to be associated with female sex, obesity, and tobacco use on multivariate analysis, whereas DVT was found to be associated with diabetes and obesity.

Discussion

The most important finding of our study was that patients who underwent ACLR in the late cohort had lower rates of postoperative complications, except for DVT. Counterintuitively, there was a significantly lower number of postoperative QT ruptures in patients who underwent ACL reconstruction in the late cohort despite increasing popularity of QT autograft over the past decade. The rate of patella tendon rupture also significantly decreased in the late cohort; however, this observation may be secondary to the decreasing popularity of BPTB autograft for ACL reconstruction over the past 2 decades (preferred graft for 90% of surgeons in 1990 to under 40% in 2021).7,11

There was a significant increase in the rate of DVTs in the late cohort. At our institution pharmacologic thromboprophylaxis is not routinely prescribed for patients following ACL reconstruction. A recent national insurance database study reported that only 3.5% of the more than 14,000 patients included in the study received pharmacologic thromboprophylaxis following ACL reconstruction.12 Interestingly, pharmacologic thromboprophylaxis other than aspirin (acetylsalicylic acid) was associated with increased risk of procedural intervention for arthrofibrosis after ACL reconstruction.12 In our study, DVT was associated with diabetes and obesity. Not using a tourniquet has also previously been reported to decrease the incidence of DVT after ACL reconstruction.13 Surveys should consider forgoing or limiting the use of tourniquet in patients who are at increased risk for DVT (those with obesity, diabetes, or who are smokers).14,15

The overall infection rate was low between the 2 cohorts, approximately 1%. Infection, not surprisingly, was associated with obesity and tobacco use, which has previously been reported.16 Baron et al.17 previously demonstrated that ACL graft preparation with vancomycin-soaked grafts was associated with a 10-fold reduction in infection rate after ACL reconstruction (0.1 vs 1.2%). Graft preparation with vancomycin-soaked gauze for high-risk patients (those with obesity or those who are smokers) should be considered.

The rate of return to the operating room for postoperative lysis of adhesion was found to be significantly lower in the late cohort. These findings may be secondary to the continued emphasis on the importance of prehabilitation before ACL reconstruction.18-20 Female sex was found to be associated with MUA; this risk factor has been previously described with similar ORs to our results.21 Interestingly there was no difference in MUA between the cohorts, despite the significant difference in lysis of adhesions.

Given the increasing popularity of QT autograft for ACL reconstruction, several studies have been published recently comparing the outcomes of QT autograft with BPTB and NT autografts. Two recently published systematic reviews demonstrated QT autograft has comparable clinical and functional outcomes and graft survival rate with BPTB and HT autografts.2,25 Several studies have demonstrated significantly less harvest-site pain in patients who underwent ACL reconstruction with QT autograft compared with BPTB autograft.22-26 However, three studies demonstrated no significant difference in donor-site pain when comparing HT autograft to QT autograft.16,27,28

Biomechanically QT autograft has properties similar to those of the native ACL.29,30 The cross-sectional area and load to failure of the native ACL is 44 mm$^2$ and 1725 to 2160 N, respectively.31 While the tensile strength of the QT autograft is 2352 N, which exceeds the load to failure of the native ACL, and is similar to the tensile strength of BPTB(2977 N) and quadriceps autograft (2422 to 4090 N).31 However, in comparison, the cross-sectional area of QT autograft is larger (62 mm$^2$) than HT (53 mm$^2$) and BPTB (35 mm$^2$) autografts.31,32 Thus, QT autograft provides a thicker graft, compared with HT and BPTB autograft, with acceptable load to failure strength and similar clinical and functional outcomes.

Both QT and BPTB autograft are harvested from the extensor mechanism; thus, potential donor-site morbidity theoretically is similar between the 2 graft choices. However, BPTB carries a greater incidence of morbidity in terms of anterior knee pain, patella fracture, patella tendon rupture, patellofemoral arthritis, kneecap pain, and infrapatellar nerve injury.30,33-37 In their series of 5364 ACL reconstructions with BPTB autograft, Benner et al.34 reported an incidence of patella tendon rupture of 0.24%. In comparison with our findings, the rate of patella tendon rupture after ACL reconstruction with BPTB autograft reported by Benner et al. is approximately 1,000 times that of QT rupture following ACL reconstruction. Thus, all-soft tissue QT autograft demonstrates a lower rate of extensor mechanism disruption when compared BPTB autograft.

Limitations

This paper has a number of limitations consistent with those of any database study. The power of this paper rests on the validity of physician billing and coding, which at times can be imprecise. Although previous studies have reported the error rate of coding to be roughly 1.3%, it is important nonetheless to acknowledge that we are unable to report the accuracy of the coding in this dataset. Unfortunately, there is only one CPT code for ACL reconstruction (29888), and it does...
not further specify between ACL repair, ACL reconstruction, and if reconstruction was performed whether autograft or allograft was used and the technique performed. Further, the PearlDiver database does not code for laterality, thus we were unable to confirm whether the 20 cases of QT rupture were on the ipsilateral side of the ACL reconstruction. Thus, it is likely that our findings overestimated the number of QT ruptures following ACL reconstructions, and our findings should be interpreted with this in mind.

Conclusions

Patients who underwent surgery in the late cohort had lower rates of postoperative complications, except for DVT. The rate of postoperative QT rupture decreased despite considerable increase in the use of QT autograft.

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### Appendix Table 1. Quadriceps Rupture Univariate Analysis

| Characteristic | Quadriceps Rupture OR (95% CI) | *P* Value |
|----------------|---------------------------------|-----------|
| Late Cohort    | 0.07 (0.01-0.33)                | **<.001** |
| Age >60 y      | 3.42 (0.45-25.99)               | .234      |
| Sex (female)   | 0.08 (0.01-0.64)                | .477      |
| Diabetes       | 5.24 (1.65-14.4)                | **.002**  |
| Obesity        | 1.36 (0.38-3.88)                | .603      |
| Tobacco        | 0.85 (0.20-2.65)                | .804      |

**NOTE.** *P* values in bold indicate statistical significance. CI, confidence interval; OR, odds ratio.

### Appendix Table 2. Patella Rupture Univariate Analysis

| Characteristic | Patella Rupture OR (95% CI) | *P* Value |
|----------------|------------------------------|-----------|
| Late cohort    | 0.08 (0.01-0.64)             | **.017**  |
| Age >60 y      | 1.76 (0.99-2.27)             | .988      |
| Sex (female)   | 0.40 (0.13-1.30)             | .126      |
| Diabetes       | 0.96 (0.12-7.38)             | .968      |
| Obesity        | 0.74 (0.16-3.32)             | .691      |
| Tobacco        | 2.31 (0.76-7.07)             | .142      |

**NOTE.** *P* values in bold indicate statistical significance. CI, confidence interval; OR, odds ratio.

### Appendix Table 3. Manipulation Univariate Analysis

| Characteristic | Manipulation OR (95% CI) | *P* Value |
|----------------|--------------------------|-----------|
| Late cohort    | 1.12 (0.92-1.35)         | .260      |
| Age >60 y      | 0.62 (0.26-1.49)         | .284      |
| Sex (female)   | 2.30 (1.86-2.85)         | **<.001** |
| Diabetes       | 1.02 (0.70-1.42)         | .927      |
| Obesity        | 1.14 (0.90-1.44)         | .265      |
| Tobacco        | 1.19 (0.95-1.49)         | .126      |

**NOTE.** *P* values in bold indicate statistical significance. CI, confidence interval; OR, odds ratio.

### Appendix Table 4. Adhesion Lysis Univariate Analysis

| Characteristic | Adhesion Lysis OR (95% CI) | *P* Value |
|----------------|----------------------------|-----------|
| Late cohort    | 0.36 (0.15-0.78)           | **.014**  |
| Age >60 y      | 2.07 (0.34-4.38)           | .981      |
| Sex (female)   | 0.69 (0.33-1.41)           | .308      |
| Diabetes       | 2.26 (0.29-4.33)           | .984      |
| Obesity        | 1.23 (0.49-2.73)           | .627      |
| Tobacco        | 1.58 (0.69-3.36)           | .248      |

**NOTE.** *P* values in bold indicate statistical significance. CI, confidence interval; OR, odds ratio.
### Appendix Table 5. Infection Univariate Analysis

| Characteristic | Infection OR (95% CI) | P Value |
|----------------|-----------------------|---------|
| Late cohort    | 0.55 (0.46-0.66)      | <.001   |
| Age ≥60 y      | 0.58 (0.23-1.18)      | .184    |
| Sex (female)   | 0.66 (0.55-0.78)      | <.001   |
| Diabetes       | 1.40 (1.07-1.85)      | .015    |
| Obese          | 1.59 (1.23-1.81)      | <.001   |
| Tobacco        | 1.66 (1.38-1.99)      | <.001   |

NOTE. P values in bold indicate statistical significance.
CI, confidence interval; OR, odds ratio.

### Appendix Table 6. Infection Multivariate Analysis

| Characteristic | Infection OR (95% CI) | P Value |
|----------------|-----------------------|---------|
| Late cohort    | 0.49 (0.43-0.55)      | <.001   |
| Sex (female)   | 0.69 (0.54-0.81)      | <.001   |
| Diabetes       | 1.14 (0.92-1.39)      | .213    |
| Obese          | 1.59 (1.23-1.81)      | <.001   |
| Tobacco        | 1.66 (1.38-1.99)      | <.001   |

NOTE. P values in bold indicate statistical significance.
CI, confidence interval; OR, odds ratio.

### Appendix Table 7. DVT Univariate Analysis

| Characteristic | DVT OR (95% CI) | P Value |
|----------------|----------------|---------|
| Late cohort    | 29.77 (9.42-94.02) | <.001   |
| Age ≥60 y      | 1.14 (0.28-4.63)  | .856    |
| Sex (female)   | 0.98 (0.65-1.48)  | .922    |
| Diabetes       | 2.43 (1.42-4.17)  | <.001   |
| Obese          | 2.73 (1.79-4.13)  | <.001   |
| Tobacco        | 1.46 (0.93-2.30)  | .104    |

NOTE. P values in bold indicate statistical significance.
CI, confidence interval; DVT, deep vein thrombosis; OR, odds ratio.

### Appendix Table 8. DVT Multivariate Analysis

| Characteristic | DVT OR (95% CI) | P Value |
|----------------|----------------|---------|
| Late cohort    | 14.05 (8.18-26.68) | <.001   |
| Diabetes       | 1.59 (1.02-2.39)  | .031    |
| Obese          | 2.15 (1.56-2.95)  | <.001   |

NOTE. P values in bold indicate statistical significance.
CI, confidence interval; DVT, deep vein thrombosis; OR, odds ratio.