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Younger age, longer delay to surgery and meniscal tears are associated with a smaller ACL remnant: An analysis from the registry of the Francophone Arthroscopic Society

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Abstract

Purpose: This study aimed to evaluate which preoperative patient, injury or clinical factors were associated with the anterior cruciate ligament (ACL) remnant volume in patients undergoing ACL surgery. It was hypothesized that the main factors determining an insufficient ACL remnant volume at the time of surgery were younger age and longer time to surgery.

Methods: A retrospective analysis from the Francophone Arthroscopic Society's registry was conducted, including 1565 patients with an ACL lesion underdoing a primary ACL surgery (reconstruction or repair) between June 2020 and June 2023. Patients were excluded in case of revision surgery and incomplete data. Preoperative factors—including patient demographics, delay to surgery, preoperative laxity and the presence of meniscal tears or cartilage lesions—were analysed to determine their influence on ACL remnant volume (estimated by the surgeon as the percentage of residual volume). Univariate, multivariate and receiver operating characteristic curve analyses were performed to explore these relationships.

Results: Multivariate analyses demonstrated that younger age (<20 years and 20–30 years compared to ≥40, $p = 0.02$), higher time from injury to surgery (≥12 months compared to <3 months, $p = 0.01$) and the presence of a medial ($p = 0.01$) or a lateral meniscal tear ($p = 0.02$) were significant predictors of an ACL remnant volume ≤ 50%.

Conclusions: Younger age (under 30 years of age), a time from injury to surgery above 12 months and the presence of medial and lateral meniscal tears are associated with higher odds of observing a smaller ACL remnant volume at the time of the ACL surgery. These factors should be considered when planning ACL remnant preservation techniques.

Level of evidence: Level III.

Abbreviations: ACL, anterior cruciate ligament; BMI, body mass index; IC, interval of confidence; OR, odds ratio; ROC, receiver operating characteristic.

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KEYWORDS
age, anterior cruciate ligament, meniscal tear, remnant, time from injury

INTRODUCTION

In recent years, special attention has been paid to anterior cruciate ligament (ACL) remnant preservation during ACL reconstruction. Its aim is to provide a more robust and functional graft than nonpreserving techniques. Over the last decade, increasing scientific evidence, based on laboratory, animal, mechanical and clinical studies [26, 31–33, 40, 41], suggested that the presence of the ACL remnant would indeed promote the healing of the graft and its ligamentization process by providing a scaffold, a cellular environment and a vascular supply. The presence of numerous mechanoreceptors within the remnant has also been suggested to play an important role in improving postoperative proprioception [17, 19]. Remnant preservation may thus facilitate functional recovery and even decrease the rate of graft rupture after primary ACL reconstruction [35].

Clinical outcomes after ACL remnant preservation techniques are still investigated and the current literature reports inconsistent results. Preserving the ACL remnant has been reported to lead to a lower percentage of tibial tunnel enlargement [16, 20, 39], which is attributed to decreased fluid seepage into these tunnels. The occurrence of cyclops lesions, however, does not appear to be different from ACL reconstructions without remnant preservation [1, 7, 10, 36]. The effect of ACL remnant preservation on knee stability and patient-reported outcomes is more controversial. Several systematic reviews and meta-analyses reported that ACL remnant preservation techniques led to better functional scores (Lysholm, International Knee Documentation Committee) and knee stability (pivot shift test, postoperative side-to-side anterior laxity) [15, 30, 34, 36]. However, two meta-analyses based on randomized-controlled trials seem to contradict these findings [20, 39].

The diversity of preservation techniques makes it difficult to properly interpret current results. It is also assumed that clinical outcomes may be highly influenced by a sufficient coverage of the graft by the remnant tissue [36]. The latter parameter has, however, been poorly investigated. Furthermore, although many studies have analysed the biological characteristics and the clinical implications of ACL remnant preservation, only a few studies in the literature have investigated which preoperative factors may influence the ACL remnant volume at the time of surgery. Yet, being able to predict whether the ACL remnant volume will be sufficient at the time of the ACL reconstruction would be of great interest to surgeons in their planification of the surgery.

The aim of the present study was, therefore, to investigate which preoperative patient, injury or clinical factors were associated with a lower ACL remnant volume at ACL surgery, using data from a registry with a large number of patients. It was hypothesized that the main factors determining an insufficient ACL remnant volume at the time of surgery were younger age and longer time to surgery.

METHODS

A retrospective analysis from the ACL registry of the Francophone Arthroscopic Society (SFA) [37] was conducted. This registry has been designed to provide systematic and standardized data collection from patients with an ACL injury treated either surgically or conservatively. Participation in this registry both for surgeons and for patients is not mandatory. It currently includes 43 surgeons specialized in arthroscopic knee surgery, affiliated to the SFA, who specifically requested to participate in the registry. The patients included have been informed of their participation in the registry and did not express any opposition to the use of their data (which corresponds to a Category 3 study in France, where giving a simplified information note is sufficient).

For the present study, all patients with an ACL lesion diagnosed preoperatively by clinical examination and magnetic resonance imaging imaging and undergoing a primary ACL surgery (reconstruction or repair) between June 2020 and June 2023 were considered. Patients were excluded if they had undergone revision surgery and in the case of incomplete data regarding age, time to surgery, preop side-to-side laxity, sex, lateral and medial meniscal tears or cartilage lesions.

Surgical technique

As for any observational study, surgical technique was left at the discretion of each surgeon and was not influenced in any way. Surgical techniques will, therefore, not be discussed in this context. This, however, should not have an impact on the interpretation of this study results as only preoperative factors were considered and no treatment outcomes were analysed.

Data extraction and coding

Sex, age at surgery, body mass index (BMI), injured knee side and time from injury to surgery in months were recorded. Age was categorized as follows: <20 years, 20–30 years, 30–40 years and ≥40 years.

Time to surgery was subdivided as follows: <3 months, 3–12 months and ≥12 months.

Each patient underwent a clinical evaluation prior to surgery. The preoperative Lachman was recorded on the operating table under anaesthesia. The laxity difference was grouped into two categories, 0–5 mm and more than 5 mm, due to its clinical relevance in our practice. During arthroscopy, the percentage of remaining ACL remnant, the presence of medial meniscal tears (Yes/No), lateral meniscal tears (Yes/No) or cartilage lesions (Yes/No) were also recorded. The amount of ACL remnant was estimated intraoperatively before any technical gesture. The evaluation was done subjectively by each surgeon who estimated the percentage of remnant compared with a hypothetical intact ligament. In the registry [37], the remnant percentage is divided into seven categories: 0%, <10%, 10%–30%, 30%–50%, 50%–70%, 70%–90% and >90%. For further analyses, the ACL remnant volume will be categorized as inferior or equal to 50% or superior to 50%. This threshold is based on a previous study from Kim et al. [14], who showed, in patients who underwent second-look arthroscopy after remnant-preserving ACL reconstruction, a thicker graft tissue with better synovial coverage in patients where the ACL remnant volume was superior to 50%.

Statistics

All calculations were carried out using SAS for Windows (v 9.4; SAS Institute Inc.).

Descriptive data analysis was conducted depending on the nature of the variable (continuous or categorical) and presented both for the entire cohort and according to the volume of ACL remnant at ACL surgery (inferior or superior to 50%).

The relationship between ACL remnant volume and gender, age, time between injury and surgery, laxity, medial meniscal tears, lateral meniscus tears and cartilage lesions was first analysed separately for each parameter using a logistic regression model. Each logistic regression modelled the probability of having an ACL remnant volume ≤50%. Factors were then included in the multivariate model if they were significantly correlated with the variable of interest (remnant ≤ 50%) at a threshold of 20% [13].

In order to further understand the contribution of the time between injury and surgery to the ACL remnant volume, receiver operating characteristic (ROC) curves were constructed for subgroups of patients in order to determine whether an optimal cut-off value could be found for time between injury and surgery to distinguish between the patients with an ACL remnant volume ≤ 50% and the patients with an ACL remnant volume > 50%. The area under the curve and its 95% confidence interval were calculated, and a cut-off value was determined according to the Youden index.

All comparisons were performed at the level of statistical significance set at $p < 0.05$.

RESULTS

One thousand five hundred and sixty-five patients met the inclusion criteria and were included in the risk factor analysis. The mean age was 29.5 ± 10.3 years (range: 12–67) and the mean BMI was 24.3 ± 3.9 kg/m^2 (range: 14.7–42.4). The median time from injury to surgery was 3.2 months (Q1–Q3: 2.0–5.9; range: 0–347.2); 52.3% ($n = 818$) of patients were operated on the left knee and 47.7% ($n = 747$) on their right knee. The ACL remnant volume was inferior or equal to 50% for 1312 patients (83.8%) and superior to 50% for 253 patients (16.2%). The distribution of preoperative patients, injury and clinical factors in the total cohort and separated according to the ACL remnant volume is summarized in Table 1.

Univariate analyses (Table 2) showed that younger age (<20 years vs. ≥40 years and 20–30 years vs. ≥40 years), longer time to surgery (≥12 months vs. <3 months and ≥12 months vs. 3–12 months), a side-to-side laxity >5 mm and the presence of a medial meniscal tear, a lateral meniscal tear or a cartilage lesion were associated with higher odds of having a lower ACL remnant volume (≤50%). Once each parameter was adjusted with each other in the multivariate analyses (Figure 1), only younger age (<20 years and 20–30 years of age, $p = 0.02$), a higher time from injury to surgery (>12 months compared to <3 months, $p = 0.01$), the presence of a medial ($p = 0.01$) or a lateral meniscal tear ($p = 0.02$) was associated with higher odds of having an insufficient ACL remnant volume (≤50%). The most important predictors of the ACL remnant volume were time from injury to surgery, followed by age.

The analysis with the ROC curves for age groups did not have enough power to discriminate a cut-off value for time between injury and surgery to distinguish between the patients with an ACL remnant volume ≤ 50% and the patients with an ACL remnant volume > 50% (Figure 2).

DISCUSSION

The main finding of this study was that younger age (under 30 years of age), a time from injury to surgery beyond 12 months and the presence of medial and lateral meniscal tears were associated with a smaller ACL remnant volume at the time of the ACL surgery. These factors are thus important when planning for ACL remnant preservation techniques in order to obtain

TABLE 1 Distribution of preoperative patient, injury and clinical characteristics in the total cohort ($n = 1565$) according to the ACL remnant volume.

	Total	ACL remnant	
	(*n* = 1565)	≤50% (*N* = 1312)	>50% (*N* = 253)
Sex, *N* (%)			
Male	943 (60.3)	799 (60.9)	144 (56.9)
Female	622 (39.7)	513 (39.1)	109 (43.1)
Age groups, *N* (%)			
<20 years	251 (16.0)	218 (16.6)	33 (13.0)
(20–30) years	680 (43.5)	580 (44.2)	100 (39.5)
(30–40) years	349 (22.3)	286 (21.8)	63 (24.9)
≥40 years	285 (18.2)	228 (17.4)	57 (22.5)
Time to surgery, *N* (%)			
<3 months	741 (47.3)	606 (46.2)	135 (53.4)
(3–12) months	628 (40.1)	527 (40.2)	101 (39.9)
≥12 months	196 (12.5)	179 (13.6)	17 (6.7)
Preoperative Lachman test, *N* (%)			
0–5 mm	280 (17.9)	221 (16.8)	59 (23.3)
>5 mm	1285 (82.1)	1091 (83.2)	194 (76.7)
Cartilage lesion, *N* (%)			
No	1226 (78.3)	1018 (77.6)	208 (82.2)
Yes	339 (21.7)	294 (22.4)	45 (17.8)
Medial meniscal tear, *N* (%)			
No	927 (59.2)	754 (57.5)	173 (68.4)
Yes	638 (40.8)	558 (42.5)	80 (31.6)
Lateral meniscal tear, *N* (%)			
No	1191 (76.1)	983 (74.9)	208 (82.2)
Yes	374 (23.9)	329 (25.1)	45 (17.8)

Abbreviation: ACL, anterior cruciate ligament.

a sufficient ACL remnant volume (>50%) and obtain a ticker graft tissue with better synovial coverage.

The present study showed that the probability of having a remnant ≤ 50% is 2.5 times higher with an interval between injury and surgery ≥12 months compared to <3 months. These findings are in agreement with previous studies [30] that showed that time to surgery was higher in patients without an ACL remnant than those in whom an ACL remnant was still present. In addition, another study by Muneta et al. [23] showed a weak, but statistically significant, negative relationship between remnant and time to surgery (Pearson's correlation coefficient: −0.215). The impact of time on the ACL remnant volume can be related to changes over time of the biological characteristics of the tissue. It has been shown that within the first 3 months after an ACL injury, there is an increased expression of collagen genes [27] and cells have been reported to show greater tendon–bone healing potential, according to laboratory studies [11, 42]. The graft-healing potential of mesenchymal stromal cells derived from ACL remnants was found to be greater in subacute tears (<6 months from injury to surgery), although tissue healing potential may remain sufficient for a much longer period (up to 23.5 months after the injury) [18]. In parallel, the number of mechanoreceptors also decreases with increasing time to surgery [3, 8, 9]. Time thus plays a key role both in the preservation of a sufficient ACL remnant volume and in its ability to heal. Surgeons willing to use ACL remnant preservation techniques should thus consider that the likelihood of having a sufficient ACL remnant volume decreased considerably after more than 12 months had passed since the injury.

The second most important predictor of the ACL remnant volume was age. Younger patients were less likely to present with a sufficient ACL remnant volume. This result is consistent with previous findings [23] that highlighted a statistically significant relationship between remnant and age (Pearson's correlation coefficient: 0.236; $p = 0.03$). Sato et al. [30] also found that age was significantly lower in the group of patients without an ACL remnant. The reduced ACL remnant volume observed in younger patients may be associated with heightened intraarticular catabolic activity in this group of patients. Research indicates a higher expression of pro-inflammatory cytokines and collagenases after meniscal and ACL tears in younger patients [2]; this may probably accelerate the breakdown of the ACL. It is important to note that this catabolic process in younger patients may somehow be compensated by their higher healing potential than older patients [24], so that age may not be a contraindication for ACL remnant preservation techniques. In the present study, the presence of a medial or a lateral meniscal tear increased the odds of having a smaller ACL remnant volume. Previous studies reported that meniscal injuries were more frequent in chronic ACL injuries [21] and time from injury is associated with a smaller remnant according to the present study. It would thus seem logical to believe that the presence of meniscal injuries is associated with a smaller remnant because of the chronicity of the ACL lesion. However, in the current study, multivariate analyses were performed, allowing to adjust our result according to the time from the injury, and the meniscal injuries were still significantly associated with a smaller ACL remnant. This highlights the multifactorial aspect behind a smaller ACL remnant volume.

TABLE 2 Univariate analysis of preoperative patient, injury and clinical characteristics according to the ACL remnant volume ($n = 1565$).

Variables		Univariate analysis	
Factor	Comparison	OR (IC 95%)	p
Sex	Male versus Female	1.18 (0.90–1.55)	n.s.
Age	<20 years versus ≥40 years	1.65 (1.04–2.66)	0.0827
	[20–30] years versus ≥40 years	1.45 (1.01–2.07)	
	[30–40] years versus ≥40 years	1.14 (0.76–1.69)	
	<20 years versus (20–30) years	1.14 (0.75–1.76)	
	<20 years versus (30–40) years	1.45 (0.93–2.32)	
	[20–30] years versus (30–40) years	1.28 (0.90–1.80)	
Time to surgery	≥12 months versus <3 months	2.35 (1.42–4.12)	0.0029
	≥12 months versus (3–12) months	2.02 (1.20–3.58)	
	(3–12) months versus <3 months	1.16 (0.88–1.55)	
Lachman test	>5 mm versus 0–5 mm	1.50 (1.08–2.07)	0.0167
Medial meniscal tear	Yes versus No	1.61 (1.21–2.15)	0.0010
Lateral meniscal tear	Yes versus No	1.61 (1.18–2.23)	0.0023
Cartilage lesion	Yes versus No	1.33 (0.95–1.91)	0.0958

Note: Each logistic regression models the probability of having an ACL remnant ≤ 50%.

Abbreviations: ACL, anterior cruciate ligament; IC, interval of confidence; n.s., not significant; OR, odds ratio.

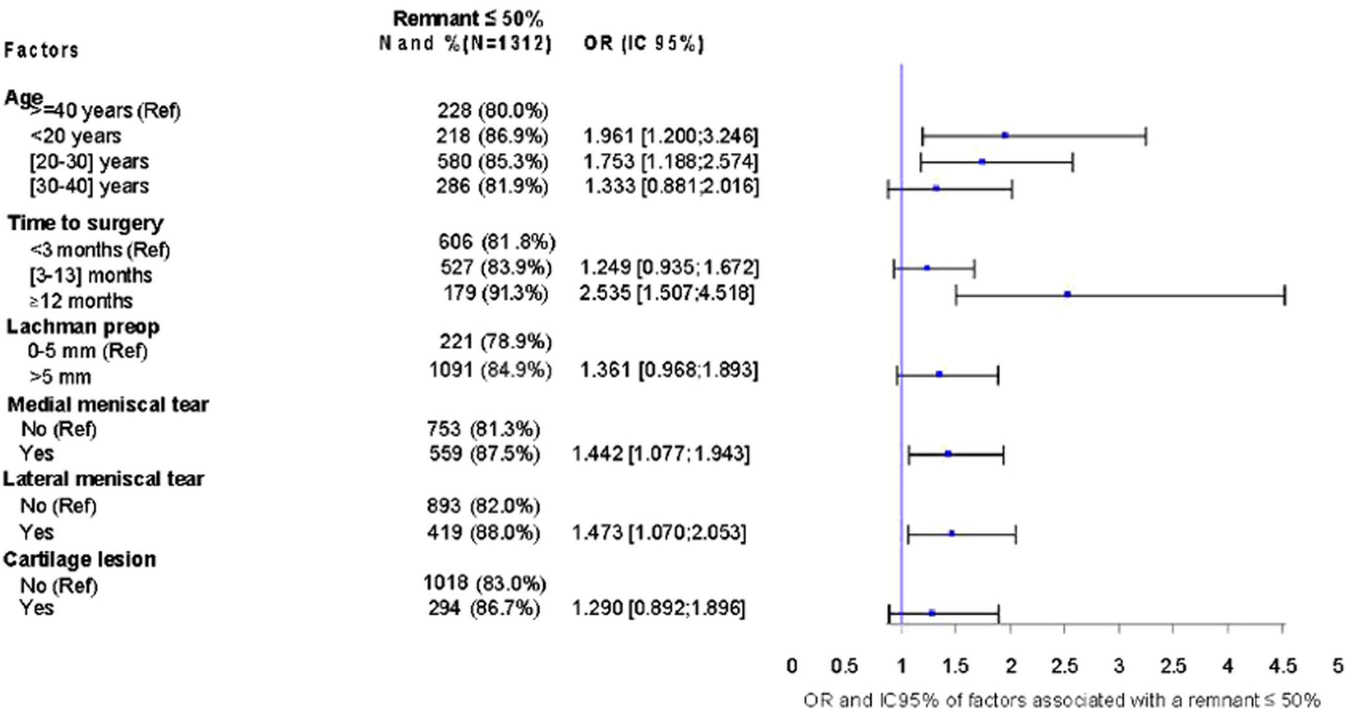

FIGURE 1 Forest plot of multivariate analysis of preoperative patients, injury and clinical characteristics according to the anterior cruciate ligament (ACL) remnant volume ($n = 1565$). Each logistic regression models the probability (odds ratio [OR] with the corresponding interval of confidence [IC]) of having an ACL remnant ≤ 50% with a level of statistical significance set at $p < 0.05$.

Meniscal injuries are reported to be particularly frequent in pivot and contact sports [5, 38], and are more likely to be associated with a complete ACL tear than with a partial ACL tear [6, 29], which could be related to a smaller ACL remnant volume. To date, the presence of meniscal lesions may, however, lead a surgeon to suspect the presence of a smaller ACL remnant volume.

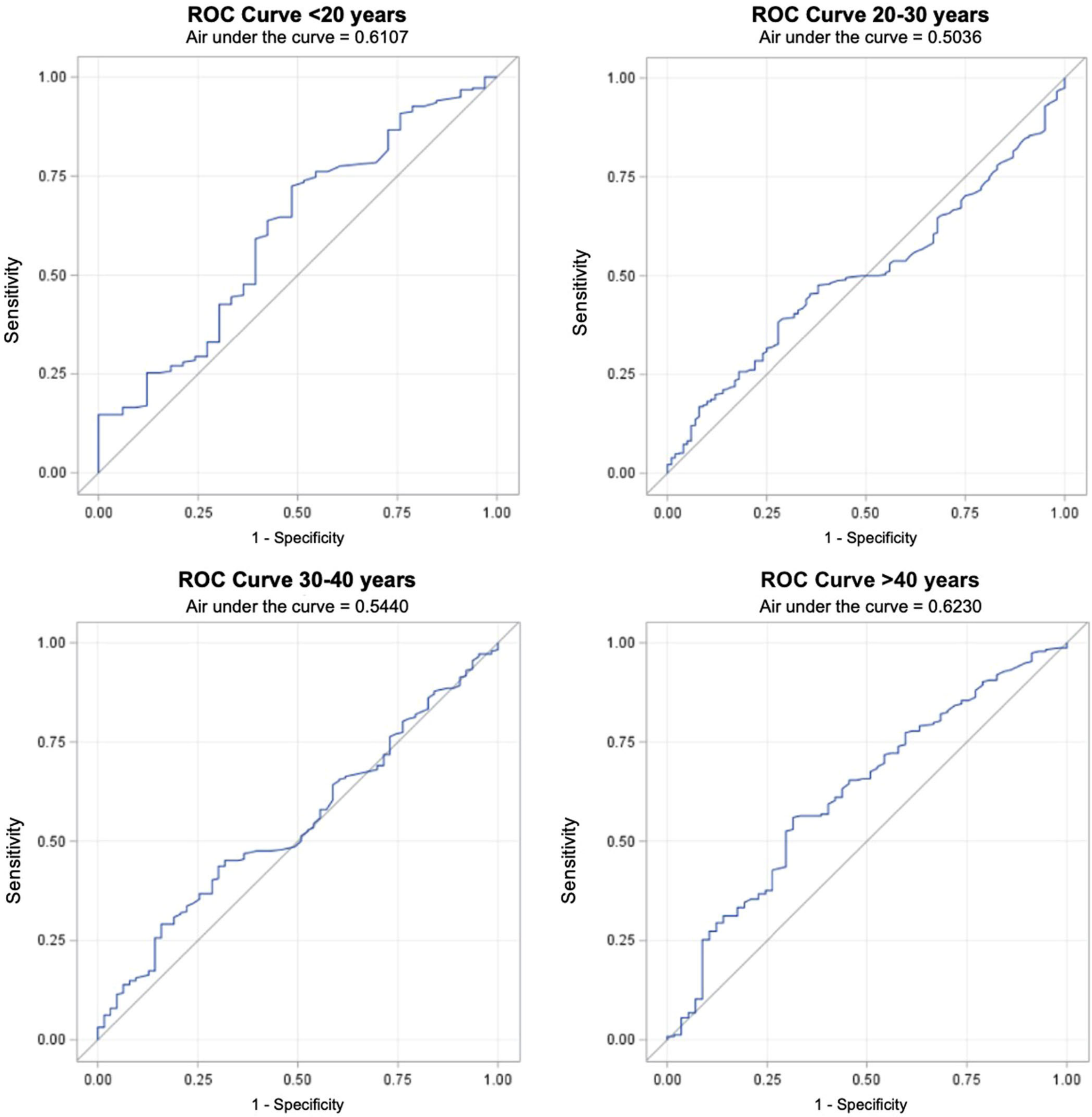

FIGURE 2 Receiver operating characteristic (ROC) curves for age subgroups to determine a cut-off value for delay before surgery, to distinguish between patients with an anterior cruciate ligament (ACL) remnant volume ≤ 50% and patients with an ACL remnant volume > 50% with a level of statistical significance set at $p < 0.05$. No curve had enough power to discriminate a cut-off value.

Neither preoperative anterior laxity nor the presence of cartilage lesions was found to be associated with an ACL remnant volume ≤ 50%. This finding is consistent with Sato et al. [30], who did not find any differences in laxity between patients with and without remnants ($p = 0.2639$). Having an ACL remnant, however, may not mean that the quality and functionality of the ACL remnant are sufficient. We know from several studies that the way in which the ACL remnant heals and the location of the ACL remnant may determine different patterns of residual knee stability. For example, ACL remnants that healed on the intercondylar notch and partial ACL tears display lower anterior laxity in comparison with complete ACL tears and ACL remnants that healed on the posterior cruciate ligament [4, 12, 22, 25, 28]. Thus, the volume of the remnant does not determine the residual stability of the knee, which is rather associated with the way in which the remnant heals. These aspects have not yet been studied in the literature and it will be interesting to study these in the future.

As mentioned above in our study, the presence of cartilage lesions was not found to be associated with an ACL remnant volume ≤ 50%, in both univariate and multivariate analyses. This is surprising since, as with meniscal lesions, the presence of cartilage lesions is more frequent in chronic ACL injuries [21] and time from injury is associated with a smaller remnant according to the present study. This underlines once again the multifactorial nature behind a smaller ACL remnant volume and further studies are needed to investigate these aspects.

In conclusion, according to the present study, in clinical practice, neither anterior preoperative laxity nor the presence of cartilage lesions should lead to suspicion of the presence of a small remnant.

The present study is not without limitations. It relies on a retrospective analysis of registry data, which introduces potential biases, including selection bias due to incomplete data capture. Additionally, this design introduces variability due to the number of different observers (i.e., surgeons) included, especially as the information reported from the ACL surgery, such as the preoperative Lachman test, the identification of meniscal tears or estimation of the ACL remnant volume, may vary from an observer to another. Another limitation is that we did not include data about the mechanism of injury. This study is, however, certainly the first to investigate which factors influence the volume of the ACL remnant in such a large series of patients, which strengthens the external validity of the present study. To achieve a sufficiently voluminous ACL remnant when planning for ACL preservation techniques, a surgeon should thus carefully find the right balance between the age of the patient, the time from the injury and the presence of meniscal lesions.

CONCLUSIONS

Younger age (under 30 years of age), time from injury to surgery beyond 12 months and the presence of medial and lateral meniscal tears were associated with higher odds of observing a smaller ACL remnant volume at the time of the ACL surgery. These factors should be considered when planning ACL remnant preservation techniques.

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AUTHOR CONTRIBUTIONS

All authors have given final approval of the submitted manuscript and their agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors have made substantial contributions to the design of the work and manuscript writing. Conceptualization of the work was by Luca Tanel, Mathieu Thaunat and Jean-Marie Fayard. The acquisition, analysis and interpretation of data were performed by Luca Tanel, Mathieu Thaunat, Jean-Marie Fayard, Caroline Mouton, Pierre-Jean Lambrey, Romain Letartre, Nicolas Graveleau, Nicolas Bouguennec, and Johannes Barth. All authors were involved in drafting the work or revising it critically for important intellectual content.

CONFLICT OF INTEREST STATEMENT

Mathieu Thaunat, Johannes Barth, Jean-Marie Fayard, Nicolas Graveleau and Romain Letartre have potential conflicts of interest. Mathieu Thaunat is a consultant for Arthrex. Johannes Barth is an employee of Arthrex, a paid consultant for Move up and an unpaid consultant for SBM. Jean-Marie Fayard is a consultant for Arthrex and New Clip Technics. Nicolas Graveleau has royalties for Newclip, Speaker for Arthrex, SBM, Stryker and FH Ortho-Olympus, a consultant for SBM, has received support from Arthrex, SBM, Stryker and Adler, and a Board of Directors member for Sport Clinic Merignac, Vivalto group. Romain Letrartre is a consultant for Arthrex and Amplitude.

ETHICS STATEMENT

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