COMPUTED TOMOGRAPHY OF THE HEAD BEFORE LUMBAR PUNCTURE IN ADULTS WITH SUSPECTED MENINGITIS

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ABSTRACT

Background In adults with suspected meningitis clinicians routinely order computed tomography (CT) of the head before performing a lumbar puncture.

Methods We prospectively studied 301 adults with suspected meningitis to determine whether clinical characteristics that were present before CT of the head was performed could be used to identify patients who were unlikely to have abnormalities on CT. The Modified National Institutes of Health Stroke Scale was used to identify neurologic abnormalities.

Results Of the 301 patients with suspected meningitis, 235 (78 percent) underwent CT of the head before undergoing lumbar puncture. In 56 of the 235 patients (24 percent), the results of CT were abnormal; 11 patients (5 percent) had evidence of a mass effect. The clinical features at base line that were associated with an abnormal finding on CT of the head were an age of at least 60 years, immunocompromise, a history of central nervous system disease, and a history of seizure within one week before presentation, as well as the following neurologic abnormalities: an abnormal level of consciousness, an inability to answer two consecutive questions correctly or to follow two consecutive commands, gaze palsy, abnormal visual fields, facial palsy, arm drift, leg drift, and abnormal language (e.g., aphasia). None of these features were present at base line in 96 of the 235 patients who underwent CT scanning of the head (41 percent). The CT scan was normal in 93 of these 96 patients, yielding a negative predictive value of 97 percent. Of the three misclassified patients, only one had a mild mass effect on CT, and all three subsequently underwent lumbar puncture, with no evidence of brain herniation one week later.

Conclusions In adults with suspected meningitis, clinical features can be used to identify those who are unlikely to have abnormal findings on CT of the head. (N Engl J Med 2001;345:1727-33.)

COMMUNITY-acquired bacterial meningitis is a medical emergency; early diagnosis and therapy reduce morbidity and mortality.[1-3] The diagnosis of meningitis requires an analysis of cerebrospinal fluid, but in the case of adult patients, clinicians routinely order computed tomography (CT) of the head before performing lumbar puncture in order to identify occult intracranial abnormalities and thus avoid the risk of brain herniation resulting from the removal of cerebrospinal fluid.[4-8] We investigated whether the absence of certain clinical features at base line could be used to identify adults with suspected meningitis who were unlikely to have abnormal findings on CT of the head.

METHODS

Patients

Adults (defined as persons older than 16 years of age) with clinically suspected meningitis who were seen in the emergency department of Yale–New Haven Hospital from July 1995 to June 1999 were eligible for enrollment whether or not they underwent CT of the head before undergoing lumbar puncture. After screening 511 patients, we excluded 210 for the following reasons: 101 were identified in the emergency department after CT of the head had been performed; 38 were identified after they had been discharged from the emergency department; 36 did not undergo lumbar puncture despite having a normal result on CT of the head; 11 had undergone CT, but the scan had been lost and the results could not be verified by an independent neuroradiologist; 11 had been enrolled in the study during a previous episode; 5 underwent CT before the collection of base-line data was complete; 4 underwent CT before they arrived at the emergency department; 2 underwent CT for a suspected stroke rather than for suspected meningitis; and 2 declined to participate. A total of 301 were therefore enrolled in the study. Informed consent was obtained from all enrolled patients in accordance with the guidelines of the Human Investigation Committee at Yale University School of Medicine.

Collection of Data

The patients' base-line characteristics were recorded in the emergency department before CT of the head and lumbar puncture were performed. Information was collected on sociodemographic characteristics; coexisting conditions (measured with use of the Charlson comorbidity index[9]); the presence or absence of immunocompromise, clinical features, and various neurologic abnormalities[10,11]; laboratory results; and management decisions. The information was obtained by a clinician in the emergency department or by a study investigator. Information regarding clinical status was available one week after study entry in the case of 293 patients.

Eleven elements of the Modified National Institutes of Health (NIH) Stroke Scale were used to evaluate patients for neurologic abnormalities, as described previously.[12] The following elements, with the score assigned for each answer given in parentheses, were assessed: level of consciousness (0, alert; 1, obtunded or not alert; and 2, unresponsive), questions (0, answers two consecutive questions correctly; 1, answers one correctly; and 2, answers neither correctly), commands (0, performs two consecutive tasks correctly; 1, performs one task correctly; and 2, performs neither task correctly), gaze (0, normal; 1, partial gaze palsy; and 2, total gaze palsy), visual fields (0, no visual loss; 1, partial hemianopsia; 2, complete hemianopsia; and 3, bilateral hemianopsia), facial palsy (0, absent; 1, minor paralysis; 2, partial paralysis; and 3, complete paralysis), motor arm (0, no drift; 1, drift before 5 seconds; 2, falls before 10 seconds; 3, no effort against gravity; and 4, no movement), motor

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leg (0, no drift; 1, drift before 5 seconds; 2, falls before 10 seconds; 3, no effort against gravity; and 4, no movement), ataxia (0, absent; 1, in one limb; and 2, in two limbs), sensory (0, normal; 1, mild loss; and 2, severe loss), aphasia (0, absent; 1, mild aphasia; 2, severe aphasia; and 3, mute), dysarthria (0, absent; 1, mild; and 2, severe), and extinction (0, normal; 1, mild; and 2, severe).

Interpretation of CT Scans

CT was performed with the use of a GE Hilight Advantage scanner (GE Medical Systems, Milwaukee), and the results were interpreted by staff neuroradiologists who had no knowledge of the patients' clinical findings. An independent neuroradiologist reviewed all CT scans. The two neuroradiologists were in agreement in the case of all but three scans; disagreements were resolved by a third neuroradiologist. The CT results were categorized as normal (or showing atrophy only), as showing a focal abnormality with (or without) a mass effect, or as showing a nonfocal abnormality with (or without) a mass effect. A mass effect was categorized on the basis of the degree of effacement of sulci, cisterns, and ventricles, as mild (effacement of less than 50 percent), moderate (effacement of 50 percent or more), or severe (effacement of 50 percent or more plus a midline shift).

Statistical Analysis

After descriptive analyses had been conducted, we conducted univariate regression analyses of base-line clinical features with respect to the target outcome (abnormal findings on CT). Clinically plausible base-line variables that were significantly associated with abnormal findings on CT were used to identify a subgroup of patients with a low likelihood of such abnormal findings. The chi-square test, Fisher's exact test, Student's t-test, and the Wilcoxon test were used. All reported P values are two-sided.

RESULTS

Base-Line Characteristics

The base-line characteristics of the 301 adults with suspected meningitis are shown in Table 1. The cohort consisted primarily of young adults (median age, 40 years), but 16 percent (47 of 301) were at least 60 years of age; 52 percent were white. Coexisting conditions were present in 81 patients (27 percent), 25 patients (8 percent) had a history of central nervous system disease, and 75 patients (25 percent) were immunocompromised; infection with the human immunodeficiency virus (HIV) was the most common cause of immunocompromise. Most patients presented with headache (79 percent) and fever (67 percent). A total of 149 patients (50 percent) had photophobia, 137 (46 percent) described a stiff neck, and 21 (7 percent) had had a seizure within one week before presentation.

Most patients (91 percent) had a normal level of consciousness (as defined by a score of 14 or 15 on the Glasgow Coma Scale). A minority of patients (50 of 301, or 17 percent) had a focal abnormality on neurologic examination with use of the Modified NIH Stroke Scale, 5 percent had Kernig's sign or Brudzinski's sign, and 1 patient had papilledema. The patient with papilledema had HIV-associated cerebral toxoplasmosis; CT revealed a severe mass effect, and the patient died of brain herniation without undergoing lumbar puncture.

A median of 7 minutes (range, 1 to 30) was necessary for the enrolling physician to perform the neurologic examination using the Modified NIH Stroke Scale. Laboratory evaluation revealed that 80 patients (27 percent) had objective evidence of meningitis (defined by the presence of more than 5 white cells per milliliter of cerebrospinal fluid), 18 patients (6 percent) had a pathogen identified on the basis of cerebrospinal fluid analysis, and 20 patients (7 percent) had a positive blood culture.

Results of CT and Clinical Outcome

Decisions made by physicians in the emergency department and the clinical status of patients one week after study entry are shown in Table 2. Of the 301 patients with suspected meningitis, 235 (78 percent) underwent CT of the head before undergoing lumbar puncture. Most patients (52 percent) were hospitalized, and 124 patients (41 percent) received empirical antibiotic therapy for meningitis. A total of 249 patients (83 percent) were evaluated by postgraduate residents, and 52 (17 percent) were evaluated by attending physicians. The percentage of patients for whom a CT scan was ordered did not differ significantly between those who were treated by residents and those who were treated by attending physicians (193 of 249 [78 percent] and 42 of 52 [81 percent], respectively; $P=0.60$). The percentage of CT scans with abnormal findings was similar among scans ordered by residents and scans ordered by attending physicians (47 of 193 [24 percent] and 9 of 42 [21 percent], respectively; $P=0.70$). Among the 201 physicians who were surveyed, 119 (59 percent) stated that their primary reason for ordering a CT scan of the head was their suspicion that a focal brain abnormality was present, 68 (34 percent) ordered the scan because they viewed it as the standard of care, and 10 (5 percent) stated that fear of litigation was their primary reason for ordering the scan; 4 ordered scans for a combination of reasons.

Of the 235 patients who underwent CT of the head, 179 patients (76 percent) had normal results (Table 3). Of the 56 patients (24 percent) with abnormal results, 29 (12 percent) had a focal abnormality without a mass effect, 12 (5 percent) had a nonfocal abnormality without a mass effect, and 4 (2 percent) had a combination of focal and nonfocal abnormalities without a mass effect. Only 11 patients (5 percent) had evidence of a mass effect on CT of the head: 9 had a focal abnormality with a mass effect, and 2 had a nonfocal abnormality with a mass effect. Of the five patients who had meningitis due to a documented bacterial cause, only two underwent CT of the head; one patient had normal results, and the other had nonfocal abnormalities without a mass effect.

The mean time from admission to the emergency department to lumbar puncture was 5.3 hours (range, 0.9 to 20.5) for patients who underwent CT before

TABLE 1. CHARACTERISTICS OF THE 301 PATIENTS WITH SUSPECTED MENINGITIS.*

CHARACTERISTIC	VALUE
Age — yr	
Median	40
Range	18–93
Age ≥60 yr — no. (%)	47 (16)
Sex — no. (%)	
Female	166 (55)
Male	135 (45)
Race or ethnic group — no. (%)	
White	157 (52)
Black	90 (30)
Hispanic	48 (16)
Other	6 (2)
Coexisting conditions — no. (%)	
Charlson comorbidity index score >1	81 (27)
History of CNS disease (mass lesion, stroke, or focal infection)	25 (8)
Immunocompromised state	75 (25)
HIV or AIDS	53 (18)
Immunosuppressive therapy	18 (6)
Transplantation	4 (1)
Symptoms at presentation — no. (%)	
Headache	239 (79)
Fever	202 (67)
Photophobia	149 (50)
Stiff neck	137 (46)
Focal motor symptom	27 (9)
Focal sensory symptom	15 (5)
Seizure within 1 wk before presentation	21 (7)
Signs and laboratory data at presentation — no. (%)	
Temperature >100.4°F	149 (50)
Normal level of consciousness (Glasgow Coma Scale >13)	274 (91)
Papilledema	1 (<1)
>5 White cells/ml of CSF	80 (27)
Pathogen identified in CSF†	18 (6)
Pathogen identified in blood‡	20 (7)

CHARACTERISTIC	VALUE
Neurologic findings — no. (%)§	
Alert	256 (85)
Answers two questions correctly	249 (83)
Follows two commands correctly	260 (86)
Gaze palsy	7 (2)
Abnormal visual fields	7 (2)
Facial palsy	10 (3)
Supranuclear	8 (3)
Peripheral	2 (1)
Arm drift	25 (8)
Leg drift	37 (12)
Limb ataxia	5 (2)
Abnormal sensation	11 (4)
Aphasia	34 (11)
Dysarthria	36 (12)
Extinction	31 (10)
Final clinical diagnoses — no. (%)	
Meningitis¶	83 (28)
Aseptic	55 (18)
Microbiologically documented pathogen in CSF	18 (6)
Associated with other CNS disease‖	8 (3)
Associated with bacteremia	2 (1)
Enterococcus	1 (<1)
Streptococcus pneumoniae	1 (<1)
Headache	70 (23)
Other CNS disease**	27 (9)
Viral syndrome	22 (7)
Pneumonia	20 (7)
Bacteremia	15 (5)
Sinusitis	13 (4)
Other††	51 (17)

*CNS denotes central nervous system, HIV human immunodeficiency virus, AIDS acquired immunodeficiency syndrome, and CSF cerebrospinal fluid.

†Pathogens identified in CSF included enterovirus in eight patients, varicella–zoster virus in one, *Cryptococcus neoformans* in six, *Neisseria meningitidis* in two, and *Streptococcus pneumoniae* in one.

‡Pathogens identified in blood included *Staphylococcus aureus* in three patients, *Strep. pneumoniae* in four, *Salmonella enterica* serotype enteritidis in three, enterococcus in two, *Escherichia coli* in two, *C. neoformans* in two, veillonella in one, coagulase-negative staphylococci in one, group A streptococcus in one, and group B streptococcus in one.

§Neurologic status was determined with use of the Modified National Institutes of Health Stroke Scale.

¶Three patients with *C. neoformans* in CSF had 5 or fewer white cells per milliliter of CSF.

‖Other CNS diseases included CNS lymphoma in two patients, grand mal seizure in two, CNS toxoplasmosis in one, subarachnoid hemorrhage in one, brain abscess in one, and metastatic carcinoma in one.

**Other CNS diseases included grand mal seizure in six patients, stroke in six, brain tumor in four, hypertensive encephalopathy in two, CNS toxoplasmosis in two, delirium in two, progressive multifocal leukoencephalopathy in two, hydrocephalus in one, HIV-related vacuolar myelopathy in one, and multiple sclerosis in one.

††Other diagnoses included urinary tract infection in eight patients; fever of unknown origin in six; pharyngitis in five; influenza in three; Lyme disease in three; systemic lupus erythematosus, infectious mononucleosis, Bell's palsy, otitis media, Rocky Mountain spotted fever, and drug toxicity in two patients each; and multiple myeloma, syncope, culture-negative endocarditis, sepsis syndrome, herpes simplex genitalis, cellulitis, neck sprain, rheumatoid arthritis, Crohn's disease, rhabdomyolysis, cholecystitis, alcohol withdrawal, vestibular neuritis, and carbon monoxide poisoning in one patient each.

undergoing lumbar puncture, as compared with a mean of 3.0 hours (range, 0.7 to 14.6) for patients who did not undergo CT ($P<0.001$). In the case of 124 patients who received empirical antibiotics, the mean (±SD) time from admission to the emergency department to the initiation of empirical therapy was 3.8±2.9 hours for the patients who underwent CT before undergoing lumbar puncture, as compared with 2.9±2.0 hours for the patients who did not undergo CT ($P=0.09$).

One week after lumbar puncture, the clinical status of 232 patients was normal, 51 patients had a persistent headache, and 6 patients (2 percent) had a residual neurologic deficit (Table 2). Four patients (1 percent) died. The clinical status of eight patients was not known.

TABLE 2. PHYSICIANS' DECISIONS IN THE EMERGENCY DEPARTMENT AND THE CLINICAL OUTCOME OF 301 ADULTS WITH SUSPECTED MENINGITIS.

VARIABLE	NO. OF PATIENTS (%)
Physicians' decisions	
Obtain CT of the head before performing lumbar puncture	235 (78)
Hospitalize patient	156 (52)
Institute empirical antibiotic therapy	124 (41)
Patients' clinical status 1 wk after study entry*	
Normal	232 (77)
Persistent headache	51 (17)
Neurologic deficit	6 (2)
Death†	4 (1)
Data unavailable	8 (3)

*The clinical status of four patients who did not undergo lumbar puncture was assessed one week after CT; the clinical status of all other patients was assessed one week after lumbar puncture.

†The causes of death were brain herniation in two patients, aspiration pneumonia with respiratory failure in one, and varicella–zoster virus pneumonia in one.

TABLE 3. RESULTS OF CT OF THE HEAD IN 235 ADULTS WITH SUSPECTED MENINGITIS.

RESULT	NO. OF PATIENTS (%)
Normal*	179 (76)
Abnormal†	56 (24)
Focal lesion without mass effect	29 (12)
Nonfocal lesion without mass effect	12 (5)
Focal lesion with mass effect‡	9 (4)
Nonfocal lesion with mild mass effect	2 (1)
Combinations of focal and nonfocal lesions without mass effect	4 (2)

*The total includes patients with cerebral atrophy.

†Nonfocal abnormalities included subarachnoid hemorrhage, meningeal enhancement, and hydrocephalus. Focal abnormalities included stroke, mass lesion, and disease of the periventricular white matter.

‡The mass effect was mild or moderate in six patients and severe in three patients.

Associations between Clinical Characteristics and Abnormal Findings on CT of the Head

Among the patients who underwent CT of the head, those who were at least 60 years of age ($P<0.001$), those who were immunocompromised ($P=0.01$), those who had a history of a central nervous system disease ($P<0.001$), and those who had had a seizure within one week before presentation ($P<0.001$) were significantly more likely to have abnormal findings on CT than patients without these characteristics at base line (Table 4). With respect to neurologic findings at base line, patients who had an abnormal level of consciousness ($P<0.001$), those who were unable to answer two consecutive questions correctly ($P<0.001$), those who were unable to follow two consecutive commands correctly ($P<0.001$), and those with gaze palsy ($P=0.003$), abnormal visual fields ($P<0.001$), facial palsy ($P<0.001$), arm drift ($P<0.001$), leg drift ($P<0.001$), or abnormal language (i.e., aphasia, dysarthria, or extinction) ($P<0.001$) were more likely than patients without these neurologic findings to have abnormal results on CT of the head (Table 4). Base-line features that were not associated with a significant risk of abnormal findings on CT included race or ethnic group, insurance status, presence or absence of a history of parameningeal disease (i.e., sinusitis, otitis, mastoiditis, or a dental procedure) within two months before presentation, and mean blood pressure.

Identification of a Subgroup with a Low Likelihood of Abnormal Findings on CT

The base-line clinical characteristics that were associated with an increased likelihood of abnormal findings on CT of the head were used to identify a subgroup of patients with a decreased likelihood of having abnormal findings on CT. As shown in Table 5, of the 235 patients with suspected meningitis who underwent CT before undergoing lumbar puncture, 96 patients (41 percent) had none of these characteristics at base line. Among these 96 patients, the results of CT were normal in 93 (97 percent) and abnormal in 3 (3 percent) (2 patients had no mass effect — 1 had a focal and 1 had a nonfocal abnormality — and 1 had hydrocephalus and a mild mass effect). Therefore, only 1 of the 96 patients had a CT scan that revealed a mass effect; the 10 other patients with a mass effect on CT were identified on the basis of the presence of one or more of the significant clinical features at base line.

Among the 235 patients with suspected meningitis who underwent CT, 4 patients (2 percent) — 3 with a severe mass effect and 1 with a mild mass effect — had abnormal findings that caused the clinician to avoid lumbar puncture. All four patients had one or more of the significant clinical characteristics at base line. Two of the patients with a severe mass effect died of brain herniation within one week after undergoing CT despite the fact that they had never undergone lumbar puncture. Of 289 patients in whom lumbar puncture was performed and for whom follow-up data were available one week later (including 5 patients with a mild mass effect and 2 patients with a moderate mass effect on CT of the head), none had herniation.

DISCUSSION

A diagnosis of meningitis requires a lumbar puncture to confirm the presence of inflammatory cells in

TABLE 4. ASSOCIATIONS BETWEEN BASE-LINE CLINICAL CHARACTERISTICS AND ABNORMAL FINDINGS ON CT OF THE HEAD IN 235 ADULTS WITH SUSPECTED MENINGITIS.*

BASE-LINE CHARACTERISTIC	TOTAL NO. OF PATIENTS	NO. OF PATIENTS WITH ABNORMAL FINDINGS ON CT	RISK RATIO (95% CI)	P VALUE
Age ≥60 yr	42	27	4.3 (2.9–6.4)	<0.001
Immunocompromised state†	70	24	1.8 (1.1–2.8)	0.01
History of CNS disease‡	25	20	4.8 (3.3–6.9)	<0.001
Seizure within 1 wk before presentation	21	13	3.2 (2.1–5.0)	<0.001
Neurologic findings				
Abnormal level of consciousness	44	24	3.3 (2.2–4.4)	<0.001
Inability to answer two questions correctly	49	28	3.8 (2.5–5.8)	<0.001
Inability to follow two commands correctly	40	25	3.9 (2.6–5.9)	<0.001
Gaze palsy	7	5	3.2 (1.9–5.4)	0.003
Abnormal visual fields	7	6	4.0 (2.7–5.9)	<0.001
Facial palsy	10	10	4.9 (3.8–6.3)	<0.001
Arm drift	25	18	4.0 (2.7–5.8)	<0.001
Leg drift	34	24	4.4 (3.0–6.5)	<0.001
Abnormal language§	44	28	4.3 (2.9–6.5)	<0.001

*CI denotes confidence interval, and CNS central nervous system.

†This category includes patients with human immunodeficiency virus infection or acquired immunodeficiency syndrome, patients who were receiving immunosuppressive therapy, and patients who had undergone transplantation.

‡The CNS diseases consisted of mass lesion, stroke, and focal infection.

§The abnormalities consisted of aphasia, dysarthria, and extinction.

the cerebrospinal fluid, to identify the infecting pathogen, and to guide antimicrobial therapy.[13,14] However, because of the potential risks of lumbar puncture, CT of the head is now widely used to identify patients in whom lumbar puncture should be avoided.

In this study of 301 adults with suspected meningitis, the majority (78 percent) underwent CT of the head before they had a lumbar puncture. Specific base-line characteristics could be used to identify a subgroup of patients who were unlikely to have abnormalities on CT of the head. Among the 56 patients with abnormal findings on CT, 4 patients had a mass effect that prompted clinicians to avoid lumbar puncture, and 2 of these 4 patients subsequently had brain herniation. The remaining 52 patients with abnormal results on CT underwent lumbar puncture, and one week later, none had had brain herniation.

Although the clinical presentation of our cohort was typical of that of adults with suspected meningitis, the cohort had several noteworthy features. The median age was 40 years, but 16 percent of patients were at least 60 years of age and 25 percent were immunocompromised. Although most patients had a normal level of consciousness, 17 percent had a focal abnormality on a neurologic examination that used the Modified NIH Stroke Scale. Although meningitis was the primary reason for lumbar puncture in all patients, only 27 percent had documented evidence of meningitis (i.e., more than 5 white cells per milliliter of cerebrospinal fluid).

TABLE 5. IDENTIFICATION OF THE SUBGROUP OF ADULTS WITH SUSPECTED MENINGITIS WHO HAVE A DECREASED LIKELIHOOD OF HAVING ABNORMAL FINDINGS ON CT OF THE HEAD.

PRESENCE OF ANY BASE-LINE CHARACTERISTIC*	RESULT ON CT OF THE HEAD†		
	NORMAL	ABNORMAL	TOTAL
	no. of patients (%)		
No	93 (97)	3 (3)	96 (100)
Yes	86 (62)	53 (38)	139 (100)
Total	179 (76)	56 (24)	235 (100)

*The characteristics consisted of age of at least 60 years, immunocompromised state, history of a central nervous system disease, and seizure within one week before presentation, and the following abnormalities: abnormal level of consciousness, inability to answer two consecutive questions correctly, inability to follow two consecutive commands correctly, gaze palsy, abnormal visual fields, facial palsy, arm drift, leg drift, and abnormal language.

†$P<0.001$ for the comparison between the proportion of abnormal scans among those who had a base-line characteristic (53 abnormal of 139 predicted to be abnormal [38 percent]) and the proportion of abnormal scans among those who did not have a base-line characteristic (93 normal of 96 predicted to be normal [97 percent]).

Our policy of including all adults with suspected meningitis allowed us to make two important observations. First, the percentage of adults with suspected meningitis who underwent CT of the head before undergoing lumbar puncture in the emergency department was high (78 percent). Second, the mean

time from admission to the emergency department to lumbar puncture was significantly longer for patients who first underwent CT than for patients who did not first undergo CT (5.3 vs. 3.0 hours, $P<0.001$). There was also a trend toward a longer time from admission to the initiation of empirical antibiotic therapy for patients who underwent CT before undergoing lumbar puncture. The absence of a significant difference in this interval between the two groups may be accounted for by the common practice of initiating antibiotic therapy before performing lumbar puncture in patients with suspected meningitis. Nonetheless, the significant delay in lumbar puncture caused by CT can affect other management decisions (e.g., whether or not to hospitalize a patient) and unnecessarily prolongs a patient's stay in the emergency department.

In most cases (76 percent), the results of CT of the head were normal. Of the 56 patients with abnormal results, only 11 had abnormalities associated with a mass effect, and only 4 (2 percent of the 235 patients who underwent CT) had abnormalities that caused the clinician to avoid lumbar puncture. Baker et al. reported similar results in a study that included a more heterogeneous cohort of adults.[15]

Our study has several advantages over previous studies.[15,16] First, our prospective approach allowed us to collect data on patients before CT was performed. Second, the base-line characteristics that we identified as being associated with an increased likelihood of abnormal findings on CT of the head are clinically plausible and easy to assess in the emergency department. Third, the neurologic findings that we identified as being associated with an increased risk of abnormalities on CT were assessed with use of the Modified NIH Stroke Scale, which has a high rate of interobserver agreement.[12,17] Finally, all CT scans were reviewed by an independent neuroradiologist to verify the abnormalities and determine whether a mass effect was present.

In identifying a subgroup of patients with a decreased likelihood of having abnormal findings on CT of the head, we used all 13 significant base-line characteristics for two reasons. First, we wanted to include the clinical features that practicing physicians would consider to be associated with an abnormal finding on CT of the head in patients with suspected meningitis. Second, since the ultimate goal is to reduce the number of unnecessary CT scans, we wished to identify a combination of features that had a high negative predictive value. As shown in Table 5, the absence of the significant clinical features at base line had a negative predictive value of 97 percent. Of the three patients who were misclassified with the use of these characteristics, only one patient had a mild mass effect, and all three patients underwent lumbar puncture without subsequent brain herniation.

Our study has limitations. Because it was conducted at a single institution, our findings will require validation in an independent cohort with different demographic features in other geographic areas.[18] However, the base-line characteristics associated with an abnormal CT are clinically plausible and the statistical associations were robust, so our data should be generalizable. Although the negative predictive value of our approach was not 100 percent, the three patients who were misclassified underwent lumbar puncture without subsequent brain herniation. Furthermore, this approach identified all three of the patients with a severe mass effect on CT (two of whom subsequently had brain herniation in the absence of lumbar puncture).

Our findings indicate that adults with suspected meningitis who have none of the significant base-line features that we identified are good candidates for immediate lumbar puncture, since they have a low risk of brain herniation as a result of lumbar puncture. The use of this approach in our cohort would have decreased the frequency of CT by 41 percent. Patients who have any of the base-line clinical features we identified should undergo CT after blood has been drawn for culture and empirical antibiotic therapy has been initiated. Our findings should inspire confidence on the part of clinicians that the risk of lumbar puncture is negligible in such patients, even in those with a mild or moderate mass effect on CT of the head. Future studies will be needed to validate our results in other geographic areas, to determine their value with respect to reducing medical and legal concerns among physicians, and to assess their ability to reduce unnecessary costs and delays in the diagnosis and treatment of meningitis.

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