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## Accuracy of physical diagnostic tests for assessing ruptures of the anterior cruciate ligament: A meta-analysis

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### Practice recommendations

- Reliable data are scarce regarding the accuracy of physical diagnostic tests in diagnosing anterior cruciate ligament ruptures in primary care.
- The pivot shift test has a favorable positive predictive value, and the Lachman test has a good negative predictive value. The anterior drawer test is of unproven benefit in diagnosing rupture of the anterior cruciate ligament (ACL).
- Although of limited predictive value, the history and physical examination, coupled with patient preference and physical demands, should form the basis for further investigation of possible ACL rupture.

**Objective:** This systematic review summarizes the evidence on the accuracy of tests for assessing ACL ruptures of the knee.

**Search strategy** A computerized search of MEDLINE (1966–2003) and EMBASE (1980–2003) with additional reference tracking.

**Selection criteria** Articles included were written in English, French, German, or Dutch, and addressed the accuracy of at least 1 physical diagnostic test for ACL rupture, using arthroscopy, arthroscopy, or magnetic resonance imaging as the gold standard.

**Data collection and analysis:** Two reviewers independently selected studies, assessed the methodological quality, and abstracted data using a standardized protocol. We calculated

sensitivity, specificity, and likelihood ratios for each test and summary estimates, when appropriate and possible.

**Main results:** Seventeen studies met the inclusion criteria. None assessed the index test and reference test independently (with blinding), and all but 2 displayed verification bias. Study results were heterogeneous. The pivot shift test seems to have favorable positive predictive value, and the Lachman test has good negative predictive value. The anterior drawer test is of unproven value.

**Conclusions:** Reliable data are rare regarding the accuracy of physical diagnostic tests for ACL ruptures, especially in a primary care setting. For the time being, history taking and physical examination, albeit of limited use, should be considered with individual patient demands to provide the basis for further evaluation.

To evaluate possible rupture of the anterior cruciate ligament (ACL), family physicians rely on the history and physical examination and primarily 3 diagnostic assessments: the anterior drawer test, the Lachman test, and the pivot shift test.<sup>1-3</sup> Preliminary findings from these tests, coupled with patient preference and physical demands, help select those who may need further work-up with arthroscopy or magnetic resonance imaging (MRI).<sup>4</sup>

We summarize the evidence for the diagnostic accuracy of physical diagnostic tests in assessing ACL ruptures of the knee.

If a patient's physical demands are low, one might proceed with a trial of conservative therapy (especially when Lachman's test is negative), which has shown to be favorable for selected patients.<sup>5</sup> However, when a patient has high demands (as is the case with athletes), more advanced diagnostic tests (eg, MRI) seem to be indicated, irrespective of the findings of physical examination.

## METHODS

### Selection of studies

A computerized literature search of MEDLINE (from 1966 to February 14, 2003) and EMBASE (1980 to February 14, 2003) was conducted to identify articles written in English, French, German, or Dutch. Key words were the medical subject headings "knee injuries," "knee joint," and "knee," and the text word "knee." This set was combined with a set consisting of the main headings "joint instability" and "anterior cruciate ligament," and the text words "laxity," "instability," "cruciate," and "effusion."

Finally, the results of these strategies were combined with a validated search strategy for the identification of diagnostic studies using the subject headings "sensitivity and specificity" (exploded), "physical examination" and "not (animal not [human and animal])" and the text words "sensitivity," "specificity," "false positive," "false negative," "accuracy," and "screening,"<sup>6</sup> supplemented with the text words "physical examination" and "clinical examination." Also, the cited references of included publications were examined.

Studies were selected by 2 reviewers independently. Studies were eligible for inclusion if they addressed the accuracy of at least 1 physical diagnostic test for the assessment of ACL ruptures of the knee, and used arthrotomy, arthroscopy, or MRI as the gold standard.

## Assessment of methodological quality and data abstraction

The methodological quality of the selected studies was assessed and data were abstracted by 2 reviewers independently. Quality assessment was accomplished with a checklist adapted from Irwig and colleagues<sup>7</sup> and the Cochrane Methods Group on Systematic Review of Screening and Diagnostic Tests.<sup>8</sup> (Table W1 and Table W1 cont.).

Statistical analysis Statistical analysis was performed<sup>9</sup> with a strategy adapted from Midgette and colleagues.<sup>10</sup> The method consists of estimating a summary receiver operating characteristic (SROC) curve by metaregression, and exploring heterogeneity by adding study characteristics and study validity items to the regression model (a full description of this strategy is available online as Appendix A).<sup>7-11</sup>

We performed an additional analysis according to a bivariate random effects model that accounts for heterogeneity of both sensitivity and specificity simultaneously, reflected in the width of the 95% confidence intervals.<sup>12,13</sup>

The summary estimates of sensitivity and specificity were used to calculate the predictive value of a positive (PV+) and negative test result (PV-) for circumstances with varying prevalences of ACL ruptures. When summary estimates of both sensitivity and specificity could not be calculated, the summary estimate of sensitivity and the accompanying specificity, estimated from the SROC curve, were used to calculate predictive values.

## RESULTS

### Selection of studies

The literature search revealed a total of 1090 potentially eligible studies, 17 of which were selected.<sup>14-30</sup> Two reports pertained to the same study,<sup>15,16</sup> and 1 additional study was found by reference tracking.<sup>2</sup> Thus, a total of 17 studies met the selection criteria.

### Methodological quality and study characteristics

No study measured the index test (ie, the object of study) and reference standard independently (with blinding). Patients whose physical test results were abnormal were more likely to undergo the gold standard test—a factor that inflates sensitivity and decreases specificity. This verification bias was present in all but 2 studies.<sup>15,27</sup> No study was performed in a primary care setting.

A detailed description of the characteristics and methodological quality of the 17 included studies is available online (Appendix B, Table W2-1, Table W2-2, Table W2-3, and Table W3).

### Accuracy of ACL tests

Details of the process of selecting studies for further meta-analysis are presented online (Appendix C).

Diagnostic accuracy of the ACL tests is shown in Table 1. Significant heterogeneity of sensitivity and specificity was seen with all ACL tests, and no significant subgroups were detected for any of the tests. The power of metaregression analysis, however, was low due to the small number of available studies (4 to 6) and because some characteristics exhibited no variation.

**Anterior drawer test.** Correlation of sensitivity and specificity for the anterior drawer test was positive (6 studies); thus, no SROC curve was estimated. Sensitivity of the anterior drawer test was 0.18–0.92, and specificity 0.78–0.98. According to the bivariate random effects model, the pooled sensitivity was 0.62 (95% confidence interval [CI], 0.42–0.78) and the pooled specificity was 0.88 (95% CI, 0.83–0.92) (Figure 1A).

## TABLE 1

**Lachman test ( Figure 2 ).** The SROC curve of the Lachman test (6 studies) is shown in **Figure 1B**. Sensitivity ranged from 0.63 to 0.93, and specificity from 0.55 to 0.99. According to the bivariate random effects model the pooled sensitivity was 0.86 (95% CI, 0.76–0.92) and the pooled specificity was 0.91 (95% CI, 0.79– 0.96).

**Pivot shift test.** The SROC curve of the pivot shift test (4 studies) is shown in **Figure 1C** . Sensitivity ranged from 0.18 to 0.48, and specificity from 0.97 to 0.99. Bivariate random effects pooling could not be performed; in this model 5 parameters must be estimated and only 4 studies were available.

**Figure 3** shows the PV+ and PV– for all tests according to varying prevalences of ACL ruptures. The pivot shift test has the highest PV+ and the Lachman test the highest PV–. If the pivot shift test is positive, there is high probability of an ACL rupture, whereas a negative Lachman test rules out a rupture.

## FIGURE 2

## FIGURE 3

## DISCUSSION

We reviewed 17 studies that examined the accuracy of physical diagnostic tests for assessing ACL ruptures of the knee. Of those tests, the pivot shift test seems to have favorable positive predictive value, and the Lachman test good negative predictive value. The anterior drawer test is of unproven diagnostic value in this setting. In view of the potential biases in the original studies, however, the accuracy of the various ACL tests might be overestimated and the poor quality of the studies impede sound conclusions about the usefulness of the tests for daily practice. In addition, no study has been performed in primary care.

Because test characteristics may be influenced substantially by referral filters leading to spectrum bias,<sup>31</sup> and because primary care physicians will be less experienced in performing these tests, the tests will presumably be less accurate in a primary care setting. Furthermore, the pivot shift test is very difficult to perform, making it less attractive for the average primary care physician.

## FUTURE RESEARCH

Useful answers would be derived from sound research on the diagnostic accuracy of the various tests (determined for each test separately and for all tests jointly) combined with patient characteristics (eg, age, physical fitness, and functional demands) and elements of the medical history (eg, type of trauma and nature of the complaints). The emergence of MRI will facilitate this research. Relevance to clinical practice would be enhanced by an assessment of the effect of a correct diagnosis on the functional outcome of patients.

## ACKNOWLEDGMENTS

The authors thank Afina Glas, MD, and Professor Koos Zwinderman, PhD, for their statistical advice. We are much obliged to 1 of the referees for his/her useful suggestions.

## TABLES AND FIGURES

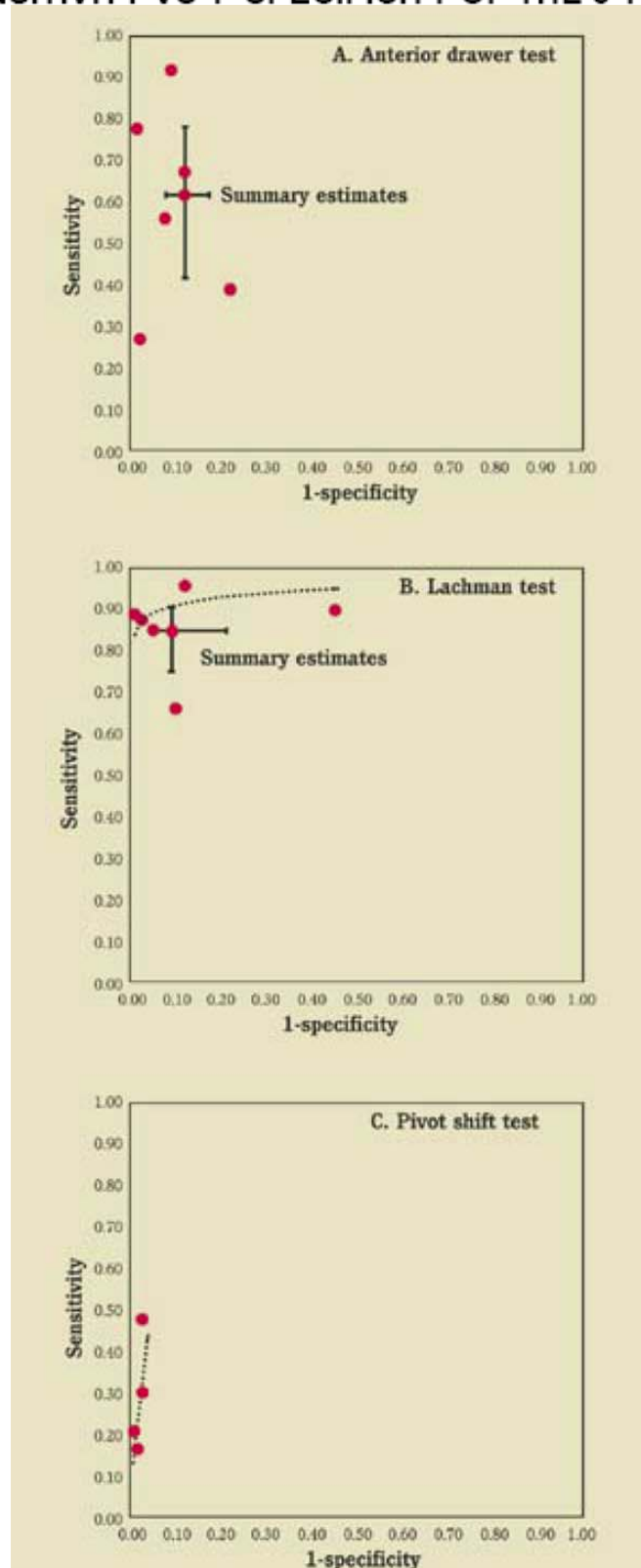
Table 1

### Diagnostic accuracy of the anterior drawer sign, Lachman test, and pivot shift test

First author	Type of ACL rupture	N	Prevalence	Sn	Sp	LR+	LR-
<b>Anterior drawer sign</b>							
Hardaker <sup>25</sup>	Partial + complete	132	0.77	0.18	—	—	—
Tonino <sup>19*†</sup>	Partial + complete	52	0.58	0.27	0.98	12.6	0.7
Rubinstein <sup>28</sup>	"ACL-deficient"	39	0.23	(0.76) <sup>§</sup>	(0.86) <sup>§</sup>	—	—
Boeree <sup>26*</sup>	Not specified	203	0.29	0.56	0.92	6.7	0.5
Lee <sup>21*</sup>	Not specified	79	0.29	0.77	0.99	87.9	0.2
Richter <sup>29*</sup>	Not specified	74	0.78	0.67	0.88	5.4	0.4
Steinbrück <sup>22*</sup>	Not specified	300	0.17	0.92	0.91	10.4	0.1
Sandberg <sup>18*‡</sup>	Not specified	182	0.68	0.39	0.78	1.7	0.8
<b>Lachman test</b>							
Hardaker <sup>25</sup>	Partial + complete	132	0.77	0.74	—	—	—
Tonino <sup>19*</sup>	Partial + complete	52	0.58	0.89	0.98	40.8	0.1
Schwarz <sup>30*‡</sup>	Partial + complete	58	0.81	0.91	0.55	2.0	0.2
Rubinstein <sup>28</sup>	"ACL-deficient"	39	0.23	(0.96) <sup>§</sup>	(1.00) <sup>§</sup>	—	—
Boeree <sup>26*</sup>	Not specified	203	0.29	0.63	0.90	6.5	0.4
Lee <sup>21*</sup>	Not specified	79	0.29	0.90	0.99	102.1	0.1
Richter <sup>29*‡</sup>	Not specified	74	0.78	0.93	0.88	7.4	0.1
Steinbrück <sup>22*</sup>	Not specified	300	0.17	0.86	0.95	17.9	0.1
Cooperman <sup>24</sup>	Not specified	32	0.41	(0.65) <sup>  </sup>	(0.42) <sup>  </sup>	—	—
<b>Pivot shift test</b>							
Hardaker <sup>25</sup>	Partial + complete	132	0.77	0.29	—	—	—
Tonino <sup>19*</sup>	Partial + complete	52	0.58	0.18	0.98	8.2	0.8
Rubinstein <sup>28</sup>	"ACL-deficient"	39	0.23	(0.93) <sup>§</sup>	(0.89) <sup>§</sup>	—	—
Boeree <sup>26*</sup>	Not specified	203	0.29	0.31	0.97	8.8	0.7
Richter <sup>29*‡</sup>	Not specified	74	0.78	0.48	0.97	16.4	0.5
Steinbrück <sup>22*</sup>	Not specified	300	0.17	0.22	0.99	26.9	0.8
* Study results used for meta-analysis							
† 0.5 added to each cell of the 2x2 table							
‡ 2x2 table reconstructed							
§ Mean result of 5 orthopedic surgeons							
Sum of results of 2 physiotherapists							
ACL, anterior cruciate ligament; Sn, sensitivity; Sp, specificity; LR+, positive likelihood ratio; LR-, negative likelihood ratio							

Figure 1

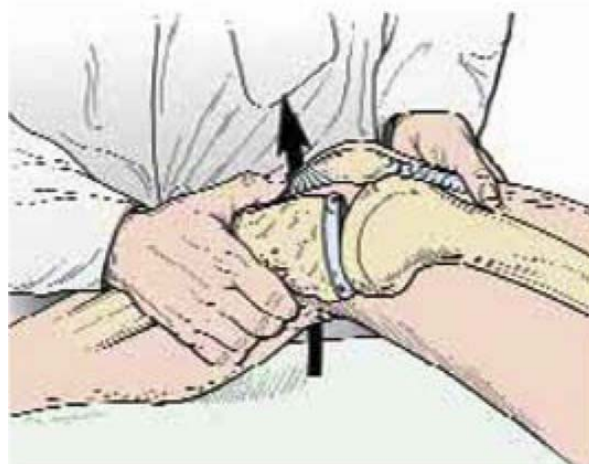
### SENSITIVITY VS 1-SPECIFICITY OF THE 3 TESTS



Scatterplots of sensitivity versus 1-specificity of A) the anterior drawer test (6 studies), B) the Lachman test (6 studies), and C) the pivot shift test (4 studies). Summary receiver operating characteristic curves and summary estimates of sensitivity and specificity (including 95% confidence intervals) are shown as appropriate.

Figure 2

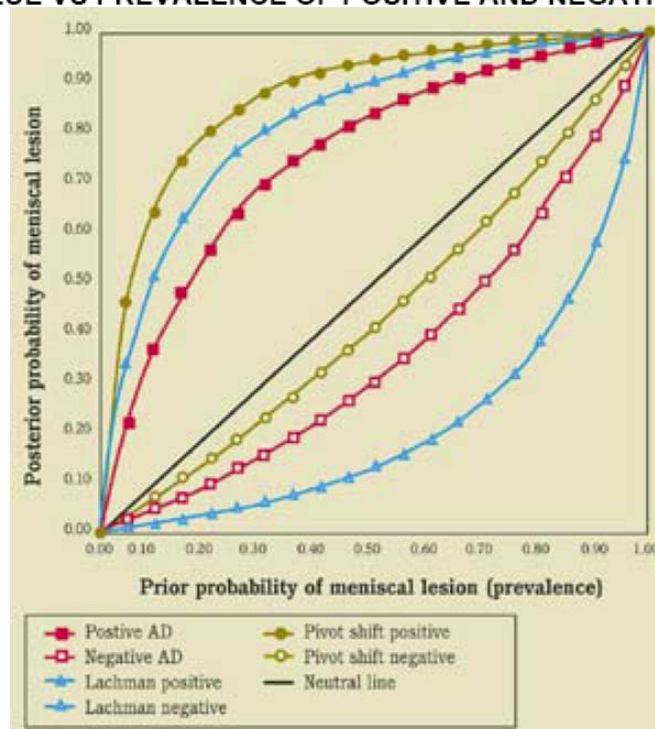
### LACHMAN TEST



*To perform the Lachman test, grasp the back of the proximal tibia posteriorly and place thumb over joint line anterolaterally. Pull the proximal tibia anteriorly and posteriorly, and compare sides for endpoint laxity.*

Figure 3

### PREDICTIVE VALUE VS PREVALENCE OF POSITIVE AND NEGATIVE TEST RESULTS



*Predictive value (posttest probability of presence of ACL rupture) vs prevalence (prior probability of presence of ACL rupture) of positive and negative test results of the anterior drawer test (sensitivity=0.62, specificity=0.88), Lachman test (sensitivity=0.86, specificity=0.91), and the pivot shift test (sensitivity=0.32, specificity=0.98).*

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