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Higher sensitivity with the lever sign test for diagnosis of anterior cruciate ligament rupture in the emergency department

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Abstract

Introduction The objective of this study was to assess the diagnostic value of the "lever sign test" to diagnose ACL rupture and to compare this test to the two most commonly used, the Lachman and anterior drawer test.

Method This prospective study was performed in the ED of the Cliniques Universitaires Saint-Luc (Brussels, Belgium) from March 2017 to May 2019. 52 patients were included undergoing knee trauma, within 8 days, with an initial radiograph excluding a fracture (except Segond fracture or tibial spine fracture). On clinical investigation, patients showed a positive lever sign test *and/or* a positive Lachman test *and/or* a positive anterior drawer test. Exclusion criteria were a complete rupture of the knee extensor mechanism and patellar dislocation. All the physicians involved in this study were residents in training. An MRI was performed within 3 weeks for all included patients after the clinical examination. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were investigated for all three tests with MRI used as our reference standard.

Results Forty out of 52 patients suffered an ACL rupture (77%) and 12 did not (23%). The sensitivity, specificity, PPV *and* NPV of the lever sign test were respectively 92.5%, 25% 82% *and* 50%. Those of the Lachman test were 54%, 54.5%, 81% *and* 25%, and those of the anterior drawer test were 56%, 82%, 90.5% *and* 37.5%. Twelve out of 40 ACL ruptures (30%) were diagnosed exclusively with a positive lever sign test.

Conclusion When investigating acute ACL ruptures (< 8 days) in the ED, the lever sign test offers a sensitivity of 92.5%, far superior to that of other well-known clinical tests. The lever sign test is relatively pain-free, easy to perform and its visual interpretation requires less experience. Positive lever sign test at the ED should lead to an MRI to combine high clinical sensitivity with high MRI specificity.

Keyword ACL rupture · Lever sign test · Lachman test · Anterior drawer test · Emergency department

Introduction

Rupture of the anterior cruciate ligament (ACL) is a frequent lesion after knee trauma, often sports being the main provider. History and clinical exam should direct clinicians towards the most appropriate technical exams. Several well-known clinical tests have proven useful and have historically been performed to assess the ACL. Lachman, anterior drawer and pivot-shift test are the most frequently used for this type of pathology [1, 2].

Literature has shown that the diagnosis of ACL rupture in an emergency department (ED) is most complicated because clinical tests are performed under difficult conditions (stress, pain, swelling, muscle contracture and apprehension). Most authors found a low rate of accurate diagnosis, ranging

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between 7 and 27% [3–8]. An early diagnosis of ACL rupture can be crucial for the future of the meniscus and cartilage of the injured knee.

The lever sign test recently described by Lelli et al. [9] presents characteristics that are better suited for clinical examination in an acute setting. The lever sign test is rather painless; it requires only a passive mobilization of the knee without the need for grabbing the tibia and with an easy learning curve since it demands only a visual interpretation.

The hypotheses for this prospective comparative study were that (i) the lever sign test has a superior sensitivity to the other tests in acute situations and (ii) it can diagnose ruptures that would have been unnoticed before.

Materials and methods

Prospective study

The authors performed a prospective, comparative, single-center study in the ED of the Cliniques Universitaires Saint-Luc (Brussels, Belgium) from March 2017 to May 2019 after approval by our institutional Ethical Committee. A total of 52 patients were included after they gave written consent to participate. The study inclusion criteria were: patients above 18 years, presenting at the ED for acute knee pain, following an acute trauma within 8 days, with an initial radiograph showing no signs of fracture (except Segond fracture or tibial spine fracture). During clinical exam a positive lever sign test *and/or* a positive Lachman test *and/or* a positive anterior drawer test had to be observed. Exclusion criteria were a complete rupture of the knee extensor mechanism and patellar dislocation. The lever sign test was also performed on the contralateral unaffected knee. Thirty-two different physicians were involved in this study. All were residents in training (orthopaedics and emergency medicine). All residents received a training to perform these clinical exams prior to the launch of this study. To prevent additional discomfort in an acute setting, intra-observer and inter-observer variability tests were not conducted. An MRI study was performed in all included patients within three weeks after the clinical examination to assess ACL status. The sensitivity, specificity, positive predictive value (PPV) and negative sspredictive value (NPV) were investigated for all three tests with MRI used as our reference standard. Overall, the mean (range) age of the study population was 33 (19–56) years, with a 2 M/1F sex distribution. The mean (range) time between injury and admission at the ED was 53 (1–192) hours. Forty-one out of 52 patients (79%) presented a sport-related etiology.

Imaging studies

MRI study included coronal T1 and proton-density fat-saturated (PDFS) MR images, sagittal T2 and PDFS MR images, transverse PDFS MR images and 3D PDFS images. A senior author, board certified musculoskeletal radiologist in imaging, reviewed all MRI studies, recording all ligament, menisci, cartilage, bone and tendon lesions. A junior author, resident in radiology, reviewed all MRI studies assessing ACL status. There was no disagreement between readers for diagnosis of ACL tear. The inter-observer variability was very good for ACL assessment (κ coefficient = 1.00; 95% CI 1.00–1.00).

Lever sign test

The patient is placed in a supine position. For a left knee, the physician places his left hand, clenched as a fist, under the calf, on its proximal third. This stationary hand acts like a support and will induce a slight flexion of the knee with the heel resting on the surface of the table. With the right hand, the physician will apply a downward pressure on the distal region of the thigh. Two situations can occur and allow the physician to evaluate the lever sign test. With an intact ACL, the force applied on the distal thigh "overrules" gravity acting downwards on the leg and the clinician can observe the heel lifting of the table. The test is called negative under these conditions (Fig. 1). In the presence of an ACL rupture, the force applied on the lower limb doesn't "overrule" gravity operating on the leg, the tibial plateau slides anteriorly and the heel doesn't lift from the table. The test is now called positive (Fig. 2).

Fig. 1 Negative lever sign test

Fig. 2 Positive lever sign test

Statistical analysis

Descriptive statistics were used to characterize our cohort and are represented as mean (SD). Sensitivity, specificity, PPV and NPV of the three clinical tests were calculated with MRI as our standard reference. A non-parametric test, the McNemar test, was used to compare paired nominal data. The level of statistical difference was set at p value < 0.05. With a medium effect size (0.3) and with a statistical power (1-β) fixed at 0.8 and $\alpha = 0.05$, it was determined that a sample size of 46 was required.

Results

The lever sign test could be performed on every included patient. Information about the realization of the Lachman test was missing in 2 patients' reports (4%). The anterior drawer test wasn't performed on 7 patients (14%) because of pain, swelling and the impossibility to bend the knee at 90°. The lever sign test on the contralateral knee was not reported on 4 patients (7.6%).

Forty out of 52 patients suffered from an ACL rupture (77%) and 12 did not (23%) (Table 1). The lever sign test presented the highest sensitivity with 92.5%. The sensitivity, specificity, PPV *and* NPV of the lever sign test, the Lachman test and the anterior drawer test are presented in Table 2.

Table 1 2×2 contingency table. Comparison of findings from MRI with the lever sign test for 52 patients

	IRM			
		ACL Rupture	ACL Intact	Total
Lever sign test	+	37	9	46
	−	3	3	6
	Total	40	12	52

Table 2 Parameters of all clinical tests with MRI used as our standard reference

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Lever sign test	92.5	25	82	50
Lachman test	54	54.5	81	25
Anterior drawer test	56	82	90.5	37.5

Twelve out of 40 ACL ruptures (30%) were diagnosed exclusively with a positive lever sign test. The superiority of the lever sign test compared to the Lachman test was statistically significant (p value = 0.0376). There was no statistically significant superiority between the lever sign test and the anterior drawer test (p value = 0.089). However, the anterior drawer test couldn't be performed on 7 patients (14%), of which 6 presented an ACL rupture combined with a positive lever sign test. On the healthy contralateral knee, only the lever sign test was performed and was negative in all cases.

In the ACL rupture group, 6 (15%) were isolated ACL ruptures, 6 (15%) were coupled with a meniscus lesion, 11 (27.5%) presented a sprained collateral ligament and 17 (42.5%) were associated with a combined meniscus and collateral ligament injury.

In the intact ACL group, 3 (25%) had a normal MRI, 1 (8.3%) had a sprained collateral ligament, 1 (8.3%) had a combined meniscus and collateral ligament injury and 2 (16.6%) had an isolated femoral condyle oedema. There was also 1 (8.3%) partial rupture of the quadriceps tendon and 2 patients (16.6%) had a bucket handle tear of the meniscus. These last two pathologies implied the impossibility to mechanically achieve a positive lever sign test and should be recognized as a differential diagnosis.

Finally, 2 patients (16.6%) presented a compartmental mirrored bone marrow oedema which could be potential cases of false negatives on MRI.

Discussion

The most important finding of this study was the high sensitivity of the lever sign test in an acute knee trauma with 92.5%, far superior to the other well-known clinical tests. Thirty percent of ACL ruptures were diagnosed only with a positive lever sign test.

Frequently performed clinical tests to diagnose ACL ruptures are the Lachman test, the anterior drawer test and the pivot-shift test. Performed on awake patients and presenting with an acute knee injury, two meta-analysis on these three tests reported a sensitivity ranging from 81 to 94%, 38 to 49% and 28 to 32% for each of the respective tests [1, 2]. Lelli et al. have recently introduced a new clinical test, the

lever sign test. They compared this new test to the three other clinical tests in 200 knees that had recent trauma, defined as less than 20 days [9]. The lever sign test presented a perfect sensitivity of 100% for ACL rupture. The Lachman test had a 54% sensitivity, the anterior drawer test 52% and the pivot-shift test 17%. They also reported a 100% specificity. However, this study presents several potential biases; all patients had an MRI before that the different tests were performed and all patients included in their cohort presented with an isolated ACL rupture. Plus, their specificity was based on the uninjured contralateral leg *and not* an ACL-intact injured knee. Even though in this current study the lever sign test was also always negative when performed on the uninjured contralateral leg (100%), we found a much lower specificity (25%) on ACL-intact injured knees, potentially because patients were not preselected by having an MRI confirmed intact ACL. We also included meniscal tears, since these were all acute knee traumas presenting at the ED, which have been reported to diminish the lever sign test specificity from 93 to 40% [10]. Furthermore, a single experienced physician performed all the tests. The inclusion of patients within 8 days from the trauma might have influenced the outcome as well as having only residents, at different stages of their career, performing the clinical exams. When performed by two orthopedic surgeons, specialized in sports medicine, Massey et al. [10] reported, on acute knee injuries with a delay inferior to two weeks after trauma, a sensitivity and specificity with the lever sign test for ACL rupture of respectively 90% and 77%. Jarbo et al. [11] reported, on knee injuries less than four weeks, a sensitivity of 68% and a specificity of 96% when performed on awake patients for the lever sign test. Their cohort had only 15 ACL rupture on 48 patients, therefore potentially underestimating their reported sensitivity. Other studies have also investigated the sensitivity of the lever sign test. However, none of them mentioned the delay between the trauma and the clinical examination. Their sensitivities were evaluated between 38 and 100% [12–15]. It can be expected that sensitivity of all three tests will increase with more time since the knee trauma and a decrease of pain, swelling and apprehension.

An early diagnosis of ACL rupture can be critical for the future of the meniscus and cartilage of the injured knee. Most of the studies evaluating the missing diagnosis of ACL ruptures are retrospective and are based on cohorts who underwent ligament reconstruction surgery. These authors found a low rate of accurate diagnosis, ranging between 7 to 16% [3, 4, 6–8]. Guillodo et al. [5] realized a prospective study, during 6 months, in an ED in which all the painful knees were send for second evaluation to a specialist within 7 days. Only 26% (7 out of 27) of all the ruptured ACL were diagnosed during the first evaluation. These literature data seem to point out that an easy to perform clinical test with a high sensitivity can be interesting for all doctors seeing acute knee trauma. The lever sign test presents characteristics that are better suited for clinical examination in this type of setting. Several studies and meta-analysis have compared the sensitivity of these clinical tests before and during anesthesia, to overcome the patient factors such as pain. These studies all demonstrated that when performed under anesthesia a massive improvement of the sensitivity of the pivot-shift-test can be obtained from 32 to 85% [1] and from 28 to 73% [2]. The sensitivity of the anterior drawer test also rises importantly from 49 to 78% [1] and from 38 to 63% [2] while only a slow rise for the Lachman test from 94 to 97% [1] and from 81 to 91% [2] is reported. As for the lever sign test, Chong et al. [12] report a slight increase from 85 to 98.5%, while Deveci et al. [16] observe a limited increase from 94 to 98%. In our study, even when performed strictly by residents, the lever sign test could identify 30% of the ACL ruptures that were not identified with the two other clinical tests.

This study presents several limitations. There were some selection biases. Only patients who had at least one positive clinical test were included. In part because of this main selection criteria and the high sensitivity of the lever sign test, our prospective cohort was composed of only 12 non-ACL injured knee. The inclusion of patients within 8 days from the trauma, which is to the best of our knowledge, the shortest reported in literature, might also have impacted the outcome. This study involved 32 different physicians, all residents in training, which brings some heterogeneity to the results. All these elements influenced the specificity reported in this prospective study. Secondly, we didn't perform the pivot-shift test. This clinical test is less appropriate for routine use in an ED as it requires greater experience and is the most impacted test by the patient factors [1, 2]. We can therefore not compare the lever test with the pivot shift test. Finally, clinical examination performances are based on MRI findings and not on gold standard knee arthroscopy. Nevertheless, different meta-analyses comparing MRI versus arthroscopy to assess ACL ruptures show excellent specificity and sensitivity, 90–95.2% and 86.5–87%, respectively [17–19]. MRI can therefore be accepted as non-invasive lesion confirmation.

The clinical importance of this study lies in the observation that an heterogeneous group of less experienced physicians can easily perform the lever sign test on acute knee trauma with a very high sensitivity.

Conclusion

The lever sign test should be considered as an excellent screening test for ACL lesions after acute knee trauma and allows because of its high sensitivity to select patients needing more specific knee imaging, such as MRI.

Author contributions Prospective study performed in *close collaboration between 3 departments of a teaching Hospital* (Emergency Department, Radiology Department, Orthopedics and Traumatology Department).

All authors fulfill the criteria according to the ICMJE Guidelines.

All authors contributed to the study design. The lever sign test teaching for all involved residents was conducted by Kevin Guiraud, Christophe Bastin, Guillaume Silvestre and Philippe Meert.

Christophe Bastin and Philippe Meert oversaw the unfolding of the study in the emergency department. MRI appointment were scheduled by Frederic Lecouvet. MRI studies were analyzed by Frederic Lecouvet and Dimitar Boyadzhiev. Data collection was performed by Kevin Guiraud. Statistical analysis and tables were performed by Adrian Benitez. Litterature review was performed by Kevin Guiraud and Guillaume Silvestre. The first draft of the manuscript was written by Kevin Guiraud and all authors commented to polish its content. Emmanuel Thienpont supervised the study and critically reviewed each draft. All authors red and approved the final manuscript.

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Declarations

Conflict of interest The authors declare no conflicts directly related to this work.
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Ethical approval The Ethical Commitee of the Cliniques Universitaires Saint-Luc approved this protocol study (2016/06DEC/528—No. B403201630470).

Informed consent Informed consent was obtained from all individual participants included in this study.

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