The Diagnostic Accuracy of Kernig's Sign, Brudzinski's Sign, and Nuchal Rigidity in Adults with Suspected Meningitis

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To determine the diagnostic accuracy of Kernig's sign, Brudzinski's sign, and nuchal rigidity for meningitis, 297 adults with suspected meningitis were prospectively evaluated for the presence of these meningeal signs before lumbar puncture was done. Kernig's sign (sensitivity, 5%; likelihood ratio for a positive test result [LR$^+$], 0.97), Brudzinski's sign (sensitivity, 5%; LR$^+$, 0.97), and nuchal rigidity (sensitivity, 30%; LR$^+$, 0.94) did not accurately discriminate between patients with meningitis (⩾6 white blood cells [WBCs]/mL of cerebrospinal fluid [CSF]) and patients without meningitis. The diagnostic accuracy of these signs was not significantly better in the subsets of patients with moderate meningeal inflammation (⩾100 WBCs/mL of CSF) or microbiological evidence of CSF infection. Only for 4 patients with severe meningeal inflammation (⩾1000 WBCs/mL of CSF) did nuchal rigidity show diagnostic value (sensitivity, 100%; negative predictive value, 100%). In the broad spectrum of adults with suspected meningitis, 3 classic meningeal signs did not have diagnostic value; better bedside diagnostic signs are needed.

Rapid and accurate clinical evaluation is required to determine the risk of meningitis and the need for lumbar puncture in adults with suspected meningitis. Community-acquired bacterial meningitis is associated with a mortality of ∼25%, despite the availability of effective antibiotic therapy, and delays in initiation of antibiotic therapy can adversely affect clinical outcome [1–3].

Optimal evaluation of the risk of meningitis requires diagnostic assessment of a patient's clinical condition. A recent meta-analysis reported that, for adults with suspected meningitis, physical signs were more reliable than clinical history for establishing a diagnosis [4].

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Kernig's sign, Brudzinski's sign, and nuchal rigidity are 3 bedside diagnostic signs used specifically to assess a patient's risk for meningitis. Although these clinical signs have been used as indicators of meningeal inflammation for almost a century [5], their diagnostic accuracy has never been rigorously investigated in a prospective manner. The primary purpose of the present study was to determine the diagnostic accuracy of Kernig's sign, Brudzinski's sign, and nuchal rigidity for meningitis in a prospective cohort of adults with suspected meningitis.

PATIENTS AND METHODS

Cohort assembly. Adults (age >16 years) who presented to the Yale–New Haven Hospital Emergency Department between July 1995 and June 1999 with clinically suspected meningitis were eligible for this study. "Suspected meningitis" was defined as the presence of clinical symptoms compatible with meningitis (i.e., fever, headache, stiff neck, photophobia, nausea, and vomiting) such that a lumbar puncture was performed to determine whether CSF inflammation was present. A complete description of this cohort has been published elsewhere, in a study that investigated the usefulness of performance of head CT before lumbar puncture [6]. Of 301 patients who were enrolled, 297 underwent lumbar puncture; the remaining 4 patients were excluded on the basis of head CT results that showed mass effect. The present study was approved by the Human Investigation Committee at Yale University School of Medicine, and all enrolled patients consented to participate.

Data collection. All clinical information, including tests for Kernig's sign, Brudzinski's sign, and nuchal rigidity, was gathered and recorded by an emergency department physician or physician-investigator before lumbar puncture was done. Enrolling physicians were required to record the clinical histories of and physical examination findings for research subjects, but physicians were not given explicit instructions about examination for meningeal signs. All diagnostic and management decisions were at the physician's discretion.

Laboratory analysis. Laboratory analysis of all CSF samples included Gram staining and bacterial culture, as well as determination of WBC count and protein and glucose levels. Additional CSF analysis (i.e., tests for viral, fungal, or mycobacterial pathogens) were ordered at the discretion of the treating physician. Meningitis was considered to be present if the CSF WBC count was $\geqslant 6$ cells/mL.

Statistical analysis. Bivariate analysis was performed using the χ^2 test and the *t* test. $P \leqslant .05$ was considered to be statistically significant. Standard definitions of sensitivity, specificity, positive predictive value, and negative predictive value were used. The likelihood ratio for a positive test result (LR^+) was calculated by dividing the sensitivity by the false-positive error rate. The likelihood ratio for a negative test result (LR^-) was calculated by dividing the false-negative error rate by the specificity. The ratio of LR^+ to LR^- ($LR^+:LR^-$) was calculated to represent the overall accuracy of the test. Statistical analysis was performed by use of SAS software (SAS Institute).

RESULTS

Description of cohort. A total of 297 adults with suspected meningitis underwent lumbar puncture; CSF analysis revealed that 80 (27%) had objective evidence of meningitis (CSF WBC count $\geqslant 6$ cells/mL). Baseline characteristics and clinical presentation of patients with meningitis were similar to those of patients without meningitis and are shown in table 1.

Emergency department physicians (28% interns, 55% residents, and 17% attending physicians) gathered the clinical history and conducted physical examinations of patients before performing a lumbar puncture. The most common presenting symptoms were headache (in 84% of patients), fever (in 68%), nausea and vomiting (in 58%), photophobia (in 53%), and stiff neck (in 46%). The majority (81%) of patients presented with $\geqslant 2$ of these symptoms. The probability of meningitis associated with different combinations of clinical symptoms characteristic of meningitis ranged from 0.42 to 0.57 (table 2).

Laboratory results. CSF analysis revealed evidence of meningitis ($\geqslant 6$ WBCs/mL of CSF) in 80 patients; 29 of those patients had evidence of moderate meningeal inflammation ($\geqslant 100$ WBCs/mL of CSF), and 4 had evidence of severe meningeal inflammation ($\geqslant 1000$ WBCs/mL of CSF). Eighteen patients had microbiological evidence of CSF infection (positive results of either a CSF culture or an antigen test); the causative pathogens identified included *Enterovirus* (8 patients), *Cryptococcus neoformans* (6 patients), *Neisseria meningitidis* (2 patients), varicella-zoster virus (1 patient), and *Streptococcus pneumoniae* (1 patient). Mean CSF indices for patients with and patients without meningitis are shown in table 1.

Diagnostic accuracy of Kernig's and Brudzinski's signs. Examination for Kernig's sign and Brudzinski's sign was done before lumbar puncture for 237 and 236 patients, respectively. Seven patients had Kernig's sign but did not have Brudzinski's sign; 7 patients had Brudzinski's sign but did not have Kernig's sign; and 4 patients had both meningeal signs. Neither sign was found in the remaining patients.

Of the 66 patients with meningitis ($\geqslant 6$ WBCs/mL of CSF) who were examined before lumbar puncture was done, 3 had Kernig's sign (sensitivity, 5%); of the 171 patients without meningitis who were examined before lumbar puncture, 163 did not have Kernig's sign (specificity, 95%) (table 3). Of the 11 patients who displayed Kernig's sign, 3 had CSF evidence of meningitis (positive predictive value, 27%); of the 226 patients who did not display Kernig's sign, 163 did not have meningitis (negative predictive value, 72%). The sensitivity (5%), specificity (95%), positive predictive value (27%), and negative predictive value (72%) for Brudzinski's sign (table 3) were identical to those for Kernig's sign. For both Kernig's sign and Brudzinski's sign, the LR^+ was 0.97, the LR^- was 1.0, and $LR^+:LR^-$ was 0.97.

Diagnostic accuracy of nuchal rigidity. All 297 patients in the cohort were examined for nuchal rigidity before lumbar puncture was done. Of the 297 patients, 93 had evidence of nuchal rigidity on physical examination. Of the 80 patients with meningitis ($\geqslant 6$ WBCs/mL of CSF), 24 had nuchal rigidity (sensitivity, 30%); of the 217 patients without meningitis, 148 did not have nuchal rigidity (specificity, 68%) (table 3). Of the 93 patients with nuchal rigidity, 24 had CSF evidence of meningitis (positive predictive value, 26%); of the 204 patients without nuchal rigidity, 148 did not have meningitis (negative predictive value, 73%). The LR^+ for nuchal rigidity was 0.94, the LR^-

Table 1. Baseline characteristics of and clinical presentation for 297 patients with suspected meningitis.

Characteristic	Patients without meningitis	Patients with meningitis[a]	All patients
At baseline			
Age, median years (range)	41 (18–93)	37 (22–92)	40 (18–93)
No. (%) of patients >60 years old	37/217 (17)	9/80 (11)	46/297(15)
Sex, *n*/*N* (%)			
Male	97/217 (45)	37/80 (46)	134/297 (45)
Female	120/217 (55)	43/80 (54)	163/297 (55)
Ethnicity, *n*/*N* (%)			
White	104/217 (48)	51/80 (64)	155/297 (52)
Black	68/217 (31)	21/80 (26)	89/297 (30)
Hispanic	40/217 (18)	7/80 (9)	47/297 (16)
Other	5/217 (2)	1/80 (1)	6/297 (2)
Immunocompetence, *n*/*N* (%)			
Unimpaired	162/217 (75)	63/80 (79)	225/297 (76)
Immunocompromised			
HIV positive	38/217 (18)	12/80 (15)	50/297 (17)
Immunosuppressed	17/217 (8)	5/80 (6)	22/297 (7)
Clinical presentation, *n*/*N* (%)			
Clinical history[b]			
Headache[c]	168/207 (81)	69/75 (92)	237/282 (84)
Fever	144/216 (67)	55/78 (71)	199/294 (68)
Nausea and vomiting[d]	113/213 (53)	54/77 (70)	167/290 (58)
Photophobia	105/206 (51)	43/75 (57)	148/281 (53)
Stiff neck	97/217 (45)	38/79 (48)	135/296 (46)
Focal motor deficit	20/210 (10)	5/78 (6)	25/288 (9)
Focal sensory deficit	11/206 (5)	2/76 (3)	13/282 (5)
Seizure	12/214 (6)	7/79 (9)	19/293 (6)
Signs			
Temperature >38°C	112/217 (52)	34/80 (43)	146/297 (49)
Glasgow Coma Scale score <13	16/217 (7)	8/80 (10)	24/297 (8)
Nuchal rigidity	69/217 (32)	24/80 (30)	93/297 (31)
Kernig's sign[e]	8/171 (5)	3/66 (5)	11/237 (5)
Brudzinski's sign[e]	8/170 (5)	3/66 (5)	11/236 (5)
CSF analysis findings			
WBC count, mean WBCs/mL (±SD)	1 (±1)	359 (±1543)	97 (±813)
Protein level, mean mg/dL (±SD)[f]	44 (±37)	90 (±102)	57 (±65)
Glucose level, mean mg/dL (±SD)	69 (±28)	64 (±40)	68 (±32)

NOTE. Because of rounding, the sum of percentages may not be 100%.
[a] Defined as ⩾6 WBCs/mL of CSF.
[b] Clinical history data were not available for some patients.
[c] Statistically significant difference between patients with and patients without meningitis; $P = .028$.
[d] Statistically significant difference between patients with and patients without meningitis; $P = .009$.
[e] *N* is the no. of patients examined before lumbar puncture was done.
[f] Statistically significant difference between patients with and patients without meningitis; $P = .0002$.

was 1.02, and LR^+:LR^- was 0.92. The combination of meningeal signs (i.e., positive results of examination for Kernig's sign, Brudzinski's sign, or nuchal rigidity) had diagnostic values that were virtually identical to those of nuchal rigidity alone (sensitivity, 30%; specificity, 67%; positive predictive value, 25%; negative predictive value, 72%; LR^+, 0.92; LR^-, 1.04; LR^+:LR^-, 0.88).

Diagnostic accuracy of meningeal signs in patients with

Table 2. Probability of meningitis for patients with different combinations of clinical symptoms characteristic of meningitis.

Symptoms	Pretest odds of meningitis[a]	Likelihood ratio for a positive test result[b]	Posttest odds of meningitis[c]
Headache and fever	.37	1.14	.42
Headache, nausea, and vomiting	.37	1.32	.49
Headache, fever, nausea, and vomiting	.37	1.50	.56
Headache, fever, nausea, vomiting, and photophobia	.37	1.45	.54
Headache, fever, nausea, vomiting, photophobia, and stiff neck	.37	1.54	.57

[a] Calculated by dividing the no. of patients with meningitis by the no. of patients without meningitis. In this cohort, the pretest odds of meningitis were .37 (80/217).
[b] Calculated by dividing the sensitivity by the false-positive error rate.
[c] Calculated by multiplying the pretest odds by the likelihood ratio for a positive test result.

more-severe meningitis. The diagnostic accuracy of Kernig's sign (LR^+, 2.07; LR^-, 0.96; LR^+:LR^-, 2.15) and that of Brudzinski's sign (LR^+, 2.06; LR^-, 0.95; LR^+:LR^-, 2.17) were only marginally better in the subset of patients ($n = 29$) with moderate meningeal inflammation (⩾100 WBCs/mL of CSF) (table 4). The same was true for the subset of patients ($n = 18$) with microbiological evidence of CSF infection (for Kernig's sign, LR^+, 3.3; LR^-, 0.90; and LR^+:LR^-, 3.6 and for Brudzinski's sign, LR^+, 1.46; LR^-, 0.97; and LR^+:LR^-, 1.5) (data not shown).

Kernig's sign and Brudzinski's sign did not accurately identify patients with severe meningeal inflammation (⩾1000 WBCs/mL of CSF) (table 5). However, clinical evidence of meningeal inflammation, as manifested by nuchal rigidity, did accurately identify all 4 patients with CSF leukocytosis ⩾1000 WBCs/mL (table 5). In this small subset of patients, the diagnostic accuracy values of nuchal rigidity were as follows: sensitivity, 100%; specificity, 70%; positive predictive value, 4%; negative predictive value, 100%; LR^+, 3.3; and LR^-, 0. LR^+:LR^- approached infinity.

DISCUSSION

In this prospective study, the 3 classic meningeal signs—Kernig's sign, Brudzinski's sign, and nuchal rigidity—were of limited clinical diagnostic value for adults with suspected meningitis. None of these meningeal signs were able to accurately discriminate patients with meningitis (⩾6 WBCs/mL of CSF) from those without it. Furthermore, no significant correlation existed between these meningeal signs and moderate meningeal inflammation (⩾100 WBCs/mL of CSF) or between these meningeal signs and microbiological evidence of CSF infection. Only for the 4 patients with severe meningeal inflammation (⩾1000 WBCs/mL of CSF) did nuchal rigidity have 100% sensitivity, 100% negative predictive value, and LR^+:LR^- that approached infinity.

In 1909, Brudzinski reported that, for patients with bacterial or tuberculous meningitis, Kernig's sign was 57% sensitive, and Brudzinski's nape-of-the-neck sign was 96% sensitive [5]. Since then, the presence of these clinical signs has been interpreted as evidence of meningeal inflammation. Despite the absence of rigorous evaluation of their diagnostic utility for almost 100 years, Kernig's and Brudzinski's signs are still widely used to assess the risk of meningitis.

Current data on the diagnostic accuracy of Kernig's and Brudzinski's signs are limited. One study reported sensitivity

Table 3. Diagnostic accuracy of Kernig's sign, Brudzinski's sign, and nuchal rigidity for patients with suspected meningitis who were examined for any of these 3 signs before lumbar puncture was done.

Sign	No. of patients		
	With meningitis[a]	Without meningitis	All
Kernig's[b]			
Present	3	8	11
Absent	63	163	226
Brudzinski's[c]			
Present	3	8	11
Absent	63	162	225
Nuchal rigidity[d]			
Present	24	69	93
Absent	56	148	204

NOTE. LR^-, likelihood ratio for a negative test result; LR^+, likelihood ratio for a positive test result.
[a] Defined as ⩾6 WBCs/mL of CSF.
[b] Sensitivity, 5%; specificity, 95%; positive predictive value, 27%; negative predictive value, 72%, LR^+, 0.97; LR^-, 1.0; ratio of LR^+ to LR^-, 0.97.
[c] Sensitivity, 5%; specificity, 95%; positive predictive value, 27%; negative predictive value, 72%; LR^+, 0.97; LR^-, 1.0; ratio of LR^+ to LR^-, 0.97.
[d] Sensitivity, 30%; specificity, 68%; positive predictive value, 26%; negative predictive value, 73%; LR^+, 0.94; LR^-, 1.02; ratio of LR^+ to LR^-, 0.92.

Table 4. Diagnostic accuracy of Kernig's sign, Brudzinski's sign, and nuchal rigidity for 29 patients with moderate meningeal inflammation.

Sign	No. of patients		
	With moderate meningeal inflammation[a]	Without moderate meningeal inflammation	All
Kernig's[b]			
Present	2	9	11
Absent	21	205	226
Brudzinski's[c]			
Present	2	9	11
Absent	21	204	225
Nuchal rigidity[d]			
Present	15	78	93
Absent	14	190	204

NOTE. LR^-, likelihood ratio for a negative test result; LR^+, likelihood ratio for a positive test result.

[a] Defined as ⩾100 WBCs/mL of CSF.

[b] Sensitivity, 9%; specificity, 96%; positive predictive value, 18%; negative predictive value, 91%; LR^+, 2.07; LR^-, 0.96; ratio of LR^+ to LR^-, 2.15.

[c] Sensitivity, 9%; specificity, 96%; positive predictive value, 18%; negative predictive value, 91%; LR^+, 2.06; LR^-, 0.95; ratio of LR^+ to LR^-, 2.17.

[d] Sensitivity, 52%; specificity, 71%; positive predictive value, 16%; negative predictive value, 93%; LR^+, 1.77; LR^-, 0.68; ratio of LR^+ to LR^-, 2.6.

values for Kernig's sign (36%) and Brudzinski's sign (39%) that are significantly higher than the 5% sensitivity observed in our cohort [7]. However, in that study, few patients ($n = 36$) were tested for the presence of meningeal signs, and the study's retrospective data collection was subject to bias, because tests for meningeal signs may have been performed after the results of lumbar puncture were known. A second smaller study, which prospectively evaluated 54 patients with fever and recent-onset headache [8], reported sensitivity and specificity values for Kernig's sign (8.8% and 100%, respectively) similar to those observed in our cohort (5% and 95%, respectively).

In the present study, the sensitivity of both Kernig's sign and Brudzinski's sign was 5%, which suggests that these bedside diagnostic tools did not reliably identify the need for lumbar puncture among patients with meningitis. Although the specificity of both signs was 95%, the high specificity values were a result of the overall paucity of positive results of examination for Kernig's sign and Brudzinski's sign, rather than a reflection of the discriminating ability of these indicators. The positive and negative predictive values for Kernig's sign (27% and 72%, respectively), Brudzinski's sign (27% and 72%, respectively), and nuchal rigidity (26% and 73%, respectively) also indicate that none of the classic meningeal signs were clinically discriminating indicators of the presence or absence of meningitis.

Among patients with meningitis (⩾6 WBCs/mL of CSF), the LR^+ for all 3 meningeal signs was <1; therefore, the posttest probability of meningitis, after examination for these signs was done, was less than the pretest probability. In addition, LR^+:LR^- for all 3 meningeal signs was <1. Statistical literature has suggested that diagnostically useful tests have LR^+:LR^- >50. [9]. Therefore, the finding of low values for LR^+:LR^- is additional evidence that these diagnostic signs do not help the clinician to identify patients who have meningitis. The minimal overlap ($n = 4$) between patients who had Kernig's sign ($n = 11$) and those who had Brudzinski's sign ($n = 11$) suggests that examining physicians evaluated each meningeal sign independently and that results of examination for one meningeal sign did not influence the results of examination for another.

The results of the present study demonstrate that the diagnostic accuracy of Kernig's sign and Brudzinski's sign was poor for patients with moderate meningeal inflammation (⩾100 WBCs/mL of CSF), patients with severe meningeal inflammation (⩾1000 WBCs/mL of CSF), and patients with microbiological evidence of CSF infection. LR^+:LR^- was not >10 for either Kernig's sign or Brudzinski's sign in any of these 3 subsets of patients. Therefore, our data suggest that, even for cases of meningitis that appeared to be more severe on the basis of laboratory evidence, Kernig's sign and Brudzinski's sign were of little diagnostic value.

Nuchal rigidity was the only meningeal sign that proved to have clinically useful discriminating power. For the 4 patients with ⩾1000 WBCs/mL of CSF, nuchal rigidity was 100% sen-

Table 5. Diagnostic accuracy of Kernig's sign, Brudzinski's sign, and nuchal rigidity for 18 patients with severe meningeal inflammation.

Sign	No. of patients		
	With severe meningeal inflammation[a]	Without severe meningeal inflammation	All
Kernig's[b]			
Present	0	11	11
Absent	4	222	226
Brudzinski's[c]			
Present	1	10	11
Absent	3	222	225
Nuchal rigidity[d]			
Present	4	89	93
Absent	0	204	204

NOTE. LR^-, likelihood ratio for a negative test result; LR^+, likelihood ratio for a positive test result.

[a] Defined as ⩾1000 WBCs/mL of CSF.

[b] Sensitivity, 0%; specificity, 95%; positive predictive value, 0%; negative predictive value, 98%; LR^+, 0; LR^-, 1.04; ratio of LR^+ to LR^-, 0.

[c] Sensitivity, 25%; specificity, 96%; positive predictive value, 9%; negative predictive value, 99%; LR^+, 5.6; LR^-, 0.78; ratio of LR^+ to LR^-, 7.2.

[d] Sensitivity, 100%; specificity, 70%; positive predictive value, 4%; negative predictive value, 100%; LR^+, 3.3; LR^-, 0; ratio of LR^+ to LR^- approaches infinity.

sitive and had a negative predictive value of 100%. Additionally, in this subset of patients, $LR^+:LR^-$ approached infinity. Therefore, among patients with severe meningeal inflammation, nuchal rigidity was found to have clinically useful discriminating power. This finding is consistent with the general findings of Brudzinski—namely, that meningeal signs can identify cases of severe meningeal inflammation.

In our cohort, only 1 of 4 patients with severe meningeal inflammation had bacterial meningitis. There were 2 other patients with proven bacterial meningitis, both of whom had CSF WBC counts <1000. Therefore, although nuchal rigidity accurately identified patients who had severe meningeal inflammation, it failed to identify 2 of 3 patients with bacterial meningitis in our cohort.

Two additional findings are worth noting. First, our data are consistent with a recently published meta-analysis [4] showing that clinical symptoms do not reliably identify patients who have meningitis. In our study, the highest probability of meningitis for any combination of clinical symptoms (including fever, headache, photophobia, stiff neck, nausea, and vomiting) was 0.57. Second, our data suggest that bacterial meningitis is uncommon, even among adults in whom meningitis is suspected on the basis of historical features. In our cohort of 297 adults with suspected meningitis, bacterial meningitis was diagnosed on the basis of a positive CSF culture for only 3 patients (1%). This finding, coupled with the risks associated with a lumbar puncture [10, 11], highlights the need for more-reliable clinical means of assessing the likelihood of meningitis.

Our study was the first to prospectively determine the diagnostic accuracy of Kernig's sign, Brudzinski's sign, and nuchal rigidity in adults with suspected meningitis. The prospective nature of the study ensured that tests for meningeal inflammation were not influenced by knowledge of laboratory results. Clinically suspected meningitis was chosen as the primary enrollment criterion, so that the entire severity spectrum of clinical disease would be included and the possibility of spectrum bias would be reduced [12, 13].

Despite its strengths, our study had limitations. Diagnostic tests in general and physical examination findings in particular are subject to individual interpretation and interobserver variability [14–16]. In the present study, descriptions of Kernig's and Brudzinski's signs were not explicitly given to physicians before physical examinations were performed; thus, the manner in which these meningeal signs were evaluated was not standardized. However, this was intentional and was designed to reflect actual clinical practice and to enable a determination of the diagnostic accuracy of these meningeal signs as they are currently used in a busy emergency department. Therefore, our observations will be generalizable to other emergency department settings in which adults with suspected meningitis are evaluated.

Although our study suggests that the classic meningeal signs do not reliably identify patients with meningitis, it does not indicate the reason. Given the design of the current study, several possibilities exist: that the diagnostic signs are incorrectly evaluated, that they are associated with poor interobserver reliability, or simply that these meningeal signs are poor diagnostic tools. Future studies that standardize examination and interpretation of these diagnostic signs and evaluate interobserver reliability will further clarify the findings of this initial study.

The sensitivity of Kernig's and Brudzinski's signs was first established nearly 100 years ago for patients with severe bacterial or tuberculous meningitis. Today, the evaluation of patients with suspected meningitis is complicated by a number of factors, including immunocompromise, a broad spectrum of clinical disease, and a variety of causative pathogens. Although the results of the present study substantiate the general conclusions of Brudzinski—that bedside meningeal signs can identify patients with severe meningeal inflammation—they also demonstrate that these diagnostic tools are too insensitive to identify the majority of patients with meningitis in contemporary practice (including patients with microbiologically treatable disease). Clinical decisions regarding further diagnostic testing and the need for a lumbar puncture should not rely solely on the presence or absence of these meningeal signs. Better bedside diagnostic tests are needed.

References

1. Quagliarello VJ, Scheld WM. Treatment of bacterial meningitis. N Engl J Med **1997**; 336:708–16.
2. Durand ML, Calderwood SB, Weber DJ, et al. Acute bacterial meningitis in adults: a review of 493 episodes. N Engl J Med **1993**; 328:21–8.
3. Aronin SI, Peduzzi P, Quagliarello VJ. Community-acquired bacterial meningitis: risk stratification for adverse clinical outcome and effect of antibiotic timing. Ann Intern Med **1998**; 129:862–9.
4. Attia J, Hatala R, Cook DJ, Wong JG. Does this adult patient have acute meningitis? JAMA **1999**; 282:175–81.
5. Verghese A, Gallenmore G. Kernig's and Brudzinski's signs revisited. Rev Infect Dis **1987**; 9:1187–92.
6. Hasbun R, Abrahams J, Jekel J, Quagliarello VJ. Computed tomography of the head before lumbar puncture in adults with suspected meningitis. N Engl J Med **2001**; 345:1727–33.
7. Elmore JG, Horwitz RI, Quagliarello VJ. Acute meningitis with a negative Gram's stain: clinical and management outcomes in 171 episodes. Am J Med **1996**; 100:78–84.
8. Uchihara T, Tsukagoshi H. Jolt accentuation of headache: the most sensitive sign of CSF pleocytosis. Headache **1991**; 31:167–71.
9. Jekel JF, Elmore JG, Katz DL. Epidemiology, biostatistics, and preventative medicine. Philadelphia: WB Saunders, **1996**.
10. Evans RW. Complications of lumbar puncture. Neurol Clin **1998**; 16:83–105.
11. Practice parameters: lumbar puncture (summary statement). Report of the Quality Standards Subcommittee of the American Academy of Neurology. Neurology **1993**; 43:625–7.
12. Ransohoff DF, Feinstein AR. Problems of spectrum and bias in evaluating the efficacy of diagnostic tests. N Engl J Med **1978**; 299:926–30.

13. Lachs MS, Nachamkin I, Edelstein PH, Goldman J, Feinstein AR, Schwartz JS. Spectrum bias in the evaluation of diagnostic tests: lessons from the rapid dipstick test for urinary tract infection. Ann Intern Med **1992**; 117:135–40.
14. Elmore JG, Wells CK, Lee CH, Howard DH, Feinstein AR. Variability in radiologists' interpretations of mammograms. N Engl J Med **1994**; 331:1493–9.
15. Wipf JE, Lipsky BA, Hirschmann JV, et al. Diagnosing pneumonia by physical examination. Arch Intern Med **1999**; 159:1082–7.
16. Lok CE, Morgan CD, Ranganathan N. The accuracy and interobserver agreement in detecting the "gallop sounds" by cardiac auscultation. Chest **1998**; 114:1283–8.