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Ramp lesions associated with ACL injuries are more likely to be present in contact injuries and complete ACL tears

Romain Seil[1,2] · Caroline Mouton[1,2] · Julien Coquay[3] · Alexander Hoffmann[1] · Christian Nührenbörger[1] · Dietrich Pape[1,2] · Daniel Theisen[2]

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Abstract
Purpose The purpose of this study was to analyse patient and injury characteristics as well as arthroscopic findings in a prospective cohort of ACL-injured patients with or without an associated ramp lesion.
Methods Two hundred and twenty-four patients undergoing a primary ($n = 196$) or revision ($n = 28$) ACL reconstruction were included. The presence of a ramp lesion was determined by a systematic arthroscopic inspection of the posteromedial compartment. Chi-square tests were used to compare the population of ACL-injured patients with and without a ramp lesion regarding sex, age, body mass index, previous ACL injuries, sport before injury, and injury characteristics. Significance was set at $p < 0.05$.
Results Fifty-three out of 224 patients had a ramp lesion (24%). The presence of the latter was not related to any of the analysed patient characteristics. The prevalence of the lesion was higher in contact injuries ($n = 19$; 41%) compared with non-contact injures ($n = 34$; 19%; $p < 0.001$). It was higher in patients with complete ACL ruptures ($n = 49$; 27%) as opposed to partial ruptures ($n = 1$; 4%; $p = 0.01$). A patient was 2.98 [95% CI 1.49–5.98] times more likely to have a ramp lesion if the ACL injury was declared to have been caused by direct contact and 8.71 [95% CI 1.15–66.12] times more likely if the ACL tear was complete.
Conclusion Ramp lesions may be anticipated in almost one out of four patients undergoing ACL reconstruction, especially if a patient sustained a contact injury and in the presence of a complete ACL tear.
Level of evidence III.

Keywords Knee · Ramp lesion · Anterior cruciate ligament · Epidemiology

Introduction

Anterior cruciate ligament (ACL) tears are associated with medial meniscus lesions in 23–41% of ACL reconstructions [9]. The number of medial meniscus lesions occurring in association with ACL tears has, however, been previously underestimated. This has been illustrated by the recent focus on lesions of the posterior part of the medial meniscus in the meniscosynovial area (ramp or "hidden" lesions). These lesions have been reported in 15–17% of patients undergoing an ACL reconstruction [14, 16, 20]. They can be associated with a mild anteromedial rotatory subluxation [3]. In a controlled laboratory study, anterior and rotational knee laxity was significantly increased after sectioning of the posteromedial meniscocapsular junction to simulate a ramp lesion in an ACL-deficient knee [21]. These results suggest that, undiagnosed, ramp lesions may result in abnormal knee laxity and subsequent meniscus lesions.

Ramp lesions are difficult to detect with magnetic resonance imaging (MRI) [3, 17] or a routine arthroscopic inspection of the knee performed through an anterior portal. Their diagnosis requires an arthroscopic inspection of

✉ Romain Seil
rseil@yahoo.com

[1] Department of Orthopaedic Surgery, Clinique d'Eich – Centre Hospitalier de Luxembourg, Luxembourg, Luxembourg

[2] Sports Medicine Research Laboratory, Department of Population Health, Luxembourg Institute of Health, Luxembourg, Luxembourg

[3] Department of Orthopaedic Surgery, Clinique St. Pierre Ottignies, Ottignies, Belgium

the posteromedial compartment, preferably using a posteromedial portal [1, 3, 14, 19]. Little has been reported about the precise circumstances of their occurrence. Only Liu et al. [14] showed that ramp lesions were more common in males and in patients under 30 years or with longer time since injury. To date, no other risk factors for ramp lesions have been identified, such as injury mechanism or joint status under routine arthroscopic inspection. However, anticipating the existence of these injuries could be facilitated based on knowledge of additional risk factors.

The purpose of this study was therefore to compare patient and injury characteristics as well as arthroscopic findings in ACL-injured patients with or without a ramp lesion. It was hypothesized that the presence of a ramp lesion would be associated with specific patient and injury characteristics as well as arthroscopic findings.

Materials and methods

Two hundred and twenty-four ACL-reconstructed patients (196 primary ACL reconstructions and 28 revisions) operated by a single surgeon between 2011 and 2015 gave their written informed consent to participate in the study, including 144 males (age: 27 ± 8 years, 179 ± 7 cm, 79 ± 13 kg) and 80 females (age: 28 ± 13 years, 167 ± 7 cm, 65 ± 12 kg). The participants reported their personal and injury characteristics by completing a standardised questionnaire (1). Patients requiring multi-ligament reconstructions were excluded from the study. The study protocol had previously been approved by the National Ethics Committee for Research (N°201101/05). Data acquisition and storage were notified to the National Data Protection Committee.

Surgical procedure

Surgery comprised an initial routine inspection of the knee with a 30° arthroscope through the anterolateral portal. This allowed reporting the status of the ACL remnant (partial or complete tears) and any lesion to the medial and lateral menisci, the articular cartilage surface of the tibia, femur and patella as well as the posterior cruciate ligament and medial/lateral collateral ligaments. First an anterior visual inspection was made of the posterior segment of the medial meniscus and palpation with a probe allowed to identify any sign of meniscus instability. To inspect the posteromedial compartment, the arthroscope was advanced through the intercondylar notch underneath the PCL as previously described [7, 8]. The 30° arthroscope did not allow to visualize the entire zone of the ramp of the medial meniscus. Therefore, a systematic percutaneous palpation of the meniscal ramp with a 21-G needle was performed from a posteromedial approach in addition to the visual inspection of the meniscosynovial area. If a ramp lesion was suspected by needle palpation, better visualization was obtained either through internal rotation of the foot, through a switch to a 70° arthroscope or through a direct visualization by applying a posteromedial arthroscopy portal [20].

In case of a confirmed ramp lesion, repair was performed with a curved needle by using a specific instrumentation (Spectrum, Conmed, Largo, FL, USA) through the posteromedial portal. Depending on the extent of the lesion, one or several PDS stitches were knotted every 5 mm after debridement of the meniscocapsular junction with a shaver. The stability of the repair was tested under arthroscopic observation with a probe.

Finally, an arthroscopically assisted anatomical single-bundle ACL reconstruction was performed using an ipsilateral bone patellar tendon bone or semitendinosus/gracilis graft and bio-interference screws for graft fixation (Arthrex, Naples, FL, USA).

Data collection

Patient characteristics assessed included: (1) gender, (2) age at injury (under 21, between 21 and 35, above 35) [18], (3) body mass index, (4) the existence of a previous ACL injury to the ipsi- or contralateral knee, (5) the preinjury level of sport practice classified into three grades [10]: level I sports (handball, soccer, basketball), level II sports (volleyball, gymnastics, tennis, alpine skiing), level III sports (running, cycling, swimming) or no regular sport activity (less than once a week), and (6) involvement in a competitive sport before injury.

Injury characteristics included (1) injury mechanism (contact or non-contact injury), (2) injury context (during a sporting activity or not), (3) type of sport at injury occurrence, and (4) delay between injury and surgery, expressed in days.

For surgical data, a standardised report was filled in by the operating team. The main outcome was the presence or not of a ramp lesion of the medial meniscus. The report included the following arthroscopic findings: the type of ACL tear (complete vs. partial) as well as the presence or absence of an ACL remnant, the presence of a medial and/or lateral meniscus lesion, and the presence of a chondral lesion in the medial or lateral compartment of the knee according to the Outerbridge classification [15].

Statistical analyses

Statistical analyses were performed using version 20.0 of the SPSS software. Chi-square tests were used for all categorical variables to determine whether the percentage of ramp lesions differed according to patient and

injury characteristics as well as to clinical and arthroscopic findings. Each expected cell count was checked to be superior to 5 to verify the test validity. If a significant difference was observed in distribution for one or more of the categorical variables, univariable logistic regressions were computed to calculate the crude odds ratio for the presence of a ramp lesion. For continuous variables, i.e. BMI and delay between injury and surgery, normality of data was checked using the Kolmogorov–Smirnov test. As normality was not assumed for both variables, the Mann–Whitney test was computed to analyse between-group differences. A sample size calculation revealed that, based on 59 patients per group and a lowest expected percentage of 10%, a difference of 20% would be detected as significant at the 0.05 threshold with a statistical power of 80%. Significance was set at $p < 0.05$ for all analyses.

Results

Ninety-one (41%) out of the 224 patients had a lesion of the medial meniscus. A ramp lesion could be identified in 53 patients (24%), representing 55% of patients with a medial meniscus tear. Ninety-three (42%) had a lesion of the lateral meniscus, of which none had a ramp lesion. Thirty-six patients (16%) displayed lesions to both menisci. Patients' characteristics and percentages of associated ramp lesions are presented in Table 1. None of the considered individual characteristics differed significantly between the two groups of patients with and without a ramp lesion.

Injury characteristics are presented in Table 2 for patients with and without an associated ramp lesion. Nineteen (41%) patients with a contact ACL injury had a ramp lesions versus 34 (19%) in patients with a non-contact ACL injury ($p = 0.002$). A patient was 2.98 times more likely to have a ramp lesion if the ACL injury was declared to have been caused by a direct contact (OR 2.98 [95% CI 1.49–5.98]). Neither the context of injury, nor the type of sport at injury or the delay between injury and surgery differed significantly between patients with or without a ramp lesion.

Clinical and arthroscopic findings are presented in Table 3. Forty-nine (27%) patients with a complete ACL injury had a ramp lesion as opposed to 1 (4%) patient with a partial ACL tear (n.s.). A patient was 8.71 times more likely to have an associated ramp lesion if she/he had a complete ACL tear (OR 8.71 [95% CI 1.15–66.12]). The presence of another meniscus tear or the cartilage status was not significantly associated with the presence of a ramp lesion.

Table 1 Individual characteristics of patients with or without an associated ramp lesion

	Ramp lesion ($n = 53$)	No ramp lesion ($n = 171$)	p value
Gender			
Male	39 (27%)	105 (73%)	n.s.
Female	14 (17%)	66 (83%)	
Age at injury			
<21	17 (25%)	52 (75%)	n.s.
21–35	28 (26%)	78 (74%)	
>35	8 (16%)	41 (84%)	
Body mass index			
Median	23.8	23.6	n.s.
Interquartile range	22.0–26.0	21.4–26.0	
Previous ACL injury (contralateral knee)			
No	42 (22%)	150 (78%)	n.s.
Yes	11 (34%)	21 (66%)	
Previous ACL surgery (same knee)			
No	45 (23%)	151 (77%)	n.s.
Yes	8 (29%)	20 (71%)	
Preinjury level of sport practice			
Level I	37 (26%)	103 (74%)	n.s.
Level II	8 (24%)	25 (76%)	
Level III	8 (16%)	43 (84%)	
Preinjury involvement in competition			
Yes	36 (26%)	104 (74%)	n.s.
No	17 (20%)	67 (80%)	

Discussion

The most important findings of this study were the high prevalence (24%) of ramp lesions associated with ACL injuries in this patient cohort, their higher prevalence in contact as opposed to non-contact ACL injuries, as well as an association between ramp lesions and complete ACL tears. A patient was 2.98 time more likely to sustain a ramp lesion in association with her/his ACL injury if she/he presented a contact injury. A patient was also 8.71 times more likely to sustain a ramp lesion if she/he had a complete ACL tear.

Almost one patient out of four in this study had a ramp lesion in association with his ACL injury (24%). This is higher than the previously reported prevalence of 15–17% [14, 16, 20] and may be related to differences in patient population, sports practice, or injury mechanism (contact versus non-contact), or the fact that both patients with primary and revision ACL reconstructions were included. Unlike a previous publication by Liu et al. on 868 ACL-injured patients with 144 ramp lesions (16.6%), individual patient characteristics did not differ

Table 2 Injury characteristics of patients with or without an associated ramp lesion

	Ramp lesion	No ramp lesion	*p* value
Mechanism			
Contact	19 (41%)	27 (59%)	0.002
Non-contact	34 (19%)	144 (81%)	
Context of the injury			
Sports related	45 (24%)	142 (76%)	n.s.
Non-sports related	8 (22%)	29 (78%)	
Sport at injury			
Football	25 (30%)	59 (70%)	n.s.
Handball	3 (15%)	17 (85%)	
Basketball	5 (21%)	19 (79%)	
Ski	3 (10%)	27 (90%)	
Other sports	9 (20%)	20 (69%)	
Delay between injury and surgery (days)			
Median	162	134	n.s.
Interquartile range	98–488	72–326	

Table 3 Arthroscopic findings in patients with or without an associated ramp lesion

	Ramp lesion	No ramp lesion	*p* value
ACL tear			
Partial	1 (4%)	24 (96%)	0.013
Complete	49 (27%)	135 (73%)	
Missing data	$n = 3$	$n = 12$	
Associated lesion to the medial meniscus			
No	43 (25%)	128 (75%)	n.s.
Yes	10 (19%)	43 (81%)	
Associated lesion to the lateral meniscus			
No	32 (25%)	94 (75%)	n.s.
Yes	20 (21%)	73 (79%)	
Missing data	$n = 1$	$n = 4$	
Associated lesion to cartilage in medial compartment			
Grade 0–1	36 (21%)	135 (79%)	n.s.
Grade 2–3–4	15 (35%)	28 (65%)	
Missing data	$n = 2$	$n = 8$	
Associated lesion to cartilage in lateral compartment ($n = 210$—missing data for 12 patients)			
Grade 0–1	44 (23%)	147 (77%)	n.s.
Grade 2–3–4	6 (29%)	15 (71%)	
Missing data	$n = 3$	$n = 9$	

between subjects with or without a ramp lesion in the present study (Table 1). Liu et al. [14] showed that the prevalence of ramp lesions was significantly higher in males (18.6 vs. 12.0% in females). While the prevalence found here was 27% for males and 17% for females, the difference was not significant. This could be explained by the statistical power which reached only 0.36. A group of at least 265 ramp lesions would have been necessary to reach a power of 80%. Liu et al. [14] also observed a higher prevalence of ramp lesions in patients under the age of 30. While a lower prevalence of ramp lesions of 10% could be noted in the present series in patients older than 35 years, the level of significance could not be reached due to our small sample size. Statistical power reached 0.65. As for gender, a group of 265 ramp lesions should have been observed to reach a power of 80%. Finally, Liu et al. found a prevalence of 18.8% of ramp lesions in chronic ACL tears versus 12.7% in an acute context (delay of less than 6 weeks). A similar association could not be found in the present study. However, the time since injury was used as a continuous variable here, and the result is in agreement with the findings of Sonnery-Cottet et al. [20].

To the authors' knowledge, this is the first time that an association between injury mechanism and the presence of ramp lesions could be found. A patient was 2.98 times more likely to sustain a ramp lesion if the associated ACL tear was caused by a contact injury. This finding suggests that the occurrence of ramp lesions may be related to the pathologic loading conditions at the moment of injury, and that ramp lesions may be more frequent in the presence of a higher-energy trauma mechanism. It is supported by a recent imaging study, showing that contact injuries predicted more severe bone bruising of the lateral tibial plateau at MRI than non-contact ACL injuries [2]. In addition, the lateral tibial plateau bone bruising was associated with medial meniscus tears which the authors suspected to be caused by higher amount of energy at the time of injury. A biomechanical cadaver study also confirmed that injury patterns of secondary knee structures are correlated with loading conditions at the moment of injury [12]. Another finding supporting the role of a high-energy trauma mechanism in the occurrence of ramp lesions was the increased likelihood of ramp lesions (OR 8.71) in patients presenting with a complete tear of the ACL. This is in accordance with previous reports showing that complete ACL tears require higher forces at the moment of injury [4–6].

Arthroscopic inspection further revealed that the number of medial ($n = 91$; 41%) and lateral ($n = 90$; 40%) meniscus tears were identical. Of note was that less than half of the medial-sided injuries ($n = 38$; 45%) concerned the meniscal body of the posterior horn, whereas 53 (55%) concerned the meniscal ramp. On the lateral side, however, not a single ramp lesion could be identified in this series. These numbers indicate not only the different injury profile of medial and lateral meniscus tears, but also that the medial meniscus should be increasingly considered as a functional anatomical unit including both the meniscal body and the meniscal ramp. Further anatomical studies

are needed to better define the latter. Leaving these lesions undiagnosed means that nearly half of the injuries of the medial meniscus may be missed.

This study is not without limitations. As ramp lesions have always been considered in association with ACL injuries, the overall incidence in the general population remains unknown. In this study, some analyses were underpowered due to small numbers in each category despite a cohort of 224 patients with ACL reconstructions. While ramp lesions were 2.98 times more likely to appear in contact ACL injuries, it should be emphasized that 72–80% of ACL injuries are non-contact injuries [11, 13]. Focusing on contact injuries to predict the presence of a ramp lesion would thus lead to an insufficient diagnostic sensitivity. Efforts must thus be pursued to better diagnose ramp lesions, which, if left untreated, may lead to subsequent instabilities or symptomatic secondary meniscus tears.

Conclusion

Ramp lesions of the medial meniscus should be systematically evaluated in ACL reconstructions. They have a comparable prevalence to the tears affecting the body of the medial meniscus. They may be anticipated in almost one out of four patients undergoing ACL reconstruction, especially if a patient sustained a contact injury and in the presence of a complete ACL tear.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Ethical approval The study was approved by the National Ethics Committee for Research of Luxembourg (N°201101/05).

Informed consent Patients gave written informed consent.

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