Knee Ligament Sprains: Diagnosing Anterior Cruciate Ligament Injuries by Patient Interview. Development and Evaluation of the Anterior Cruciate Ligament Injury Score (ACLIS).

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Original article

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ABSTRACT

Background: Knee ligament sprains are a common reason for emergency-room visits. Initially, the often difficult physical examination provides limited information, creating a risk of missing cruciate-ligament injuries, which can result in substantial functional impairments. No simple tool is available to emergency and primary-care physicians for decisions regarding specialist referral of patients with knee ligament sprains. An easy to use clinical score for the emergency setting would help identify patients at high risk of anterior cruciate ligament (ACL) tears after knee ligament sprains. The primary objective of this study, in two separate cohorts with acute knee injuries, was to develop, then validate a score for assessing the probability of ACL tear and, therefore, the need for specialist referral.

Hypothesis: A score based on patient-interview information with a cut-off associated to good sensitivity and positive predictive value (PPV) for ACL tears can be developed.

Material and Methods: A literature review identified seven items to be used in the score: pivoting and contact activity at the time of injury, perceived cracking sound, sensation of dislocation, joint effusion, suggestive mechanism, inability to resume the activity, and immediate sensation of instability upon walking. To select the most relevant items, we recruited a development cohort of 228 patients (127 males and 101 females) with a mean age of 32±9 years who were seen for knee injuries between November 2017 and November 2018 at three healthcare institutions; 183 (80%) had ACL tears. The score was then tested in a validation cohort of 121 patients (79 males and 42 females) with a mean age of 28±2.5 years seen at two healthcare institutions between November 2019 and November 2020; 81 (67%) had ACL tears. In all patients, the diagnosis of ACL tear was confirmed by a specialist examination and magnetic resonance imaging.

Results: Four items proved both sensitive and specific for ACL injury and were combined into the score: an immediate sensation of knee instability, an inability to resume the sports activity, a sensation of dislocation, and injury during a pivoting-contact activity. Patient report of two or more of these four criteria had 96% sensitivity and 66% specificity for ACL tear, with a PPV of 91% and an NPV of 83%. Results were similar in the validation cohort, confirming that a cut-off of at least two of the four items strongly suggested an ACL tear, with 94% sensitivity, 56% specificity, a PPV of 82% and an NPV of 82%.

Conclusion: The ACLIS score performs well for the emergency-room diagnosis of ACL tear, with 95% sensitivity, 62% specificity, an 88% PPV, and an 82% NPV. Patients with ACLIS scores of 2 or more probably require specialist referral with or without magnetic resonance imaging. The ACLIS score could be used routinely in emergency departments to decrease the proportion of patients with undiagnosed ACL tears.

Level of evidence: III, prospective case-control study of a diagnostic score

Key words: Knee. Sprain. Anterior cruciate ligament. Score.

1. Introduction

Nearly 60,000 knee ligament surgeries are performed annually in France [1]. Trauma due to any cause accounts for nearly half of all emergency-room visits [2]. Among knee injuries, half are ligament sprains, contributing to 15% to 50% of sports-related injuries [3-5]. At the knee, sprains are injuries to at least one peripheral ligament and are classified as severe when the anterior cruciate ligament (ACL) and/or posterior cruciate ligament (PCL) are injured [6]. The diagnosis of severe knee ligament sprains relies on a well-conducted physical examination and on investigations including radiographs and magnetic resonance imaging (MRI). The clinical presentation varies widely, however, and greater symptom intensity does not correlate with greater lesion severity [7,8]. Consequently, difficulties may arise in determining the appropriate level of investigation and care, resulting in diagnostic delays [9,10]. A 2008 study by Guillodo et al. [11] showed that 75% of cruciate ligament injuries were missed in the emergency room. Decision rules have been developed to help determine when radiographs are needed to look for fractures in patients with acute ankle [12] or knee [13] injuries. We reasoned that a similar tool could be developed to identify ACL injuries.

The primary objective of this study in two separate cohorts with acute knee injuries was to develop then validate a score for assessing the probability of ACL tear and, thus, the need for specialist referral [14,15,16]. The secondary objective was to determine whether a score cut-off had greater than 80% positive predictive value (PPV) and an information-utility index greater than 0.35 [17].

2. Material and methods

The first step of our study consisted in building a score in a development cohort. The score was then tested in a validation cohort. A calibration procedure done on both populations established the optimal score cut-off.

2.1 Development cohort for building the score

2.1.1 Population

The development cohort was composed of 228 consecutive patients included prospectively and seen on an emergency or post-emergency basis for an acute knee injury, at any of three community hospitals located in Cambrai (n=16), Louvières (n=184), and Valenciennes, (n=28), in France, between November 2017 and November 2018. (Figure 1). Patients included were older than 16 years and seen for a recent knee ligament sprain during the study period. Patients with a history of knee surgery and those with contra-indications to MRI were excluded. For each patient, an observer who was blinded to the findings provided by the initial physical examination and MRI were entered into a standardised form. Mean age in the development cohort was 32 years (range, 15–68 years).

2.1.2 Items selected to build the score

Based on a review of the current literature [6, 9,18-24] and on advice from experts in the field, we identified seven items. Among them, three were subjective patient perceptions: a heard or felt cracking sensation as described by Bonnet [18]; perceived dislocation followed by spontaneous reduction; and perceived sensation of instability upon resumption of walking, potentially indicating loss of rotational knee control. The four other items were objective facts reported by the patients: occurrence of the knee injury while participating in a pivoting contact sport [19-21] (Supplemental Table S1), mechanism consistent with injury to the cruciate ligaments (valgus, flexion, and external rotation or varus, flexion, and internal rotation or hyperextension) [22-24], an inability to resume the previous activity, and presence of a knee effusion [9].

2.1.3 Diagnostic reference standard

The goal of the score was to identify patients with ACL tears. The reference standard was MRI confirming the presence of structural ACL damage combined with a specialist physical examination. At all three participating hospitals, MRI was performed routinely to evaluate patients with knee ligament sprains.

2.2 Validation cohort for testing the score

The objective was to validate the findings in the development cohort and to identify the optimal cut-off score for suggesting an ACL tear. The ACLIS was used to classify patients as having severe or mild ligament sprains. We then determined whether the classification of each patient matched that established by MRI and specialist examination.

2.2.1 Population

Patients for the validation cohort were recruited prospectively at two centres: the emergency-department of the Lille university hospital (France) included 70 patients between November 2019 and October 2020 and the Louvières community hospital (France) 51 patients between May 2020 and October 2020. The inclusion and exclusion criteria were the same as for the development cohort. (Figure 2). Of the 121 patients, 81 (67%) were males. Mean age was 28 years (range, 17–68 years). The diagnoses in these 121 patients were as follows: ACL tear, n=81 (67%); patellar dislocation followed by spontaneous reduction, n= 3 (2%); isolated meniscal lesions, n=12 (10%); and intact menisci and ligaments, n=25 (21%).

2.2.2 Study variables

In each validation-cohort patient, we tested the score built using the seven above-described items.

2.2.3 Identification of the optimal score cut-off

Using the two cohorts, we determined the cut-off score above which patients should be prescribed an MRI scan. This cut-off was then tested on the overall population (development and validation cohorts pooled).

2.3 Statistical methods

2.3.1 Descriptive statistics

Qualitative, binary, and discrete variables with very few modalities were described as n (%) and quantitative variables as mean±SD (range for age) when shown by the histogram to be normally distributed and as median [interquartile range] otherwise.

2.3.2 Bivariate analyses

Independence of two qualitative variables was assessed using the chi-square test or logistic regression with the results reported as odds ratios (ORs) and associated 95% confidence intervals (95%CIs).

2.3.3 Score validation

To evaluate scores producing quantitative or ordinal qualitative responses, we plotted the receiver operating characteristics (ROC) curves and computed the areas under these curves (AUROCs) with their 95%CIs. We classified AUROC values as follows: >0.9, exceptional; ≥0.8, excellent; ≥0.7, acceptable; and ≤0.7, non-discriminating. To assess scores with a binary response or with an ordinal response and set cut-off, we computed sensitivity, specificity, the positive predictive value (PPV) and negative predictive value (NPV), and the distance to the upper left corner (d= square toot of $((1\text{-sensitivity})^2+(1\text{-specificity})^2)$.

2.3.4 Multivariate analyses

We used a decision tree to model and test associations linking candidate co-variables to a binary variable. All available co-variables were included in this analysis and were selected automatically during decision-tree construction. We describe only the final model.

2.3.5 Statistical significance

All statistical tests were two-sided. Values of p below 0.05 were taken to indicate statistically significant differences. Confidence intervals were computed for a 95% level of confidence.

3. Results

3.1 Description and comparison of the development and validation cohorts

Table 1 reports the main baseline features of the development and validation cohorts.

3.2 Construction of the Anterior Cruciate Ligament Injury Score (ACLIS)

Table 2 compares the clinical variables in the groups with mild sprains vs. severe sprains involving cruciate ligament injury. The between-group differences were statistically significant for all variables.

Based on the results of the multivariate logistic regression analysis, classification trees, and correlation analyses, we selected the following four items: injury during a pivoting-contact event, sensation of dislocation at the time of injury, inability to resume the prior activity, and sensation of instability at the first attempt to walk.

Table 3 reports the diagnostic performances according to the number of items present and Figure 3 shows the corresponding ROC curve, with an AUROC of 0.850 (95%CI, 0.755–0.946). The ACLIS is considered positive in patients with at least two of the four items (Supplemental Table S2).

3.2 Testing in the validation cohort

3.2.1 Validation of the optimal cut-off

With the four-item score, we computed the different cut-offs using the questionnaire data from the 121 patients in the validation cohort (Table 4). The AUROC was similar to that in the development cohort (0.871; 95%CI, 0.775–0.967).

3.2.2 Confirmation of the cut-off

The statistical analysis on the overall population obtained by pooling the two cohorts (n=349) showed similar diagnostic performance. With the two-item cut-off, sensitivity was 95%, specificity 62%, PPV 88%, and NPV 82%. In the pooled population, patients with at least two items had a 2.5-fold higher risk of ACL tear compared to patients with less than two items (positive likelihood ratio, 2.5). The information-utility index was 0.54.

4. Discussion

No simple tools are currently available to reliably identify ACL tears without referral to an orthopaedic surgeon or slice imaging. The ACLIS exhibited excellent performance for diagnosing ACL tears, with an AUROC in the 0.8–0.9 range.

We applied the method used to develop the Ottawa ankle rules in 1994 [12]. These rules rely on five items to help determine when radiographs are required in patients with acute ankle injuries. The rules were validated using 259 records of adults and 37 records of patients younger than 16 years. Sensitivity was 97%, specificity 30%, PPV 17%, and NPV 97%. Applying the rules would have decreased the number of patients who underwent radiography by 26.3%. A single fracture was missed [12,13]. These findings are comparable to those obtained in our study with the ACLIS.

The test on the validation cohort allowed us to select four items and to validate a cut-off of two of four items. This cut-off allows room for discussion. In the pooled population of 349 patients, 264 patients had ACL tears and, among these, 12 (4.5%) had ACLIS values of 0 or 1. In all our study centres, patients with acute knee injuries routinely underwent specialist referral and MRI. However, this policy is not applied in all centres. In the pooled population, using the ACLIS with the cut-off of two items would have avoided 67 MRIs in patients with intact cruciate ligaments. The resulting logistical and cost-saving benefits would be substantial. A positive ACLIS allows more expeditious specialist referral.

Out study has several limitations. The presence of a majority of patients with ACL tears in the development cohort spuriously increased the PPV, thereby introducing bias. Nonetheless, the results were similar in the validation cohort, which had a lower prevalence of ACL tears. Moreover, the frequency of ACL tears in patients with acute knee injuries may be underestimated by current management strategies [11]. Also, in a standard population with a lower prevalence of ACL tears compared to our development cohort, the false-negative rate would be expected to be lower than in our study. The development of the ACLIS followed the steps described by L. Herzig et al., except for the impact analysis, which is only very rarely completed [25]. The utility of the ACLIS lies in its ability to identify those patients who require further evaluation such as specialist referral and/or MRI in order to optimise the management and avoid inappropriate treatments that may result in functional loss.

The strongest feature of the ACLIS is its simplicity. The four items are easy to understand and require only yes/no answers. A brief interview is sufficient to collect the items, and no paper or digital questionnaire is needed.

Recent studies indicate a marked tendency towards score simplification. Decreasing the number of items avoids redundancies, thereby improving adherence while providing similar performance [26]. The Parker score often used in elderly trauma patients also has a small number of items with limited response options and is thus easy to use in everyday practice [27,28].

5. Conclusion

The four-item ACLIS is a simple tool for detecting ACL tears in patients with acute knee injuries. Score values of at least 2/4 have 95% sensitivity and 85% PPV for ACL tears. This tool seems particularly relevant for guiding decisions made by primary-care and emergency physicians performing initial evaluations of patients with acute knee injuries. We believe the routine use of this score in emergency departments can be recommended.

Conflicts of interest

None of the authors has any conflicts of interest to disclose.

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None

Contributions of each author

S. Lukas conceived the study, collected data, drafted the manuscript, and revised the manuscript for important intellectual content.

S. Putman: drafted the manuscript and revised the manuscript for important intellectual content.

C. Delay et A. Blairon collected data.

E. Chazard performed the statistical analysis and drafted the manuscript.

R. Letartre conceived the study, collected data, drafted the manuscript, and revised the manuscript for important intellectual content.

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Table 1: Main features of the development and validation cohorts

	Development cohort	Validation cohort	Total
Features			
Males, n (%)	128 (56%)	79 (65%)	207 (59%)
Age, years, median [IQR]	32.6 [15–68]	28.3 [17–68]	31.1 [15–68]
Diagnostic MRI, n (%)			
Torn ACL	183 (80%)	81 (67%)	264 (76%)
Meniscal injury	6 (3%)	12 (10%)	18 (5%)
Patellar dislocation	4 (2%)	3 (2%)	7 (2%)
No lesions	35 (15%)	25 (21%)	60 (17%)

MRI: magnetic resonance imaging; ACL: anterior cruciate ligament

Table 2: Description of the clinical variables in patients with and without MRI evidence of cruciate ligament injury

	No cruciate-ligament injury N=44	Cruciate-ligament injury N=184	TOTAL N=228	Odds ratio	*p* value
Pivoting-contact sport	27 (61.4%)	167 (90.8%)	194 (85.1%)	6.18 [2.82–13.57]	$<10^{-4}$
Sensation of dislocation	8 (18.2%)	120 (65.2%)	128 (56.1%)	8.437 [3.70–19.23]	$<10^{-4}$
Cracking sound or feeling	20 (45.5%)	136 (73.9%)	156 (68.4%)	3.4 [1.72–6.70]	$<10^{-4}$
Suggestive mechanism	31 (70.5%)	158 (85.9%)	189 (82.9%)	2.548 [1.18–5.50]	0.017
Effusion	21 (47.7%)	158 (85.9%)	179 (78.5%)	6.656 [3.23–13.70]	$<10^{-4}$
Sensation of instability	8 (18.2%)	157 (85.3%)	165 (72.4%)	26.167 [10.98–62.94]	$<10^{-4}$
Inability to resume activity	13 (29.5%)	162 (88%)	175 (76.8%)	17.759 [8.00–38.53]	$<10^{-4}$

Table 3: Diagnostic performance of various ACLIS cut-offs in the development cohort

Number of items	Sensitivity	Specificity	PPV	NPV
≥0	1.00	0.00	0.78	(not computable)
≥1	0.99	0.18	0.81	0.90
≥2	0.96	0.66	0.91	0.82
≥3	0.84	0.78	0.93	0.57
4	0.47	0.88	0.93	0.32

PPV: positive predictive value; NPV: negative predictive value

Table 4: Diagnostic performance of the ACLIS in the validation cohort

Number of items	Sensitivity	Specificity	PPV	NPV
≥0	1.00	0.00	0.68	(not computable)
≥1	0.99	0.15	0.71	0.86
≥2	0.94	0.56	0.82	0.81
≥3	0.85	0.82	0.91	0.73
4	0.55	0.92	0.94	0.49

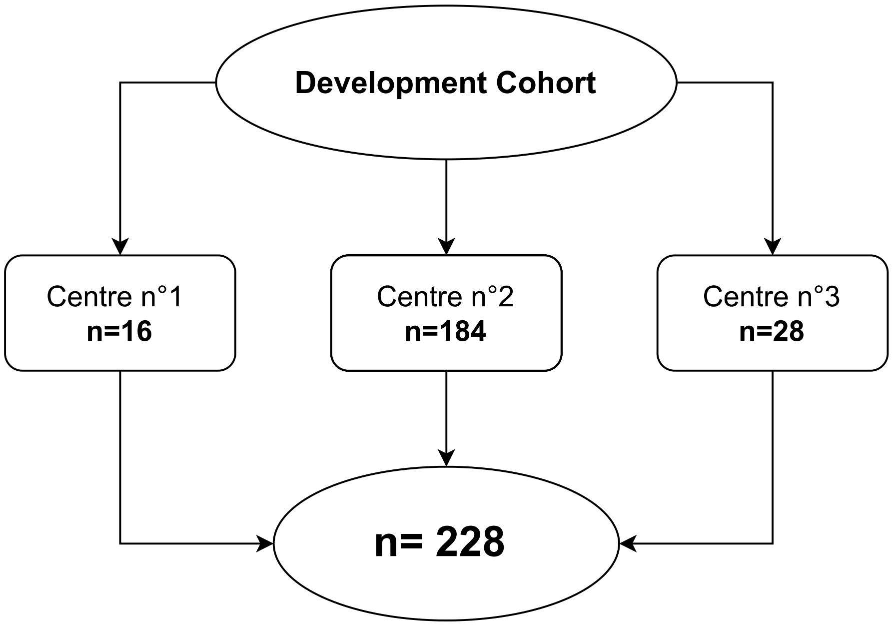
PPV: positive predictive value; NPV: negative predictive value

FIGURE LEGEND

Figure 1: Flow chart for the development cohort

Figure 2: Flow chart for the validation cohort

Figure 3: ROC curve for the ACLIS score in the development cohort (AUROC, 0.850; 95% confidence interval, 0.755–0.946)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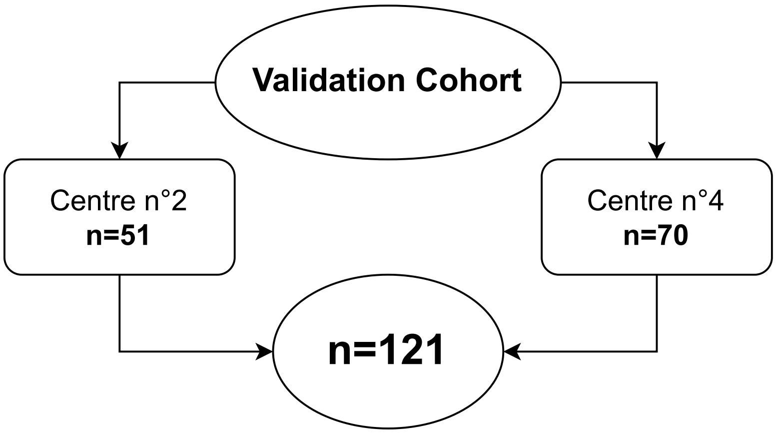
n=16
Centre n°2
n=184
Centre n°3
n=28
n= 228


Validation Cohort
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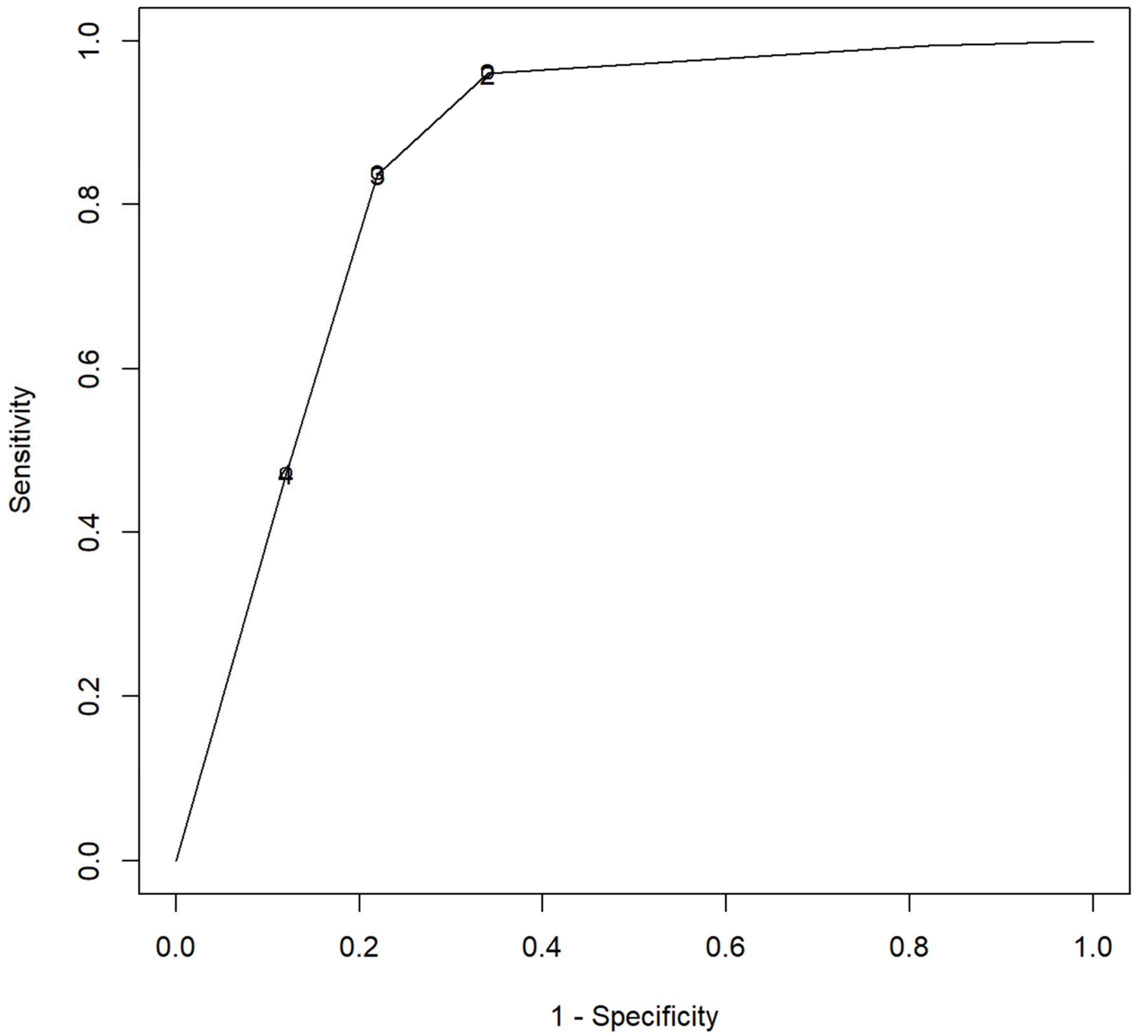
Centre n°4
n=70
n=121


1.0
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