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The "Lever Sign": a new clinical test for the diagnosis of anterior cruciate ligament rupture

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Abstract
Purpose A new clinical test for the diagnosis of ACL rupture is described: the so-called "Lever Sign". This prospective study on four groups of patients divided subjects on the basis of MRI findings (complete or partial ACL lesion) and the clinical phase of the injury (acute or chronic). The hypothesis was that this manual test would be diagnostic for both partial and complete tears of the ACL regardless of the elapsed time from injury.
Methods A total of 400 patients were evaluated and divided into four, equal-sized groups based on time elapsed from injury and MRI findings: *Group A* (acute phase with positive MRI for complete ACL rupture), *Group B* (chronic phase with positive MRI for complete ACL rupture), *Group C* (acute phase with positive MRI for partial ACL rupture), and *Group D* (chronic phase with positive MRI for partial ACL rupture). Clinical assessment was performed with the Lachman test, the Anterior Drawer test, the Pivot Shift test, and the Lever Sign test. The Lever Sign test involves placing a fulcrum under the supine patient's calf and applying a downward force to the quadriceps. Depending on whether the ACL is intact or not, the patient's heel will either rise off of the examination table or remain down. Additionally, the Lever Sign test was performed on the un-injured leg of all 400 patients as a control.
Results All tests were nearly 100 % sensitive for patients with chronic, complete tears of the ACL. However, for patients with acute, partial tears, the sensitivity was much lower for the Lachman test (0.42), Anterior Drawer test (0.29), and Pivot Shift test (0.11), but not the Lever Sign test (1.00).
Conclusion In general, chronic, complete tears were most successfully diagnosed but acute, partial tears were least successfully diagnosed. The Lever Sign test is more sensitive to correctly diagnosing both acute and partial tears of the ACL compared with other common manual tests. The clinical relevance is that some ACL ruptures may be more accurately diagnosed.

Keywords ACL rupture · Lachman test · Anterior Drawer test · Pivot Shift test · Lever Sign test

Introduction

The anterior cruciate ligament (ACL) is the most commonly injured structure of the knee [1]. While arthroscopic visualisation is the gold standard for diagnosing rupture of the ACL, magnetic resonance imaging (MRI) is a valid and non-invasive diagnostic method, with a specificity and sensitivity of 94–98 % [2, 6, 9, 11]. To augment the diagnosis of ACL rupture, the three most commonly used physical examinations are the Lachman test, the Anterior Drawer test, and the Pivot Shift test [7, 12]. All of these tests work to some extent and are recommended diagnostic tools [8], but their drawbacks, including the influence of patient guarding due to the pain associated with rapidly translating or twisting a potentially injury [1, 5, 12] and difficulty diagnosing partial tears

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[3], are well documented. Despite their limitations, manual tests offer several benefits over MRI, including being completely non-invasive, easy to perform, and inexpensive.

In 2005, a new physical test called the "Lever Sign" test was conceived of and put into practice. The Lever Sign test has proved superior to other manual tests, being equally definitive for partial as well as complete tears and additionally being diagnostic even for acute injuries. In this paper, the authors describe this novel manual test (which takes advantage of the fact that the ACL provides most of the restraining force against anterior tibial fixation, especially around 30° [10]) and its use in a prospective study performed with 400 patients. That the Lever Sign test would be diagnostic for both partial and complete tears of the ACL regardless of the elapsed time from injury was the hypothesis of this study. To the best of our knowledge, this physical examination technique has not been described previously in the literature and therefore, providing the results of this prospective study may help to stimulate discussion on physical examination tests for diagnosing ACL rupture.

Materials and methods

Lever Sign test

The patient is placed supine with the knees fully extended on a hard surface such as the examining table. The examiner stands at the side of the patient and places a closed fist under the proximal third of the calf. This causes the knee to flex slightly. With his other hand, he applies moderate downward force to the distal third of the quadriceps. With this configuration, the patient's leg acts as a lever over a fulcrum—the clinician's fist. There are two downward forces on the patient's leg that must be considered: the force of the clinician's hand on the quadriceps and the force of gravity on the foot and lower leg. In an intact knee, the creation of a complete lever by the ACL allows the downward force on the quadriceps to more than offset the force of gravity, the knee joint rotates into full extension, and the heel rises up off of the examination table (Fig. 1a). With a partially or completely ruptured ACL, the ability to offset the force of gravity on the lower leg is compromised and then tibial plateau slides anteriorly with respect to the femoral condyles. In this case, the gravity pulls the heel down to the examination table (Fig. 1b). One potential advantage of this physical examination method is that rapid motions of the injured knee can be avoided, likely reducing the incidence for additional patient pain and resultant guarding.

Prospective study

Over the course of roughly an 8-month period at a dedicated surgery centre, the authors collected 400 patients with a definitive MRI diagnosis of unilateral ACL rupture (partial or complete). Patients were divided into four equally sized groups on the basis of the MRI findings (complete or partial ACL lesion) and the clinical phase (acute or chronic): Group A (acute phase with MRI finding of complete ACL rupture), Group B (chronic phase with MRI finding of complete ACL rupture), Group C (acute phase with MRI finding of partial ACL rupture), Group D (chronic phase with MRI finding of partial ACL rupture). The acute phase was defined to be less than 20 days from injury, whereas chronic phase was defined to be more than 20 days from injury (range 20 days–4 years). Consecutive patients were added to the various groups until the number of patients in a particular group reached 100. Exclusion criteria included co-morbidities such as cartilage defects, multi-ligamentous injuries, and meniscal injuries as well as prior reconstructions of the affected ACL. The demographic information on

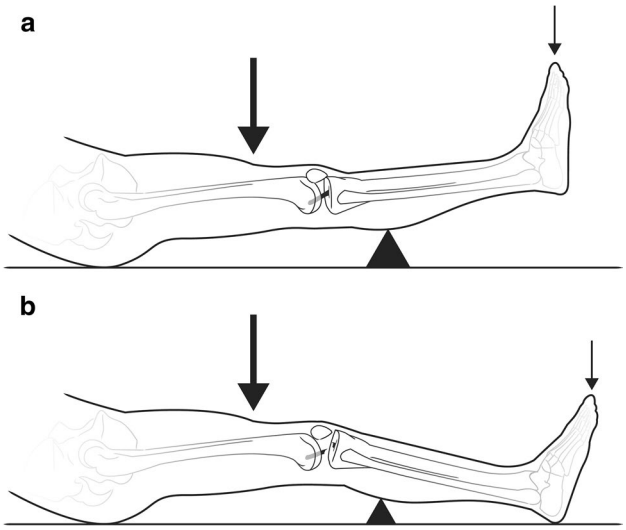

Fig. 1 **a** Force diagram of negative Lever Sign test. With the fist acting as a fulcrum under the calf and a second hand pushing down on the quadriceps (*large arrow*), the ACL is able to counteract the downward force on the foot due to gravity (*small arrow*). **b** Force diagram of positive Lever Sign test. With the fist acting as a fulcrum under the calf and a second hand pushing down on the quadriceps (*large arrow*), the ruptured ACL is not able to counteract the downward force on the foot and the foot remains on the examination table (*small arrow*)

Table 1 Demographic information for four, equal-sized groups of patients

Group	Number of patients	Mean age (years)	Sex (% female)
A	100	27.0	29
B	100	26.0	35
C	100	26.8	24
D	100	25.9	31

Table 2 Percentage of patients successfully diagnosed with the three most common physical examinations and the proposed Lever Sign test

Group	Lachman test	Anterior Drawer test	Pivot Shift test	Lever Sign test (%)
A	66 %	75 %	23 %	100
B	100 %	100 %	98 %	100
C	42 %	29 %	11 %	100
D	39 %	83 %	56 %	100
Contralateral knees	N/A	N/A	N/A	0

Group A ($n = 100$) comprised patients with an acute, complete tear of the ACL, while group B ($n = 100$) comprised patients with chronic, complete tears. Group C ($n = 100$) comprised patients with acute, partial tears and group D (=100) comprised patients with chronic, partial tears. All tears were unilateral, but only the Lever Sign test was performed on the uninjured (contralateral) knees ($n = 400$)

the groups was summarised, with no significant differences among the various groups of patients (Table 1). Overall, the average age of the patients was 26.4 ± 14.9 years, with 29.8 % being female and 70.2 % being male. The study satisfied the requirements of the institution regarding the use of human subjects in scientific research.

Statistical analysis

In order to have homogeneous data, all of the physical examinations were performed by a single clinician. He was blinded to the MRI findings. As part of the clinical evaluation, every patient underwent the same series of physical tests, including the Lachman test, Anterior Drawer test, Pivot Shift test, and Lever Sign test. Additionally, as a control group, the contralateral (uninjured) leg of all patients was evaluated with the Lever Sign test. Using a sample size calculator for the McNemar test (StatsToDo, Queensland Australia), it was estimated (with 80 % power) that 97 patients per group were sufficient to detect a difference in successful diagnoses between 60 and 95 % for any two physical tests.

Results

The data for Group A, B, C, and D were summarised (Table 2). Group B patients (complete tear, chronic injury) were most likely to be successfully diagnosed using physical examination, while Group C patients (partial tear, acute injury) were least likely to be successfully diagnosed. On the contralateral side, the Lever Sign test was negative in all 400 cases.

In the two groups of patients with MRI diagnosis of complete ACL rupture (groups A and B), the mean sensitivity of the three clinical tests was superior to the two groups of patients with partial ACL lesion (Groups C and D). Interestingly, mean sensitivity data for acute injuries were lower than the mean data for chronic injuries. When data from all 400 patients were pooled, the mean sensitivity was: 0.62 for the Lachman test, 0.72 for the Anterior Drawer test, 0.47 for the Pivot Shift test, and 1.00 for the Lever Sign test. The specificity of the Lever Sign test was also 1.00 (no false positive results), although this result was not confirmed with arthroscopic visualisation.

Discussion

The most significant finding of this study was the perfect agreement between the outcome of the Lever Sign test and the MRI findings, regardless of whether the ACL was partially or completely ruptured and regardless of the time elapsed from the injury. MR has been shown to have a specificity and sensitivity of 94–98 % in detecting ACL injury [2, 6, 9, 11].

Two meta-analyses of the Lachman test, Anterior Drawer test, and Pivot Shift test concluded that the Lachman test generally had the highest sensitivity [1, 12], with pooled sensitivities for non-anaesthetised patients of 0.81 and 0.85 for the Lachman test, 0.38 and 0.92 (chronic injury data only) for the Anterior Drawer test, and 0.28 and 0.24 for the Pivot Shift test. It was noted that the Anterior Drawer test had lowered sensitivity for acute injuries. In the current study, sensitivity values were lower for the Lachman test and higher for the Pivot Shift test, which may be due to the large number of patients with acute injuries in this study. Acute ACL injuries are generally regarded as being more difficult to diagnose [4]. In looking at the effect of acute versus chronic ACL injury, it has been reported that the sensitivity for acute injuries is 0.78 for the Lachman test, 0.22 for the Anterior Drawer test, and 0.89 for the Pivot Shift test [5]. These values were 0.85, 0.54, and 0.85 (respectively) for chronic injuries. This trend of higher sensitivity for chronic injuries was confirmed by the current results and points to the need for a manual test robust to the elapsed time between injury and physical examination. Differences in values may be due to the large number of patients with partial tears in the current study.

There were multiple limitations to this study, including the fact that all physical exams were performed by a

single clinician. This, coupled with the somewhat subjective nature of all manual tests, could have introduced bias as the results from one test could have influenced his ability to be objective for subsequent manual tests. Additionally, the ability to learn the Lever Sign test has not been evaluated and other clinicians may not be as facile, at least initially. However, choosing to have a single clinician perform all physical tests likely improves the homogeneity of the data. Future work will include an investigation of inter-observer variability. Another limitation was the fact that only the Lever Sign test was performed on the "healthy", contra-lateral legs and thus specificity data were not acquired for the other physical exams. This too represents an opportunity for future work to better compare the benefits of the various manual tests. Administering the physical tests to injured knees with intact ACLs would also provide a clearer picture of the specificity. Finally, the magnitude of the partial tears was not captured in the MRI findings. Typically, the vast majority of partial ACL tears involve the posterolateral bundle, but the lesion is not always completely through this bundle.

Since the Lever Sign test has been shown to be more sensitive to correctly diagnosing both acute and partial tears of the ACL compared with other common manual tests, the clinical relevance of this level III evidence is that some ACL ruptures may be more accurately diagnosed.

Conclusion

A new manual test for the diagnosis of partial and complete ruptures of the ACL has been described. In a prospective clinical study, this test was found to have higher sensitivity than the other commonly performed tests performed during physical examination.

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