Fatal Lumbar Puncture: Fact Versus Fiction—An Approach to a Clinical Dilemma

William J. Oliver, MD, FAAP*; Thomas C. Shope, MD, FAAP*; and Lawrence R. Kuhns, MD, FACR‡

ABSTRACT. Recent reports and commentaries have emphasized the alleged risk of cerebral herniation complicating lumbar puncture performed to diagnose acute bacterial meningitis. Instead, knowledge of facts relevant to the disease process can provide a rational and reassuring approach to management. All cases of purulent meningitis are associated with increased intracranial pressure, but herniation is a rare complication (5%). Despite suggestions to the contrary, cranial computed tomography (CT) is normal in most cases of purulent meningitis, including those with subsequent herniation. Additionally, CT may be associated with long-term radiation effects. An accurate clinical history combined with recognition of the early systemic and neurologic findings of bacterial meningitis will indicate a safe setting for performance of a diagnostic lumbar puncture with little likelihood of complicating herniation. In contrast, in patients in whom the disease process has progressed to the neurologic findings associated with impending cerebral herniation, a delay of the diagnostic procedure is indicated. In this latter circumstance, a different approach in management can be developed. *Pediatrics* **2003;112:e174–e176. URL: http://www.pediatrics.org/cgi/content/full/112/3/e174;** ***lumbar puncture, computed tomography.***

ABBREVIATIONS. CSF, cerebrospinal fluid, CT, computed tomography; ICP, intracranial pressure.

Failure to make the diagnosis of bacterial meningitis promptly may result in death or severe, disabling neurologic sequelae. For the diagnosis, cerebrospinal fluid (CSF) obtained by lumbar puncture is required. However, in recent years a number of reports and commentaries have emphasized the alleged risk of cerebral herniation complicating diagnostic lumbar puncture.[1–4] As a consequence of this concern, cranial computed tomography (CT) has been recommended as a wise precaution before lumbar puncture to predict and to avoid a high likelihood of complicating cerebral herniation. This line of reasoning has led to confusion among physicians and resulted in an increasing number of CT examinations performed before a lumbar puncture is considered to be a safe procedure. A further consideration is the increasing concern for the long-term risk of radiation-induced fatal cancer associated with use of CT in the pediatric population.[5,6] Facts and practices pertinent to this multifaceted clinical dilemma should be clearly understood by physicians to develop a rational approach when confronted with the patient for whom a diagnostic lumbar puncture is indicated. It is the intent of this commentary to provide information relevant to this bacterial disease process and its management.

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EVERY CASE OF PURULENT MENINGITIS IS ASSOCIATED WITH INCREASED INTRACRANIAL PRESSURE (ICP)

In the initial phase of bacterial meningitis, the protective defenses provided by the skull, the pia, arachnoid and dural meninges covering the brain, and the blood-brain barrier have been breached by the offending pathogen. Bacterial products initiate a host cytokine response.[7] These inflammatory mediators lead to altered vascular permeability (edema) and endothelial damage (intravascular clotting and occlusion) as well as to the recruitment of additional inflammatory cells. Inflammatory cells elaborate toxins directed at bacteria, but the cellular toxins also incidentally damage mammalian cells, leading to brain cell destruction and more edema.

The accumulated increase of intracranial contents results in an acute rise of ICP. One impressive manifestation of this increase in pressure is separation of the cranial sutures. In one report separation of the cranial sutures occurred in 9 of 24 subjects with acute bacterial meningitis between the ages of 2 months and 4 years.[8] This was evident within 2 days of onset of symptoms in one 4-month old infant and by 4 days of symptoms in 4 additional subjects. Minns et al[9] documented significant elevation in CSF pressure (median: 204 mm water) in 33 of 35 infants and children with pyogenic meningitis, and Dodge and Swartz[10] recorded even higher mean levels (median: 307 mm water) on the day of admission in 106 patients. Importantly, Minns reported that despite the high pressures no complications developed subsequent to the lumbar puncture and there were no fatalities.

OPENING PRESSURES ARE RARELY OBTAINED DURING LUMBAR PUNCTURE FOR SPINAL FLUID EXAMINATION

Spinal fluid opening pressures are almost never obtained during routine efforts to diagnose meningitis. The reason usually cited is the difficulty in quieting a frightened, struggling child who is being forcibly held in a curled up, probably painful position. Pressures obtained under these conditions would be difficult or impossible to interpret.

HERNIATION IS A RARE COMPLICATION OF BACTERIAL MENINGITIS

Dodge and Swartz[10] examined this potential problem carefully. In 207 patients with bacterial meningitis, brain herniation was considered to be a contributing factor or directly responsible for death in 9 of 30 fatal cases (4.3%). In another series, Rennick et al[11] reported herniation in 19 of 445 patients (4.3%). Although herniation was observed to occur within 3 hours of the lumbar puncture in 8 children, the authors noted that in 6 of those, the neurologic status indicated that the procedure should have been delayed. Among 302 infants and children with bacterial meningitis, Horowitz et al[12] found an incidence of 6% of cerebral herniation, as determined by their definition of the complication, in 3 of 10 fatal cases and in 15 surviving patients but could confirm the diagnosis by pathologic correlation in only 1 patient.

CT IS NORMAL IN MOST CASES OF PURULENT MENINGITIS, INCLUDING THOSE INVOLVING SUBSEQUENT HERNIATION

In a prospective study of acute bacterial meningitis in infants and children older than 2 months of age, CT scans were normal in 30 of 43 patients with proven bacterial meningitis.[13] The authors stated: "In our unselected series, no clinically significant CT abnormalities were found that were not suspected on clinical assessment." Haslam[14] concluded that CT is not helpful in the diagnosis of uncomplicated bacterial meningitis as results are normal in most cases. Others have concurred.[15] Rennick et al[11] found that CT was normal in 5 of 14 children at or about the time of their hernation. Similar data of normal CT examinations have been reported in adults with bacterial meningitis.[16–19] Pertinently, Larsen and Goldstein[20] noted: "It is important to remember that computed tomography (CT) does not measure intracranial pressure (ICP), and there may be clinically significant increased ICP in the absence of any abnormality on a CT scan." Addition of intravenous contrast does not increase sensitivity of the examination.[13,14]

CT EXAMINATION RISKS A DELAY IN START OF ANTIMICROBIAL MANAGEMENT OF MENINGITIS

Talan et al[21] retrospectively reviewed medical records of 122 patients admitted for suspected bacterial meningitis. Interposition of CT scanning before lumbar puncture delayed initiation of antibiotic therapy by an average of 2 hours. Similar data on delay of initiation of treatment were reported by Gopal et al[17] and Linden et al.[22] In the hospital setting of the study reported by Talan et al, CT scanning was available 24 hours a day. Even in settings where CT examination can be completed in 15 to 20 minutes, there is always the possibility of unexpected delay.

POSSIBLE RADIATION EFFECT OF CT IMAGING

CT is a high-dose radiation procedure. In an adult, a single abdominal CT scan gives an effective radiologic dose equal to 500 chest radiographs.[6] For pediatric patients, as detailed by Hall,[6] several factors amplify the adverse consequences. First, children are more radiosensitive. A 1-year-old child is 10 to 15 times more likely to develop a malignancy as a 50-year-old adult secondary to the same radiologic dose. Second, the proximity of nearby internal tissues and organs to the cranial CT imaging site results in greater radiation to nearby structures such as the thyroid. Finally, the short exposure time required for helical CT with little or no need for a sedative leads to the temptation for its use as a screening procedure. This is suggested by the estimate that 2.7 million CT scans were performed on children under 15 years of age in the year 2000.[6]

Based on over 50 years of observation of the long-term carcinogenic effects resulting from atomic bombs dropped on Hiroshima and Nagasaki, Japan, the lifetime cancer mortality risk calculated to be attributable to the radiation of a single abdominal CT study in a 1-year-old is in the order of 1 in 550.[5] For a cranial CT, the risk is about one-third that value. However, the risk of radiation hazard associated with cranial CT is augmented by recent data suggesting that brain tissue is far more radiosensitive than previously thought.[23]

Thus, the ease of ordering a CT study and its relatively rapid and atraumatic execution should not blunt recognition of the possible long-term radiation consequences.

DISCUSSION AND SUGGESTED APPROACH TO THE INDICATIONS AND TIMING FOR PERFORMING A LUMBAR PUNCTURE IN SUSPECTED MENINGITIS

There is no substitute for a complete, accurate history and a careful physical examination with particular attention to the neurologic examination. The history can delineate the duration of the illness and associated symptoms. For example, a brain tumor and brain abscess give symptoms over weeks and months while meningitis is an acute disease with a short history. The examination can define the extent of the neurologic abnormalities resulting from the inflammatory process and associated increased ICP. The findings can correctly guide the physician in reaching a decision of indications or contraindications for immediate lumbar puncture.

The basic elements of the early clinical features of bacterial meningitis are fever and inconsolable irritability. Findings of meningeal irritation (stiff neck, positive Kernig's sign, positive Brudzinski's sign) and a dulled sensorium may also be present. Occurrence of a short (<15 minute), generalized clonic-tonic convulsion further underscores the likelihood of a central nervous system infection. At this phase of the disease, the brain edema is generalized and the later findings associated with impending cerebral herniation are absent. A diagnostic lumbar puncture can be appropriately performed with the assurance that a complicating cerebral herniation would be an unlikely possibility.

In performing the lumbar puncture, care should be taken to avoid extreme flexion of the spine with resultant compromise of the cardiopulmonary status. In some critically ill patients, there may be a need for supplementary oxygen and/or parenteral fluids dur-

ing the procedure. Removal of spinal fluid should be performed slowly using a small caliber needle (22–25 gauge). Generally 2 to 3 mL is sufficient for the required studies.[12] Measurement of initial spinal fluid pressure provides useful information, but the need to obtain spinal fluid for study has a first priority.

Progression of the cascade of pathologic events occurring within the central nervous system during the course of bacterial meningitis results in further increases in cerebral swelling and ICP. The clinical features become more ominous. The heightened cerebral edema is manifested by increasing stupor progressing to coma while neurologic signs resulting from compression of the temporal lobes, cerebellum, and associated structures are reflected by focal neurologic findings. The latter include 1) dilated and/or fixed pupils; 2) paralyses of the 3rd and 6th nerves, resulting in fixed deviations of the eyes; 3) change in muscle tone with decorticate or decerebrate posture or hemiparesis; and 4) respiratory abnormalities characterized by Cheyne-Stokes respiration, hyperventilation, or apnea. Serial assessments using the Glasgow Coma Scale can augment other clinical observations.

At this phase of the disease, the diagnosis of cerebral herniation usually can be made. Recall that herniation is not common and is reported in ~5% of cases of acute bacterial meningitis.[10–12,14] On review of the several series of pediatric patients for whom this diagnosis was made, the neurologic picture is quite distinct.[11,12] It is characterized by a usually comatous state, rarely only stuporous, and accompanied by readily evident cranial nerve and postural abnormalities. Convulsions often precede a terminal respiratory arrest. Prospectively, criteria for the clinical diagnosis of cerebral herniation include the presence of altered consciousness (stupor or coma) and 2 or more focal neurologic signs.[11–13] In this clinical circumstance a lumbar puncture could result in an acute change of pressure dynamics in the CSF system with potential herniation. In fact, delay in performing a diagnostic lumbar puncture may be life saving.[14] Instead, a blood culture should be drawn and antimicrobials appropriate for age, season, and presenting features should be administrated. In addition, immediate measures to monitor and reduce ICP should be initiated.

In addition to findings of cerebral herniation, lumbar puncture is also contraindicated in the presence of papilledema. A further contraindication is the patient whose clinical status is precarious as a result of septic shock.

On initial consideration a cranial CT would seem to be an appropriate and potentially useful diagnostic study for confirming the diagnosis of cerebral herniataion. The fallacy in this assessment has been emphasized by the finding that no clinically significant CT abnormalities are found that are not suspected on clinical assessments.[11,13] Further, as previously noted, a normal CT examination may be found at about the time of a fatal herniation.[11] Thus, the practical usefulness of a cranial CT in the majority of pediatric patients is limited to those rare patients whose increased ICP is secondary to mass lesions, not in the initial approach to acute meningitis.

Finally, is there any usefulness of CT in the management of bacterial meningitis? For the patient whose response to therapy is atypical with late persistence of fever or development of neurologic signs, CT may identify subdural effusions, brain abscesses or brain parenchymal changes. Although these abnormalities may be detected by CT, specific intervention is seldom useful.[24]

We hope these comments provide a rational approach to the diagnosis of meningitis in children with a minimum of extra procedures and without an untimely delay in instituting appropriate management.

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