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High incidence of RAMP lesions and a nonnegligible incidence of anterolateral ligament and posterior oblique ligament rupture in acute ACL injury

Riccardo D'Ambrosi[1,2] | **Luca Maria Sconfienza[1,2]** | **Domenico Albano[1,2]** | **Carmelo Messina[1,2]** | **Laura Mangiavini[1,2]** | **Nicola Ursino[1]** | **Simone Rinaldi[3,4]** | **Andrea Zanirato[4,5]** | **Alberto Tagliafico[3,4]** | **Matteo Formica[4,5]**

[1]IRCCS Ospedale Galeazzi—Sant'Ambrogio, Milan, Italy

[2]Dipartimento di Scienze Biomediche per la Salute, Università degli Studi di Milano, Milan, Italy

[3]DISSAL, Università di Genova, Genova, Italy

[4]IRCCS Ospedale Policlinico San Martino, Genova, Italy

[5]DISC—Dipartimento di scienze chirurgiche e diagnostiche integrate, Università di Genova, Genova, Italy

Correspondence

Riccardo D'Ambrosi, MD, IRCCS Ospedale Galeazzi— Sant'Ambrogio, Milan, Italy.
Email: riccardo.dambrosi@hotmail.it

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Abstract

Purpose: The purpose of this study was to assess the frequency of medial collateral ligament (MCL), posterior oblique ligament (POL) and anterolateral ligament (ALL) tears and different types of RAMP lesions of patients with verified acute anterior cruciate ligament (ACL) tears by magnetic resonance imaging (MRI).

Methods: MRI was performed on patients with a clinical diagnosis of acute ACL injury. Patients were eligible for inclusion if they had an initially clinically noted ACL tear confirmed on MRI within 30 days of trauma.

Results: A total of 146 patients were included in the study, 42 (28.8%) females and 104 (71.2%) males. The mean age at MRI was 27.2 ± 9.4 years, and the mean time from injury to MRI was 15.7 ± 7.8 days. Thirty-four (23.3%) patients had a complete MCL lesion, 32 (21.9%) had a complete POL lesion and 28 (19.2%) had a complete ALL lesion. One hundred and fourteen patients (78.1%) presented with RAMP lesions, while 20 (13.7%) patients reported other meniscal lesions. The mean medial and lateral tibial slopes were 4.0° ± 2.7° and 4.0° ± 3.1°, respectively. Only 10 (6.8%) patients reported no lesions associated with ACL rupture. The most common injuries were isolated RAMP type 3 (18–12.3%) and isolated RAMP type 1 (17–11.6%). Thirteen (8.9%) patients had a combination of MCL, POL and ALL rupture.

Conclusions: Isolated lesions of the ACL are extremely rare. In most cases, a single RAMP lesion should be investigated. In the presence of MCL injury, POL injury should always be suspected as well, while nearly 20% of patients present a rupture of the ALL. About one in 10 patients had three lesions (MCL, ALL and POL), and most of them had a combined RAMP lesion.

Level of Evidence: Level IV.

KEYWORDS

ACL, anterior cruciate ligament, anterolateral ligament, MRI, posterior oblique ligament, RAMP

Abbreviations: ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; ALL, anterolateral ligament; IR, internal rotation; MCL, medial collateral ligament; MRI, magnetic resonance imaging; POL, posterior oblique ligament; sMCL, superficial medial collateral ligament; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology.

INTRODUCTION

Despite the growing recognition of anterolateral ligament (ALL) tears and RAMP lesions in patients with anterior cruciate ligament (ACL) tears, the rate of these lesions has been significantly underestimated [24]. This difficulty is primarily attributed to the low sensitivity and specificity of magnetic resonance imaging (MRI) for preoperative diagnosis or insufficient visualisation of the posterior horn of the medial meniscus during arthroscopy [6]. Moreover, the clinical evaluation of ALL tears is challenging [17]. The ALL restricts internal rotation (IR) of the tibia and functions as a stabiliser to prevent IR when the knee joint is in a flexed position. The manifestation of tears in deficient ACL knees leads to augmented anterior tibial translation and heightened IR [18]. RAMP lesions are associated with notable augmentation of anterior translational mobility and external rotational instability of the tibia [19]. During clinical examination, both types of damage cause an augmentation in motion when the subject is doing the pivot-shift test [6, 18, 19]. In individuals diagnosed with an ACL injury and accompanying ALL tear or RAMP lesion, complete restoration of knee joint stability is frequently not achieved via ACL reconstruction alone [6, 22, 24]. However, this can be accomplished by implementing supplementary reconstruction of the ALL or by addressing the RAMP lesion [24]. Untreated RAMP lesions can induce lasting instability in the knee joint as a consequence of destabilising the posterior horn of the medial meniscus [2]. This leads to an elevated rate of ACL reconstruction (ACLR) failure, cartilage degeneration and risk of osteoarthritis [6]. Sonnery-Cottet et al. demonstrated that additional ALL reconstruction resulted in a significant decrease in the ACL rerupture rate, with a minimum reduction of 2.5 times [22]. Hence, the preoperative evaluation of both ALL and RAMP lesions holds significant value in assisting surgeons in making informed decisions on the most suitable procedures for knee stabilisation [24].

The inconsistency frequency of ALL tears detected by MRI in patients with ACL tears has been reported to range from 26% to 62% [8, 9]. A recent study [20] prospectively evaluated 575 knees with meniscal tears and ACL deficiency and demonstrated that 60.2% of all knees with ACL deficiency had peripheral posterior horn tears, while 40.0% of all knees with ACL deficiency had peripheral tears in the posterior horn of the medial meniscus. These tears account for 75.4% of all medial meniscal tears in ACL-deficient knees and 40% of all meniscal tears in ACL-deficient knees [20].

In this scenario, the posterior oblique ligament (POL) also plays a key role; in fact, the POL is a primary stabiliser for internal rotation (IR) and a secondary stabiliser for valgus and external rotation, while the superficial medial collateral ligament (sMCL) is the primary knee valgus stabiliser across all knee flexion angles, and it also acts as a secondary stabiliser for external and internal rotation depending on the knee flexion angle [4, 5]. Isolated injury of the POL is rare and, in most cases, is associated with complete peripheral meniscal detachment and MCL. The mechanism of injury typically involves valgus knee loading, tibial external rotation or a combined force vector of valgus loading and external rotation that occurs in sports, such as skiing, ice hockey and soccer, which require knee flexion [4, 5].

Therefore, the aim of the current study was to assess the frequency of MCL, POL and ALL tears and different types of RAMP lesions in patients with verified acute ACL tears by MRI and to analyse the injuries associated with these lesions. Limited literature is available on the frequency of concomitant MCL, POL and ALL tears and different types of RAMP lesions in patients with acute ACL tears, but these lesions may lead to persistent instability after ACL reconstruction if left untreated.

MATERIALS AND METHODS

After Institutional Review Board approval (ACL-L2104), the first author reviewed the MR images of all patients with a clinical diagnosis of acute ACL injury.

The present study was conducted following the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement [3]. All procedures were conducted in accordance with the standards highlighted in the 1964 Declaration of Helsinki and its later amendments.

Patients were eligible for inclusion if they were initially noted to have an ACL tear clinically as confirmed by MRI. Patients were excluded from the study if they had a history of previous surgery at the index knee; concomitant injuries such as a tibial or femoral fracture; a complete tear of the posterior cruciate ligament, quadriceps or patellar tendon; intra-articular infection or a tumour.

Patients with low-resolution preoperative MRI data, given the presence of motion artifacts, inadequate magnetic field strength (minimum 1.5 T) or poor resolution that precluded adequate visualisation of the posteromedial knee structure and ALL, were also excluded [17]. Since delayed treatment of ACL injury has been implicated in the development of subsequent meniscal tears, patients who underwent MRI more than 30 days after their initial injury were also excluded [7]. Baseline demographic variables, including patient age, sex and involved side, were manually recorded.

Radiologic assessment

All MRI scans were independently analysed by an orthopaedic surgeon specialising in knee surgery and a musculoskeletal radiologist. A conjoined, second-phase MRI assessment was performed to reach consensus in the event of inconsistencies after 4–6 weeks. All suitable MRI scans were transferred to a DICOM medical imaging viewer (Horos v3.0; Horos project). Imaging was performed using a digital ruler via a DICOM medical imaging viewer (Horos v3.0; Horos project) with an accuracy of 1.0 mm on T1-weighted MR images by two independent reviewers.

Medial meniscus lesions were categorised as no lesion (0), a RAMP lesion (1) or other meniscal tears (2). In turn, RAMP lesions were classified according to Thaunat et al. [25] as follows:

Type 1: Meniscocapsular lesions. These lesions are peripherally located in the synovial sheath.
Type 2: Partial superior lesions.
Type 3: Partial inferior or hidden lesions.
Type 4: Complete tear in the red–red zone.
Type 5: Double tear.

The presence of MCL, POL and ALL injuries was assessed on coronal and axial images of proton-density fat-saturation or T2-weighted sequences. Coronal sequences were oriented according to the position of the femur parallel to the femoral condyles.

The MCL was categorised into three types according to Hughston et al. [13]: (0) no lesion (grade 0), (1) partial injury (grade 1 or 2) or (2) complete disruption (grade 3).

POL was categorised into three types according to House et al. [11]: (0) no lesion, (1) partial injury or (2) complete disruption.

ALL tears were categorised into three types according to Helito et al. [10]: (0) no lesion, (1) partial injury or (2) complete disruption.

Medial and lateral tibial slopes were recorded using MRI according to Karimi et al. [14]. A first line was drawn tangent to the posterior tibial cortex and another line was drawn perpendicular to the first line. A third line was drawn tangent to the surface of the tibial plateau. The angle between the third and the second lines was considered the posterior tibial slope [14].

Statistical analysis

Descriptive statistics are presented for the overall cohort, by sex and by age in the form of absolute frequencies and percentages or means with their standard deviations. Continuous variables were tested for normality with the Shapiro–Wilk test. The presence of concomitant lesions was evaluated for each participant by counting the presence of meniscal lesions, ALL lesions, MCL lesions and POL lesions, and the type of lesion is described. Differences by sex and age (<27 years versus ≥27 years) were assessed with the χ^2 test or Fisher's exact test for categorical variables or Student's t-test for continuous variables. Spearman's rank correlation coefficients between the collected variables were calculated. To further explore the subgroups of RAMP lesions, subgroup analyses were conducted for patients with RAMP lesions by sex and age, and Spearman's rank correlations between the collected variables were calculated. A two-tailed p value <0.05 was considered to indicate statistical significance. Cohen's κ was calculated for interrater agreement, and the interrater correlation coefficient (ICC) was calculated for interrater reliability between the two readers. Statistical significance was set at $p < 0.05$. All the statistical tests were performed with R version 4.3.0 (R Foundation for Statistical Computing; https://www.R-project.org/).

At least 144 subjects were needed to detect a 20% proportion of patients with meniscal and ALL lesions with 80% power, 5% alpha and 10% effect size using a two-sided binomial test. Additional participants were recruited to ensure statistical significance in case of dropout due to adverse events [21].

RESULTS

Cohen's κ showed excellent agreement between the two readers (0.949, $p < 0.001$). The ICC for the reliability of MRI measurements was 0.96 (95% confidence interval [CI]: 0.94–0.97).

A total of 146 patients were enrolled in the study, including 42 (28.8%) females and 104 (71.2%) males. The mean age at MRI was 27.2 ± 9.4 years, and the mean time from injury to MRI was 15.7 ± 7.8 days.

Thirty-four (23.3%) patients had a complete MCL lesion, 32 (21.9%) had a complete POL lesion and 28 (19.2%) had a complete ALL lesion. All patients with POL rupture had MCL injury.

One hundred and fourteen patients (78.1%) presented with RAMP lesions, while 20 (13.7%) patients had other meniscal lesions.

The mean medial and lateral tibial slopes were 4.0° ± 2.7° and 4.0° ± 3.1°, respectively.

Detailed results are reported in Table 1.

Subgroup analysis by sex and age

Only the lateral tibial slope (female 2.6° ± 3.7° versus male 4.5° ± 2.7°; $p = 0.001$) and the incidence of type 4

TABLE 1 Demographic data.

	N = 146 n (%)
Sex	
Female	42 (28.8)
Male	104 (71.2)
Age (mean ± SD)	27.2 ± 9.4
Age	
<27 years	79 (54.1)
≥27 years	67 (45.9)
Side	
Right	75 (51.4)
Left	71 (48.6)
Meniscal lesion	
No lesion	12 (8.2)
RAMP lesion	114 (78.1)
Other lesion	20 (13.7)
RAMP lesion (classification)	
1	35 (30.7)
2	12 (10.5)
3	41 (36.0)
4	21 (18.4)
5	5 (4.4)
Medial collateral ligament	
No lesion	90 (61.6)
Partial	22 (15.1)
Complete	34 (23.3)
Posterior oblique ligament	
No lesion	90 (61.6)
Partial	24 (16.4)
Complete	32 (21.9)
Anterolateral ligament	
No lesion	100 (68.5)
Partial	18 (12.3)
Complete	28 (19.2)
Medial tibial slope (mean ± SD)	4.0° ± 2.7°
Lateral tibial slope (mean ± SD)	4.0° ± 3.1°

RAMP lesions (female 1 versus male 20; $p = 0.003$) differed by sex.

There were more young patients without meniscal lesions than older patients (10 versus 2; $p = 0.004$). Type 1 RAMP lesions were more common than the other types (27 versus 8; $p = 0.02$).

Associated injuries

Only 10 (6.8%) patients had isolated ACL rupture. The most common injuries were isolated RAMP type 3 (18%–12.3%) and RAMP type 1 (17%–11.6%). Thirteen (8.9%) patients presented with a combination of LCM, POL and ALL rupture, and most of them (11/13%–84.61%) also had a RAMP lesion. Details of the combinations of lesions are reported in Table 2 and Figures 1, 2, 3, 4 and 5.

Statistically significant correlations

Statistically significant correlations in the whole cohort are reported in Table 3, while Table 4 shows significant correlations only in patients with RAMP lesions.

DISCUSSION

The main findings of our study are that in more than 10% of patients with acute ACL injury, there is a concomitant injury involving the LCM, the POL and the ALL, and most of these injuries are associated with a RAMP lesion. Nearly 20% of the patients reported a rupture of the POL or the ALL. According to the current literature, no study has analysed concomitant POL and ALL injuries in association with RAMP lesions. Our findings reveal new scenarios of the causes of knee instability.

In the present study, a relatively low number of patients with isolated ACL injury (<7%) was found, consistent with the literature; many studies have shown that isolated ACL tears are rare (<10%), and ACL tears are mostly accompanied by meniscus, articular cartilage and collateral ligament injuries [15].

Stranger et al. also recently assessed the frequency of ALL tears and RAMP lesions detected by MRI in patients with ACL tears and described associated injuries indicative of these lesions [24]. One hundred and sixty-four patients with surgically verified ACL tears were included. Preoperative MRI scans were reviewed for ALL tears and different types of RAMP. All coexisting meniscal tears, tears in the medial and lateral collateral bands and posterior–medial tibial bone marrow oedema were recorded. ALL tears and RAMP combined were detected in 28 patients (17.1%), ALL tears alone in 48 patients (29.3%) and RAMP in 54 patients (32.9%), which were significantly associated with each other. ALL tears were significantly associated with tears in the posterior horn of the lateral meniscus, bone marrow oedema and tears in the lateral collateral

TABLE 2 Associated lesions.

	***N* = 146** ***n* (%)**
No lesion	10 (6.8)
One lesion	
RAMP lesion type 1	17 (11.6)
RAMP lesion type 2	5 (3.4)
RAMP lesion type 3	18 (12.3)
RAMP lesion type 4	9 (6.2)
RAMP lesion type 5	3 (2.1)
Meniscal lesion (other)	9 (6.2)
ALL partial	1 (0.7)
Two lesions	
RAMP lesion type 1 + ALL partial	3 (2.1)
RAMP lesion type 2 + ALL partial	1 (0.7)
RAMP lesion type 3 + ALL partial	3 (2.1)
Meniscal lesion (other) + ALL partial	2 (1.4)
RAMP lesion type 1 + ALL complete	4 (2.7)
RAMP lesion type 2 + ALL complete	1 (0.7)
RAMP lesion type 3 + ALL complete	3 (2.1)
Meniscal lesion (other) + ALL complete	1 (0.7)
Three lesions	
RAMP lesion type 1 + MCL partial + POL partial	1 (0.7)
RAMP lesion type 2 + MCL partial + POL partial	1 (0.7)
RAMP lesion type 3 + MCL partial + POL partial	4 (2.7)
RAMP lesion type 4 + MCL partial + POL partial	4 (2.7)
Meniscal lesion (other) + MCL partial + POL partial	1 (0.7)
RAMP lesion type 2 + MCL complete + POL partial	1 (0.7)
RAMP lesion type 3 + MCL complete + POL partial	1 (0.7)
RAMP lesion type 4 + MCL complete + POL partial	1 (0.7)
Meniscal lesion (other) + MCL partial + POL complete	1 (0.7)
RAMP lesion type 1 + MCL complete + POL complete	4 (2.7)
RAMP lesion type 3 + MCL complete + POL complete	4 (2.7)
RAMP lesion type 4 + MCL complete + POL complete	2 (1.4)
RAMP lesion type 5 + MCL complete + POL complete	1 (0.7)
Meniscal lesion (other) + MCL complete + POL complete	3 (2.1)
MCL complete + POL complete + ALL complete	1 (0.7)
Four lesions	
RAMP lesion type 3 + MCL partial + POL partial + ALL partial	2 (1.4)
RAMP lesion type 4 + MCL partial + POL partial + ALL partial	1 (0.7)

(Continues)

TABLE 2 (Continued)

	N **= 146** ***n*** **(%)**
RAMP lesion type 5 + MCL partial + POL partial + ALL partial	1 (0.7)
RAMP lesion type 1 + MCL partial + POL partial + ALL complete	2 (1.4)
RAMP lesion type 2 + MCL partial + POL partial + ALL complete	1 (0.7)
RAMP lesion type 3 + MCL partial + POL partial + ALL complete	1 (0.7)
RAMP lesion type 4 + MCL partial + POL partial + ALL complete	1 (0.7)
RAMP lesion type 1 + MCL complete + POL complete + ALL partial	2 (1.4)
RAMP lesion type 3 + MCL complete + POL complete + ALL partial	1 (0.7)
Meniscal lesion (other) + MCL partial + POL partial + ALL complete	1 (0.7)
Meniscal lesion (other) + MCL complete + POL complete + ALL partial	1 (0.7)
RAMP lesion type 1 + MCL complete + POL complete + ALL complete	2 (1.4)
RAMP lesion type 2 + MCL complete + POL complete + ALL complete	2 (1.4)
RAMP lesion type 3 + MCL complete + POL complete + ALL complete	4 (2.7)
RAMP lesion type 4 + MCL complete + POL complete + ALL complete	3 (2.1)
Meniscal lesion (other) + MCL complete + POL complete + ALL complete	1 (0.7)

Abbreviations: ALL, anterolateral ligament; MCL, medial collateral ligament; POL, posterior oblique ligament.

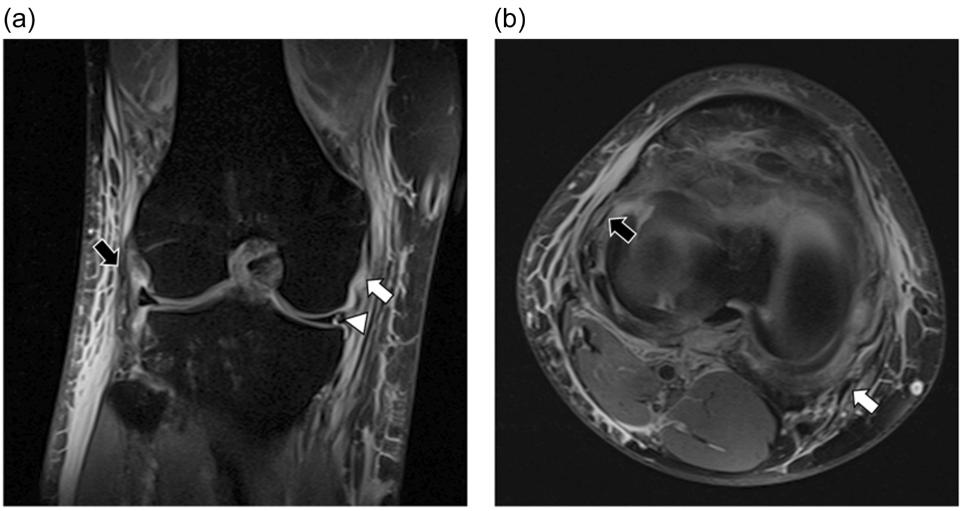

FIGURE 1 Coronal (a) and axial (b) proton-density-weighted fat-saturated magnetic resonance images of a 35-year-old male patient showing an associated RAMP type 4 lesion (white arrowhead in a), a posterior oblique ligament complete lesion (white arrow in a and b) and an anterolateral ligament incomplete lesion (black arrow in a and b).

ligament and MCL [24]. In line with our findings, they concluded that ACL tears are associated with RAMP or ALL tears in approximately one-third of cases and with both RAMP and ALL tears in approximately one-fifth of cases. ALL tears and RAMP are significantly associated with additional posttraumatic injuries, which can thus be indicative of these lesions [24].

Lee et al. assessed whether POL and distal semimembranosus tendon tears are associated with posterior horn medial meniscus tears on MRI. Of the 56 patients enrolled, 43 who had a posterior horn with a medial meniscus tear were included in the study group. A control group of 13 individuals was formed for comparison [16]. Two radiologists reviewed the MR images and recorded the presence and grades of POL and distal semimembranosus tendon tears. The mean grades for POL and distal semimembranosus tendon tears were significantly higher in the study group. The

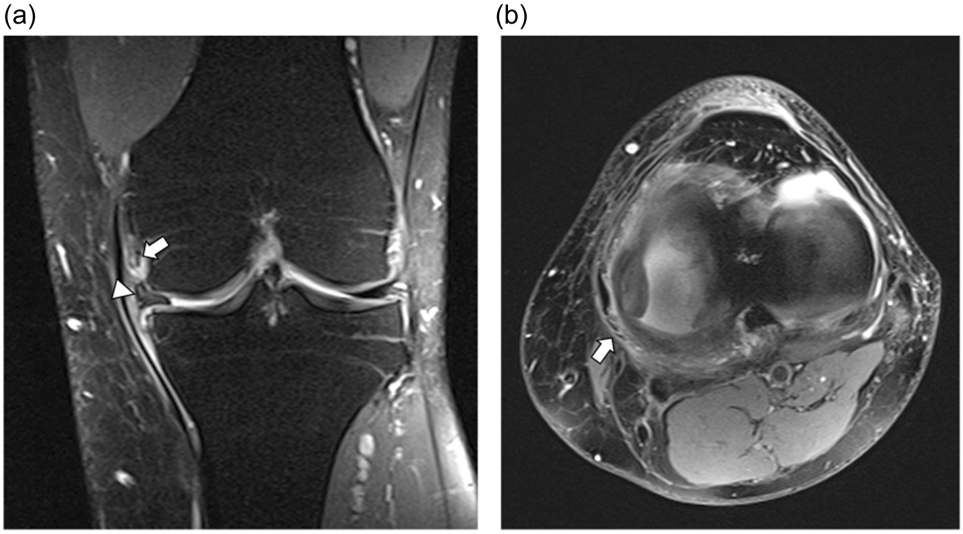

FIGURE 2 Coronal (a) and axial (b) proton-density-weighted fat-saturated magnetic resonance images of a 47-year-old male patient showing an associated RAMP type 2 lesion (white arrowhead in a) and anterolateral ligament complete lesion (white arrow in a and b).

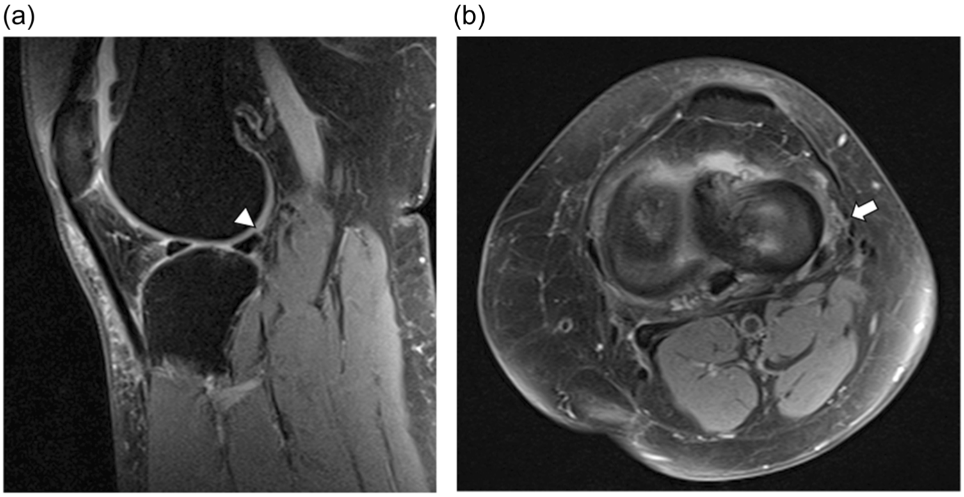

FIGURE 3 Sagittal (a) and axial (b) proton-density-weighted fat-saturated magnetic resonance images of a 45-year-old female patient with an associated RAMP type 1 lesion (white arrowhead in a) and complete anterolateral ligament lesion (white arrow in b).

authors concluded that POL and distal semimembranosus tendon tears are significantly associated with posterior horn tears of the medial meniscus and medial meniscus posterior root tears, and the peel-back mechanism could be related to this association [16].

The importance of ensuring knee stability in the structures analysed (MCL, POL, ALL and medial meniscus) in our study has been widely reported and analysed in the literature; in fact, several biomechanical studies have demonstrated that the ALL acts as a secondary stabilizer of anterolateral rotatory instability [18].

The role of the POL is to be a primary stabiliser for internal rotation and a secondary stabiliser for valgus and external rotation, while the role of the sMCL is to be the primary knee valgus stabiliser across all knee flexion angles, and it also acts as a secondary stabiliser for external and internal rotation depending on the knee flexion angle [5].

RAMP lesions are reported to increase forces on the ACL, and lesions of the meniscotibial ligaments may increase rotatory instability of the knee. A cadaveric study by Stephen et al. demonstrated that anterior tibial translation and external rotational laxities were significantly increased after sectioning of the posteromedial meniscocapsular junction (equivalent to a RAMP lesion) in an ACL-deficient knee [23].

The current literature extensively describes posteromedial, anterolateral or posterolateral rotatory instability, but our findings can help highlight a more complex pattern [12].

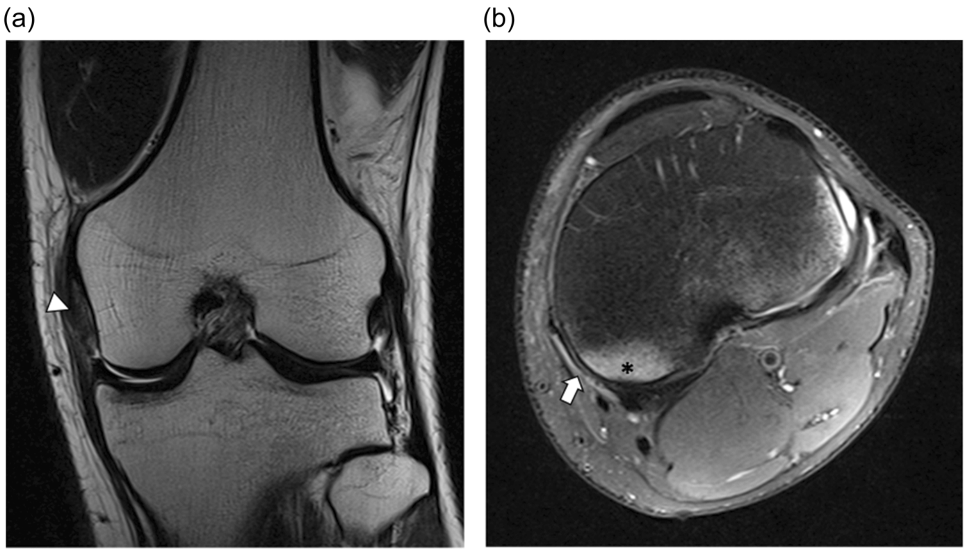

FIGURE 4 Coronal T2-weighted (a) and axial proton-density-weighted fat-saturated (b) magnetic resonance images of a 24-year-old male patient with an associated intermediate-grade medial collateral ligament (white arrowhead in a) and posterior oblique ligament incomplete lesion (white arrow in b). Note the bone contusion in the medial tibial plateau (* in b).

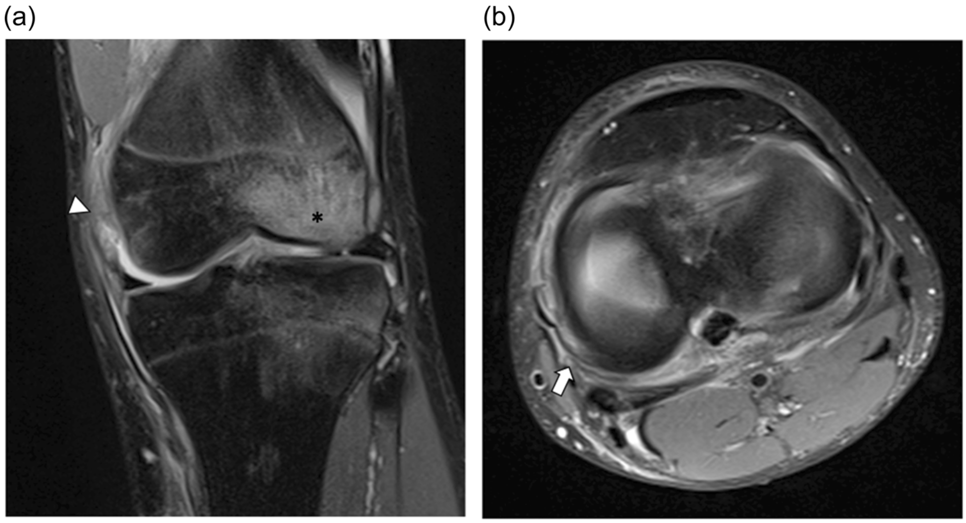

FIGURE 5 Coronal (a) and axial (b) proton-density-weighted fat-saturated magnetic resonance images of a 17-year-old female patient with an associated high-grade medial collateral ligament (white arrowhead in a) and posterior oblique ligament complete lesion (white arrow in b). Note the bone contusion in the lateral femoral condyle (* in a).

For this reason, we believe it is necessary to develop a radiological protocol for identifying associated injuries in the knee so that we can properly plan surgical strategies to be implemented.

Another key finding of our study is the relatively high frequency of RAMP type 3 (>30%), in contrast with the literature. In fact, in their recent study, Thaunat et al. reported that type 1 RAMP was the most common, encompassing almost 50% of total RAMP lesions, but as they explained, the classification system has highly subjective criteria and seems to depend on several parameters that are difficult to identify preoperatively by imaging and intraoperatively (hyperlaxity, lesion of the meniscotibial ligament, lengthwise extension of tear, height of the meniscal fragment tested relative to the space between the femur and tibia) [26]. The authors therefore believe that it is critical to validate a classification that allows us to stratify RAMP lesions according to their characteristics and determine whether they need to be repaired surgically [26].

Furthermore, RAMP type 3 lesions are the most likely to be missed (almost 50%). These tears are easy to miss because they are partial and occur on the inferior aspect (hidden) of the meniscus, giving very few diagnostic clues

TABLE 3 Significant correlations in the whole group.

Variables		ρ	p Value
Number of lesions	Age	0.17	0.036*
	MCL	0.86	<0.001*
	POL	0.86	<0.001*
	ALL	0.63	<0.001*
	Meniscal lesion (all types)	0.27	0.001*
Lateral tibial slope	Female	−0.25	0.002*
	Age	−0.19	0.023*
	ALL	−0.15	0.070*
	Medial tibial slope	0.24	0.003*
ALL	MCL	0.31	<0.001*
	POL	0.32	<0.001*
MCL	POL	0.99	<0.001*
Meniscal lesion (all types)	Age	0.31	<0.001*

Note: Spearman's rank correlation coefficients are given.

Abbreviations: ALL, anterolateral ligament; MCL, medial collateral ligament; POL, posterior oblique ligament.

TABLE 4 Significant correlations in the RAMP subgroup.

Variables		ρ	p Value
Number of lesions	Age	0.17	0.036*
	MCL	0.86	<0.001*
	POL	0.86	<0.001*
	ALL	0.63	<0.001*
	Meniscal lesion (all types)	0.27	0.001*
Lateral tibial slope	Female	−0.25	0.002*
	Age	−0.19	0.023*
	ALL	−0.15	0.070*
	Medial tibial slope	0.24	0.003*
ALL	MCL	0.31	<0.001*
	POL	0.32	<0.001*
MCL	POL	0.99	<0.001*
Meniscal lesion (all types)	Age	0.31	<0.001*

Note: Spearman rank correlation coefficients are given.

Abbreviations: ALL, anterolateral ligament; MCL, medial collateral ligament; POL, posterior oblique ligament.

on preoperative MRI scans (e.g., a thin fluid signal interposed between the posterior horn of the medial meniscus and the posteromedial capsule, or posterior marginal irregularity of the posterior horn of the medial meniscus) [1, 26].

Limitations

The current study has a few potential limitations. First is the presence of concomitant MCL, ALL, POL and meniscus lesions were determined only by presurgical MRI because of the lack of arthroscopic surgery reports. The second limitation was the small number of patients, especially for the individual subtypes of RAMP lesions. Due to the low number of these different types of RAMP lesions, there is limited information about concomitant injuries and their distribution. Finally, this was a retrospective study and MRI was performed at different clinics with different scanners. All the scans were performed with a minimum strength of 1.5 T, but with different protocols, though all the MR images were assessed by the same two examiners.

CONCLUSIONS

Isolated lesions of the ACL are extremely rare; in most cases, a RAMP lesion should be investigated. In the presence of MCL injury, POL injury should always be suspected as well, while nearly 20% of patients present a rupture of the ALL. About one in 10 patients had three lesions (MCL, ALL and POL), and most of them also had a RAMP lesion.

AUTHOR CONTRIBUTIONS

Riccardo D'Ambrosi: Conceptualisation; data curation; methodology; writing—original draft; writing—review and editing; supervision. **Luca Maria Sconfienza**: Methodology; supervision; data curation; investigation; writing—review and editing. **Domenico Albano**: Methodology; data curation; investigation. **Carmelo Messina**: Methodology; data curation; investigation. **Laura Mangiavini**: Writing—review and editing; supervision. **Nicola Ursino**: Conceptualisation; supervision. **Simone Rinaldi**: Methodology; data curation; investigation. **Andrea Zanirato**: Methodology; data curation; investigation. **Alberto Tagliafico**: Conceptualisation; methodology; data curation; investigation; writing—original draft; writing—review and editing; supervision. **Matteo Formica**: Conceptualisation; methodology; data curation; investigation; writing—review and editing; supervision.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The raw data sets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

Ethical approval was obtained from the local ethical committee. All patients signed informed consent to participate in the study. All authors approved the publication of the paper.

ORCID

Riccardo D'Ambrosi http://orcid.org/0000-0002-1216-792X

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