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Anterior cruciate ligament reconstruction performed within 12 months of the index injury is associated with a lower rate of medial meniscus tears

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Abstract

Purpose To verify the correlation of time to surgery with the prevalence of concomitant intra-articular injuries detected on arthroscopy during anterior cruciate ligament (ACL) reconstruction.

Methods The medical records of 653 patients who underwent ACL reconstruction surgery were retrospectively analyzed. Univariate and multivariate logistic regression analysis was performed to identify factors that were associated with the presence of at least one intra-articular injury, medial meniscus tears, lateral meniscus tears and chondral injuries at the time of surgery. Further univariate analysis was conducted to determine the earliest time-point for surgery, after which the rate of concomitant injuries was significantly higher.

Results Longer time to surgery (OR 1.019 95% CI 1.010, 1.028, $p = 0.000$), male sex (OR 1.695 95% CI 1.074, 2.675 $p = 0.023$), and higher BMI (OR 1.050 95% CI 1.006, 1.097 $p = 0.025$) were correlated with a higher prevalence of medial meniscus tears. There was an increased prevalence of medial meniscus tears when surgery was carried out more than 12 months after the index injury (OR 2.274 95% CI 1.469, 3.522, $p = 0.000$). The correlation between longer time to surgery and chondral injuries approached statistical significance (OR 1.006 95% CI 0.999, 1.012, $p = 0.073$). However, a longer time to surgery was not associated with an increased prevalence of lateral meniscus tears (OR 1.003 95% CI 0.998, 1.009, $p =$ n.s.).

Conclusions Longer time to surgery is associated with an increased prevalence of medial meniscus tears in ACL reconstruction. Surgery performed within 12 months of the index injury reduces the prevalence of medial meniscus tears. Prioritizing males and overweight patients for counselling and early intervention can be considered.

Level of evidence Therapeutic level III retrospective cohort study.

Keywords Timing · Anterior cruciate ligament · Meniscus tears · Cartilage lesions

Introduction

The Anterior Cruciate Ligament (ACL) is a key structure in the knee, acting as the primary restraint to anterior tibia displacement [2]. ACL tears are frequently seen in orthopedic clinical practice [32] and the status of the meniscus and articular cartilage after the incident injury has been found to be related to the development of osteoarthritis [11, 14, 25, 33]. The optimal treatment for ACL tears remains controversial with some authors recommending a strategy of rehabilitation with the option of delayed reconstruction [12] while several others suggest early reconstruction [3, 6].

It has been established that the risks of developing additional injuries to the menisci and cartilage increase with delay in the surgical reconstruction of a ruptured ACL [1, 3, 5, 7, 14, 22–23, 27, 28, 30, 34, 35], possibly due to recurrent pivot shift events after the incident injury resulting from the instability of the knee [4, 17]. As such, this suggests that early ACL reconstruction could reduce or prevent additional chondral and meniscal injury and in turn prevent the development of secondary osteoarthritis of the knee. Several studies have attempted to ascertain the optimal time frame in

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which to carry out surgical reconstruction of the torn ACL. Previous studies have identified this duration to be as short as 6 weeks [17] to as long as 12 months [3, 6] of injury to be of significance in reducing the prevalence of concomitant intra-articular injuries [17]. Therefore, there is still no consensus on the optimal timing of surgery to prevent subsequent intra-articular injuries.

Other risk factors have also been reported for the development of intra-articular injuries associated with ACL tears, including increased age, increased Body Mass Index (BMI) [6, 7, 9, 15, 16, 19, 21, 22, 35–37] and male gender [3, 5, 10, 14, 17, 23]. These are important factors that may influence a surgeon in counselling a patient regarding the timing of his or her ACL reconstruction.

The purpose of this study was to verify the correlation of time to surgery, BMI, age and gender with the prevalence of concomitant intra-articular injuries detected on arthroscopy during ACL reconstruction. The hypothesis of this study was that longer time to surgery would be associated with an increased prevalence of concomitant intra-articular injuries.

Materials and methods

This is a retrospective study conducted at a large tertiary public hospital. Patients who underwent arthroscopic primary ACL reconstruction surgery registered in our ACL reconstruction registry were identified. Eligible patients were those who sustained an ACL tear with or without concomitant meniscus and cartilage injuries. Patients with multi-ligamentous injuries and those who underwent revision ACL reconstruction surgeries were excluded. All arthroscopic surgeries were performed by a team made up of six fellowship-trained surgeons.

Relevant clinical information was extracted from the electronic medical records and registry data. This included patient characteristics such as age, gender and body mass index (BMI). Details regarding the surgery was also extracted from the clinical notes pertaining to the mechanism of injury (contact or non-contact) and activity during which the injury was sustained (sports or non-sports). Time to surgery was measured as a continuous variable in months and also categorized into '0–3 months', '3–6 months', '6–12 months' and '> 12 months'. BMI was analyzed both as a continuous variable and categorically based on the World Health Organization [24] definition of overweight (BMI > 25 kg/m^2).

All concomitant meniscus and cartilage injuries were identified on diagnostic arthroscopy. Intra-operative arthroscopic findings were traced using the institution's operative theater record system. The concomitant injuries that were routinely identified for each standardized intra-operative report are as follows: the presence or absence (regardless of size, pattern or number) of medial meniscus tear, lateral meniscus tear, and cartilage injuries of the medial femoral condyle, lateral femoral condyle, medial tibial plateau, lateral tibial plateau, femoral trochlea and patella. Magnetic resonance imaging was done during diagnosis of the ACL rupture but not used for data collection on the secondary injuries.

Ethical aspects

This study was ethically approved by the National University Hospital (NUH) institutional review board (IRB) and the National Health Care Group (NHG) domain-specific review board (DSRB) under the reference number (2016/01003).

Statistical analysis

All data were compiled in Microsoft Excel 2003 (Microsoft Corp., Redmond, WA, USA) and the statistical analysis was performed using Statistical Package for the Social Sciences Version 23.0 (SPSS Inc, Chicago, II, USA). Categorical variables are represented in percentages and continuous variables as means with standard deviations (SD) or median with range, after testing for normality.

Univariate analysis using the chi-square test was performed to assess the association between the prevalence of meniscus and cartilage injuries with age, gender, obesity, duration to definitive surgery, mechanism of injury and type of activity as discrete variables. Multivariate logistic regression analysis was similarly performed to identify associated factors for medial meniscus tears, lateral meniscus tears and cartilage injuries while adjusting for possible confounders. The odds ratio for each factor was calculated. Level of significance was set to be below 0.05. We also included 95% confidence interval (95% CI) in all our analyses to reflect the adequacy of power in our study.

Based on a 95% confidence interval, with an estimated prevalence of chondral injuries detected at 20%, combined with a precision of 3.25%, a sample size of 582 patients was required. Chondral injuries were chosen for the sample size calculation as they are the least common injury associated with ACL tears.

Results

Out of the 696 patients in the database, 43 patients had missing information on their time to surgery and thus were excluded from the analysis. The remaining 653 patients were analyzed for this study, of which a further 38 patients did not have their mechanism of injury indicated in the database. 493 (80.2%) of the patients had the ACL rupture during sporting activity, of which the most

common sport was soccer—229 (46.3%), followed by basketball—76 (15.2%) and netball—21 (4.2%). Examples of 'military' types of activities include obstacle course training and field camps while 'other' types of activities include accidental slips, falls, or trips.

Table 1 summarizes the patient demographics and preoperative characteristics of the study cohort. The mean body mass index (BMI) in our study population was 24.3 kg/m^2, SD = 4.0 and the mean duration from time of injury to definitive ACL reconstruction surgery was 12.5 months, SD = 25.7. There were no significant differences among the various time to surgery groups with regards to gender, age, BMI, type of activities and mechanism of injury.

Table 2 presents the univariate and multivariate logistic regressions of the various factors identified to be correlated with the presence of at least one intra-articular injury, chondral injury, medial meniscus injury and lateral meniscus injury respectively.

Chondral injury

148 (21.3%) of our patients sustained a chondral injury. On multivariate analysis, the presence of these chondral injuries was not significantly correlated with time to surgery but significantly associated with BMI ($p = 0.014$) and age ($p = 0.000$).

Lateral meniscus tear

Lateral meniscus tears were found in 286 (41.1%) of the patients but they were not associated with a longer time to surgery, BMI or age. They were, however, significantly associated with male gender ($p = 0.020$) in the univariate analysis.

Medial meniscus tear

276 (39.7%) of the study population had a medial meniscus tear detected on arthroscopy. The presence of medial meniscus tears was significantly associated with increasing time to surgery, male gender, BMI and age on univariate analysis. On multivariate analysis, time to surgery ($p = 0.000$), male gender ($p = 0.023$) and BMI ($p = 0.025$) remained significantly associated with the presence of medial meniscus tears.

Table 3 presents the results of univariate logistic regression analyzing the incidence of intra-articular injuries at the time of surgical reconstruction between the different surgical timing groups '0–3 months', '3–6 months', '6–12 months' and '> 12 months'.

There was a statistically significant increase in the risk of having at medial meniscus tears in patients who underwent ACL reconstruction more than 12 months after the index injury, compared to patients who had surgery performed within the first 3 months of their injury ($p = 0.000$).

Discussion

The main finding of this study was that increased time between incident injury and ACL reconstruction was significantly correlated with medial meniscus lesions ($p = 0.000$) but not lateral meniscus lesions. This was especially so if surgery was performed more than 12 months when compared with the reference period of up to 3 months ($p = 0.000$). This is in accordance with the study performed by Brambilla et al. [3], which compared the rate of injuries between six different interval lengths: 0–3, 3–6, 6–12, 12–24, 24–60 months.

This study also found that the incidence of lateral meniscal tears did not increase in a time-dependent manner, similar to other studies [1, 3, 5, 8, 9, 17, 18, 29, 30, 38]. This is consistent with the observation that lateral meniscus tears

Table 1 Patient demographics and preoperative characteristics

Variable	Study population ($N = 653$)	0–3 months ($N = 182$)	3–6 months (N = 182)	6–12 months ($N = 124$)	> 12 months ($N = 165$)	*P* Value
Gender						
Males	528 (80.9%)	139 (76.4%)	155 (85.2%)	96 (77.4%)	138 (83.6%)	n.s
Females	125 (19.1%)	43 (23.6%)	27 (14.8%)	28 (22.6%)	27 (16.4%)	n.s
Median age (range)	25.7 (14–52)	25.33 (15–52)	25.46 (15–54)	25.6 (15–60)	26.31 (7.58)	n.s
BMI (SD)	24.3 (4.0)	23.84 (3.95)	24.02 (3.86)	24.21 (3.86)	25.03 (4.25)	n.s
Type of activity—sports (missing = 38)						
Sports	493 (80.2%)	143/178 (80.3%)	141/173 (81.5%)	97/ 118 (82.2%)	112/146 (76.7%)	n.s
Non-sports (military, road traffic accidents, others)	122 (19.8%)	35 (19.7%)	32 (18.5%)	21 (17.8%)	34 (23.3%)	

Table 2 Univariate and multivariate logistic regression analysis for association between independent variables and the presence of at least one intra-articular injury, medial meniscus tear, lateral meniscus tear, chondral injury

Variable	Medial meniscus tear ($N=276$, 39.7%)				Lateral meniscus tear ($N=286$, 41.1%)				Chondral injury ($N=148$; 21.3%)			
	Univariate logistic regression		Multivariate logistic regression		Univariate logistic regression		Multivariate logistic regression		Univariate logistic regression		Multivariate logistic regression	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Surgical timing	1.018 (1.009, 1.026)	0.000	1.019 (1.010, 1.028)	0.000	1.003 (0.998, 1.009)	n. s			1.006 (0.999, 1.012)	n. s		
Male sex	1.863 (1.229, 2.822)	0.003	1.695 (1.074, 2.675)	0.023	1.611 (1.077, 2.410)	0.020			1.254 (0.771–2.037)	n. s		
BMI	1.070 (1.027, 1.115)	0.001	1.050 (1.006, 1.097)	0.025	1.026 (0.985, 1.068)	n. s			1.083 (1.033, 1.135)	0.001	1.064 (1.013, 1.118)	0.014
BMI group												
< 25	1	–			1	–			1	–		
> 25	1.542 (1.109, 2.146)	0.010			1.247 (0.899, 1.730)	n. s			1.574 (1.065, 2.324)	0.023		
Age	1.023 (1.001, 1.044)	0.036	1.001 (0.977, 1.025)	n. s	0.989 (0.968, 1.010)	n. s			1.076 (1.051, 1.102)	0.000	1.065 (1.038, 1.093)	0.000
Age group												
< 30	1	–			1	–			1	–		
> 30	1.336 (0.941, 1.897)	n. s			0.924 (0.649, 1.316)	n. s			3.215 (2.179, 4.741)	0.000		

Table 3 Duration to reconstructive surgery and the associated frequency of concomitant intra-articular injuries

Surgical timing (group) (months)	Medial meniscus injury ($N=276$, 39.7%)		Lateral meniscus injury ($N=286$, 41.1%)		Chondral injury ($N=148$; 21.3%)	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
0–3	1	–	1	–	1	
3–6	1.308 (0.848, 2.019)	n. s	1.071 (0.704, 1.630)	n. s	1.338 (0.809, 2.213)	n. s
6–12	1.433 (0.889, 2.309)	n. s	0.891 (0.556, 1.428)	n. s	1.251 (0.724, 2.161)	n. s
> 12	2.274 (1.469, 3.522)	0.000	1.471 (0.961, 2.254)	n. s	0.868 (0.515, 1.463)	n. s

occur more commonly at the time of the primary injury and not secondarily after the incident injury.

One possible reason for the above findings is that the medial meniscus acts as a secondary stabilizer of the knee against anterior displacement of the tibia via the 'door stopper' effect. The medial meniscus being less mobile, is also less able to follow the increased anterior and rotational translation of the tibia especially in dynamic situations in the absence of the ACL [3] and thus is more likely to undergo shear stresses [20] unlike the lateral meniscus. Its stabilizing role is, therefore, increased in the ACL-deficient knee, especially during recurrent episodes of instability and pivot shift events [5, 18] after the incident injury, resulting in significantly more tears in the setting of delayed reconstruction.

Other recent studies have also found a higher prevalence of medial meniscal tears in patients undergoing reconstruction after 6 weeks [17], 3 months [26, 29, 30], 5 months [9], 6 months [1, 8, 18, 23, 38] or, like our study, as long as after 12 months [3, 6]. We also found that the odds for medial meniscus injury increased by 1.018 per month for each month elapsed since injury, similar to the finding of the Granan et al. [14] who based their results on 3475 patients from the Norwegian National Ligament Registry. The question that arises is whether there is in fact an "optimal time frame" within which to reconstruct the ligament or whether the appearance of such a time frame is the result of the power and design of current published studies, depending on the studies' sample sizes and the time periods into which the surgeries are grouped. For example, in our study, we were unable to provide an adequate analysis for patients with reconstruction within 6 weeks, as this would place only 48 patients into this group, causing an imbalance of statistical power. Nonetheless, our study found the prevalence of medial meniscal tears to be significantly higher when surgery is delayed by more than 12 months.

It may be argued that this finding merely reflects the degenerative process after an ACL rupture at different stages and does not represent the influence of surgical reconstruction on subsequent concomitant intra-articular injuries. Several long-term follow-up studies suggest that the fate of the ACL-deficient knee is sealed at the point of injury and ACL reconstruction, even though improve symptomatic instability is unable to alter the natural history of knee degeneration. Potter et al [27], in an MRI follow-up study of 42 knees found that all knees sustained chondral damage at initial index injury, which progressed over time, with or without surgical ACL reconstruction. However, Sanders et al [31] compared 509 early ACL reconstructions, 91 late and 364 non-operatively treated patients at 14 years follow-up and found that non-operatively and delayed ACL reconstruction patients had higher risk of medial meniscus tear and osteoarthritis than early ACL reconstruction patients, suggesting early ACL reconstruction and its accompanying restoration of kinematics may have a protective effect on the meniscus and cartilage, conferring long-term benefits. It is still yet to be seen if modern surgical techniques will modify the natural history of the ACL-deficient knee in the long-term.

The present study also suggests that special considerations should be given to males and patients with high BMI in prioritizing them for counselling and early intervention. Higher BMI was also found to be a risk factor for the development of medial meniscus tears ($p=0.025$) and chondral injuries ($p=0.014$) when analyzed as a continuous variable as well as when analyzed categorically based on the World Health Organization [24] definition of overweight (BMI > 25 kg/m^2). Previous studies have reported similar findings [6, 7, 9, 15, 16, 19, 21, 22, 35–37]. In accordance with previous studies, the association between male gender and medial ($p=0.023$) and lateral ($p=0.020$) meniscus tears was also confirmed by our study [3, 5, 10, 14, 17, 23].

Under multivariate analysis, the presence of chondral injuries was significantly ($p=0.000$) associated with increased age, especially in patients aged > 30 years ($p=0.000$), in accordance with other studies [5, 9, 13, 17, 34, 35]. In our study, correlation between time to surgery and the presence of chondral injuries at the point of ACL reconstruction was not statistically significant ($p=$n.s.). A possible reason for the lack of significance, would be the lower incidence of chondral injuries compared to other studies [3–5, 8, 14, 23, 27].

An important strength of this study was that it involved a large, heterogeneous and comparable sample size to published studies on factors associated with intra-articular

injuries in ACL tears. This allowed accurate analysis, evaluation of multiple variables and ability for results to be generalized.

This study had a number of limitations. First, data collection was retrospective in nature and the data set was incomplete in our cohort. However, we reported data from a large number of patients ($n = 696$) and all components of our results were analyzed from at least 89% of our cohort. Second, the size and type of meniscal tear or the thickness of articular cartilage lesions were not characterized and thus any relationship between the two could not be determined. Third, due to the lack of standardized documentation, other variables that could potentially be linked to intra-articular knee injuries, such as the number of instability episodes, post-injury physical activity level or compliance to rehabilitation and bracing during the interim period between injury and surgery, were not included.

Despite these limitations, our study demonstrates and reaffirms that increased time to surgery is associated with an increased prevalence of medial meniscus tears observed at reconstruction.

Conclusion

Definitive reconstructive surgery performed within 12 months of the index injury reduces the prevalence of medial meniscus tears observed at ACL reconstruction. Prioritizing males and overweight patients for counselling and early intervention can be considered.

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Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

Ethical approval This study was ethically approved by the National University Hospital (NUH) institutional review board (IRB) and the National Health Care Group (NHG) domain-specific review board (DSRB) under the reference number (2016/01003).

Informed consent For this type of study, formal consent is not required.

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