

Personal Practice

Potential Risk of Fatal Cerebral Herniation After Lumbar Puncture in Suspected CNS Infection

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Abstract

Lumbar puncture is important in the investigation of suspected CNS infection. However, there is genuine concern and controversy about the risk of cerebral herniation after lumbar puncture. CT scan brain is widely performed before lumbar puncture whenever raised intracranial pressure is suspected. The pros and cons of interposition of CT scanning before lumbar puncture pose a clinical dilemma and have led to confusion among paediatricians and even a delay in initiation of therapy. CT scan brain only provides structural information and is considered insensitive in the exclusion of raised intracranial pressure. Clinical signs, not a CT scan brain, are the best indicators of when to or when not to do lumbar puncture. To exercise caution, relevant questions need to be addressed before performing a lumbar puncture. Literature is reviewed regarding lumbar puncture and cerebral herniation. The aim is to formulate a rational approach in managing children with suspected CNS infection.

Key words

Cerebral herniation; Children; Lumbar puncture

Introduction

Cerebral herniation after lumbar puncture is a nightmare for every paediatrician. The event is catastrophic and often fatal. As a consequence of this concern, CT scan brain has been widely recommended before lumbar puncture, whenever raised intracranial pressure is suspected. However, the pros and cons of interposition of CT scanning before lumbar puncture pose a clinical dilemma and have led to confusion among paediatricians and might even result

in a delay in initiation of therapy. Relevant literature regarding cerebral herniation and lumbar puncture are appraised with the aim to formulate a rational approach in the management of children with suspected CNS infection.

Lumbar puncture has been used extensively in the investigation of many neurological conditions. Cerebrospinal fluid analysis and culture is the definitive method of diagnosing CNS infection. Lumbar puncture is mandatory in any patients in whom meningitis is suspected.¹ However, there is an increasing anxiety that this procedure carries risk in cerebral herniation. Knowledge of facts relevant to disease process leading to cerebral herniation is helpful. The seven questions that paediatricians need to address before performing lumbar puncture are: (1) Is lumbar puncture indicated? (2) Are there any contraindications for lumbar puncture? (3) What are the precautions when one performs lumbar puncture? (4) Is neuro-imaging required before the procedure? (5) What is the risk of cerebral herniation in CNS infection and its relationship to lumbar puncture? (6) How can one recognise cerebral herniation? If cerebral herniation does occur, what are the subsequent measures? (7) If lumbar puncture is not considered safe, what should be done?

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(1) Is Lumbar Puncture Indicated?

The basic elements of clinical features of bacterial meningitis are fever, inconsolable irritability, findings of meningeal irritation such as neck stiffness and a dull sensorium. However, the "classical signs" of meningitis are often absent in infants. Lumbar puncture is advocated for any infant who is drowsy or ill without awaiting development of meningeal signs.² Lumbar puncture is recommended (Evidence rating: Level A) in the evaluation of viral encephalitis.³ Lumbar puncture should only be delayed in the presence of straight contraindications.^{4,5} Cultures of CSF after parental antibiotics have been given are sterile within 2 hours in meningococcal and 6 hours after pneumococcal meningitis.⁶ Cellular and biochemical changes remain in the CSF only up to 44-68 hours after antibiotics are started.⁷ Blood culture is positive in 40-50% meningococcal meningitis and 80% in pneumococcal meningitis.⁷ The information obtained can guide subsequent management. Avoiding lumbar puncture can result in missing the exact bacterial cause of meningitis and the antibiotic susceptibility.

(2) Are There Any Contraindications for Lumbar Puncture?

In the presence of contraindications, lumbar puncture should not be performed. There are eight commentaries found in the literature concerning when to do or when not

to do lumbar puncture in suspected meningitis.^{4,5,8-13} Lumbar puncture should be deferred if there are signs of incipient cerebral herniation. There is some mild disagreement on what exact level of Glasgow coma score (GCS) would contraindicate lumbar puncture. Some debate exists as to whether GCS <13 or 12 is a more appropriate cut-off.^{14,15} Deteriorating conscious level is more commonly agreed as a contraindication.¹³ Decerebrate posturing, may be mistaken as tonic seizures, indicates early brain herniation and definitely contraindicates lumbar puncture. Neck rigidity can be one of the signs of herniation through foramen magnum. Meningococcal infection with purpuric rash is considered by some workers to be a contraindication because of cardio-respiratory compromise and impending cerebral oedema.^{16,17} Papilloedema is uncommon in meningitis as it may take at least 24-48 hours to develop in raised intracranial pressure. Its absence does not mean it is safe to do lumbar puncture. Normal CT scan brain does not mean it is safe to do lumbar puncture (details will be discussed in subsequent text). Clinical signs, not a CT scan brain, are the best indicators of when to or when not to do lumbar puncture.¹² Table 1 provides a summary of general recommended contraindications of lumbar puncture.

(3) What Are the Precautions When One Performs Lumbar Puncture?

In some ill patients, there may be a need for supplementary oxygen and parenteral fluid during the

Table 1 Contraindications for lumbar puncture^{4,5,8,10,13-15}

Parameters

Level of consciousness abnormal (GCS <13)
Deteriorating conscious level
Dilated or fixed or unequal pupils
Fixed deviation of eyes and/or absent doll's eyes reflex
Decorticate or decerebrate posturing
Focal neurological signs
Respiratory abnormalities including Cheynes-Stokes, hyperventilation, or apnoea
Papilloedema
Seizures-prolonged or recent (within 30 minutes) or focal or tonic
Hypertension with bradycardia
Bleeding tendencies
Cardiorespiratory compromise
Local infection in the area of needle
When CT brain shows features of raised ICP (see further discussion) or space occupying lesion

****Normal CT scan brain does not mean it is safe to do lumbar puncture**

procedure. Care should be taken to avoid excessive flexion that might compromise cardiorespiratory status. A small caliber needle should be used. The smallest sample volume should be obtained whenever possible. Opening pressure provides important information.¹² Vital monitoring of patients during the procedure is crucial. The detection of an elevated opening pressure in a well-sedated patient should alert the adoption of subsequent remedial measures to reduce intracranial pressure.

(4) Is Neuroimaging Required Before Lumbar Puncture?

When one considers CT scan, we have to remember that the procedure is associated with risks of high-dose radiation. Children are more radiosensitive than adults.¹⁸ Brain tissue is far more radiosensitive than previously thought, thus the risk of long-term radiation cannot be ignored.¹⁹ CT scan brain is considered unhelpful as it is normal in 69.8% of uncomplicated cases of acute bacterial meningitis.²⁰ No clinically significant CT scan abnormalities were found that was not unsuspected on clinical assessment.²⁰ CT scan brain only provides structural information and does not measure intracranial pressure. Structural information characterising brain shift anatomically provided by CT scan brain from which pressure data must be inferred are: "tense dura, flattened gyri, narrowed sulci, effaced cisterns, compressed ventricles and displacement of brain" (Table 2).^{21,22} CT scan brain is an insensitive method for exclusion of raised intracranial pressure. Talan et al reviewed 122 patients admitted for suspected acute bacterial meningitis. Interposition of CT scan brain before lumbar puncture delayed initiation of antibiotics therapy by an average of 2 hours.²³ Rennick et al found that CT scan brain was normal in 5 of the 14 children at or about time of herniation.²⁴ Several reasons have been proposed to explain why CT scan brain cannot reliably detect cerebral herniation. (i) Considerable variability in the size of normal lateral

ventricles. (ii) Purulent material may prevent narrowing of the subarachnoid and ventricular spaces. (iii) Meningeal hardening from inflammation may cause decreased meningeal compliances.¹³ A prospective study involving 301 adults with suspected meningitis confirmed that clinical features could be used to identify patients who are likely to have abnormal CT scan findings. Predictors of abnormal findings included: immuno-compromised status, presence of signs that are suspicious of space-occupying lesions, or moderate-to-severe impairment of consciousness (Table 3).²⁵ The overall clinical impression made by physicians was shown to have the highest predictive value in identifying patients with CT-defined contraindications to lumbar puncture (Likelihood ratio LR 18.8).²⁶ Neuroimaging is advised in diseases mimicking meningitis, e.g., posterior fossa tumour, acute hydrocephalus, cerebral abscess and intracranial hemorrhage (Table 4).²⁷ In children, failure to respond to treatment is another indication for neuroimaging, even though there is seldom any specific intervention.²⁸ CT scan brain is considered not helpful in the management of uncomplicated meningitis.⁹ There is no substitute for a complete, accurate history and physical examination. The findings can correctly guide us in reaching a decision of whether to do or delay lumbar puncture.¹² For children indicated for neuroimaging, they should be stabilised prior to the procedure and properly escorted with adequate monitoring of vital functions when performing CT scan brain.

(5) What Is the Risk of Cerebral Herniation in CNS Infection and Its Relationship to Lumbar Puncture?

Brain herniation was considered to be a contributory factor in 30% of fatal cases of acute bacterial meningitis.^{29,30} A retrospective review of 300 children with acute bacterial meningitis, 18 (6%) had episode of cerebral herniation diagnosed clinically and accountable for at least 20% of

Table 2 Structural information provided by CT brain from which pressure data must be inferred^{13,21,22}

CT scan abnormalities

- Lateral shift of midline structures indicating unequal supratentorial ICP
- Loss of suprachiasmatic and basilar cisterns
- Lateral ventricles may be small or in setting of obstructive hydrocephalus, they may be large
- Obliteration or shift of the fourth ventricles
- Obliteration of the superior cerebellar and quadrigeminal plate cisterns indicating upward cerebellar herniation

mortality.³⁰ Intracranial pressure is usually elevated in acute bacterial meningitis. Minns et al, found 33 (94%) of 35 children with acute bacterial meningitis had raised intracranial pressure, with a median opening pressure of 15 mmHg.³¹ Raised intracranial pressure by itself does not cause herniation. One of the advocated treatments

of benign intracranial pressure is CSF drainage through repeated lumbar punctures. Regardless of intracranial pressure, lumbar puncture can only result in herniation if brain shift is present, i.e. when there are differences in pressure between different brain compartments. Herniation can occur at two sites, the cerebellar tonsils

Table 3 Predictors of abnormal neuroimaging findings constituting contraindications for LP^{4,13,20,21,25,26}

Children	Adult
1. Glasgow coma scale <8	1. Age ≥ 60 (Probably because of associated comorbid state, history of CNS disease)
2. Prolonged tonic seizure	2. History of CNS disease (e.g mass lesion, stroke, focal infection)
3. Focal neurologic signs	3. Immunocompromised state e.g HIV infection, immunosuppressive therapy or transplantation
4. Abnormalities in posture and respiratory pattern	4. A history of seizure ≤ 1 week before presentation
5. Pupillary changes	6. Specific abnormal neurological findings <ul style="list-style-type: none"> • Inability to answer 2 consecutive questions correctly • Follow 2 consecutive commands • Gaze palsy • Abnormal visual fields • Facial palsy • Arm drift • Leg drift • Abnormal language
7. Absent oculocephalic reflexes	
8. Papilloedema	

Table 4 Roles of CT brain in the management of children with suspected CNS infections^{1,4,12,13,21,27,28,34}

Roles of CT brain in suspected CNS infection

- CT brain is normal in most cases of purulent meningitis, including those involving subsequent herniation
- The best predictive ability of neuroimaging for brain lesion is anticipated in cases with contraindications for LP
- Indications of CT scan brain in suspected meningitis:
 - ✧ Exclusion of conditions that may mimic bacterial meningitis with raised ICP:
 - Posterior fossa tumours
 - Acute hydrocephalus
 - Cerebral abscess
 - Intracranial bleeding
 - ✧ For the patient with meningitis whose response to therapy is suboptimal or development of neurological signs:
 - Subdural effusions
 - Brain abscesses
 - Brain parenchymal changes

CAVEATS:

- Normal CT brain does not rule out raised ICP
- Normal CT brain does not rule out herniation after LP
- CT examination risks a delay in the start of antimicrobial management of meningitis
- Possible radiation effect of CT imaging

may protrude through foramen magnum or mesial temporal lobes may move downward through tentorial opening. What is the relationship between brain herniation and lumbar puncture? Van Crevel et al noted that lumbar puncture "removes the stopper from below, thus adding to the effects of the compression from above".²¹ There are at least 22 case reports of deterioration and herniation after lumbar puncture.^{13,32-34} The literature provides a strong temporal association between lumbar puncture and cerebral herniation.²⁴ Rennick et al showed that the odds ratio of herniation in the first 12 hours after lumbar puncture was 32.6 (95% CI, 8.5 to 117.3, $P < 0.001$).²⁴ Doing lumbar puncture in the setting of contraindications complete the process of brain herniation.

(6) How Can One Recognise Cerebral Herniation? If Cerebral Herniation Does Occur, What Are the Subsequent Measures?

Physicians should be able to recognise early signs of cerebral herniation after lumbar puncture. Close surveillance of possible herniation is warranted. The diagnosis of cerebral herniation is made by characteristic neurological picture of comatose state, palsy of cranial nerves and postural abnormalities (Table 5).³⁵ Ninety-eight herniation episodes were analysed, 37% of herniation occurred within 3 hours, 41% 4-12 hours of lumbar puncture.^{4,13,24,29,30,36} The overall mortality of cerebral herniation is 56% and half of the survivors had good outcome.^{13,24,37} Many of the survivors had very high intracranial pressure during their treatment course. The literature suggests that herniation in CNS infection is not necessarily dismal. Prompt implementation of interventions to control intracranial pressure and neuro-critical measures is recommended.^{1,38} These include intermittent administration of osmotic diuretics to maintain an intracranial pressure of < 15 mmHg and an optimal cerebral perfusion pressure. Electroencephalographic monitoring

is indicated in patients with seizures or fluctuating consciousness.¹

(7) If Lumbar Puncture Is Not Considered Safe, What Should Be Done?

Empirical antibiotics should be given without delay. Blood for cultures drawn before antibiotics can be positive in 70-80% of patients. Third generation cephalosporin is likely to be adequate.⁴ However, in countries where there is pneumococcal resistance to cephalosporins, vancomycin should be added.³⁹ When viral encephalitis is suspected especially for herpes encephalitis, acyclovir should be commenced. MRI brain can be helpful in differentiating the diagnoses after stabilisation of patients. In patients contraindicated for lumbar puncture, interventions to control raised intracranial pressure, attention to airway, breathing and circulation, together with appropriate antibiotics should be the priorities. Then this is followed by neuro-imaging, not a lumbar puncture, after the child has been stabilised (Figure 1). Patients with CNS infections are advised to be managed in an institution with access to intensive care unit.^{1,3}

Conclusion

The vast majority of patients presenting with CNS infection have no clinical evidence of herniation and routine CT scan brain is not indicated. Lumbar puncture should be done in the absence of contraindications followed by prompt initiation of appropriate antibiotics and in addition acyclovir if herpes encephalitis is suspected. As CT scan brain is not sensitive in the exclusion of raised intracranial pressure, a normal appearance of the CT scan brain does not necessarily mean it is definitely safe to do lumbar puncture. CT scan brain can be normal even in patients with incipient herniation. There is no substitute for a complete, accurate history and thorough examination, especially neurological

Table 5 Clinical features of cerebral herniation^{5,12,24,30,35}

Features of cerebral herniation

- Increasing stupor with progression to coma
- Dilated and/or fixed pupils
- Paralysis of the 3rd and 6th nerves, resulting in fixed deviations of the eyes
- Changes in muscle tone with decorticate or decerebrate posture or hemiparesis
- Respiratory abnormalities characterised by Cheyne-Stokes respiration, hyperventilation or apnoea

examination. However, CT scan brain is indicated in excluding diseases that mimic bacterial meningitis and in a complicated case of meningitis that fails to respond to treatment. The best implication for an abnormal CT scan brain is the ascertainment of significant contraindication for lumbar puncture. Nevertheless, spotting clinical signs of impending herniation are the best indicators of who should not have a lumbar puncture done. To practice as a routine, measurement of opening pressure, proper stabilisation and monitoring of patients during and after

lumbar puncture is important. Most cerebral herniation occurred within twelve hours of lumbar puncture, close surveillance, early recognition and prompt treatment of impending herniation is warranted. Patients with CNS infections are advised to be managed in an institution with access to intensive care unit. For children at risk of cerebral herniation, interventions to control raised intracranial pressure and neurocritical care are crucial. Appropriate therapy should be the priority, followed by urgent neuro-imaging and not a lumbar puncture.

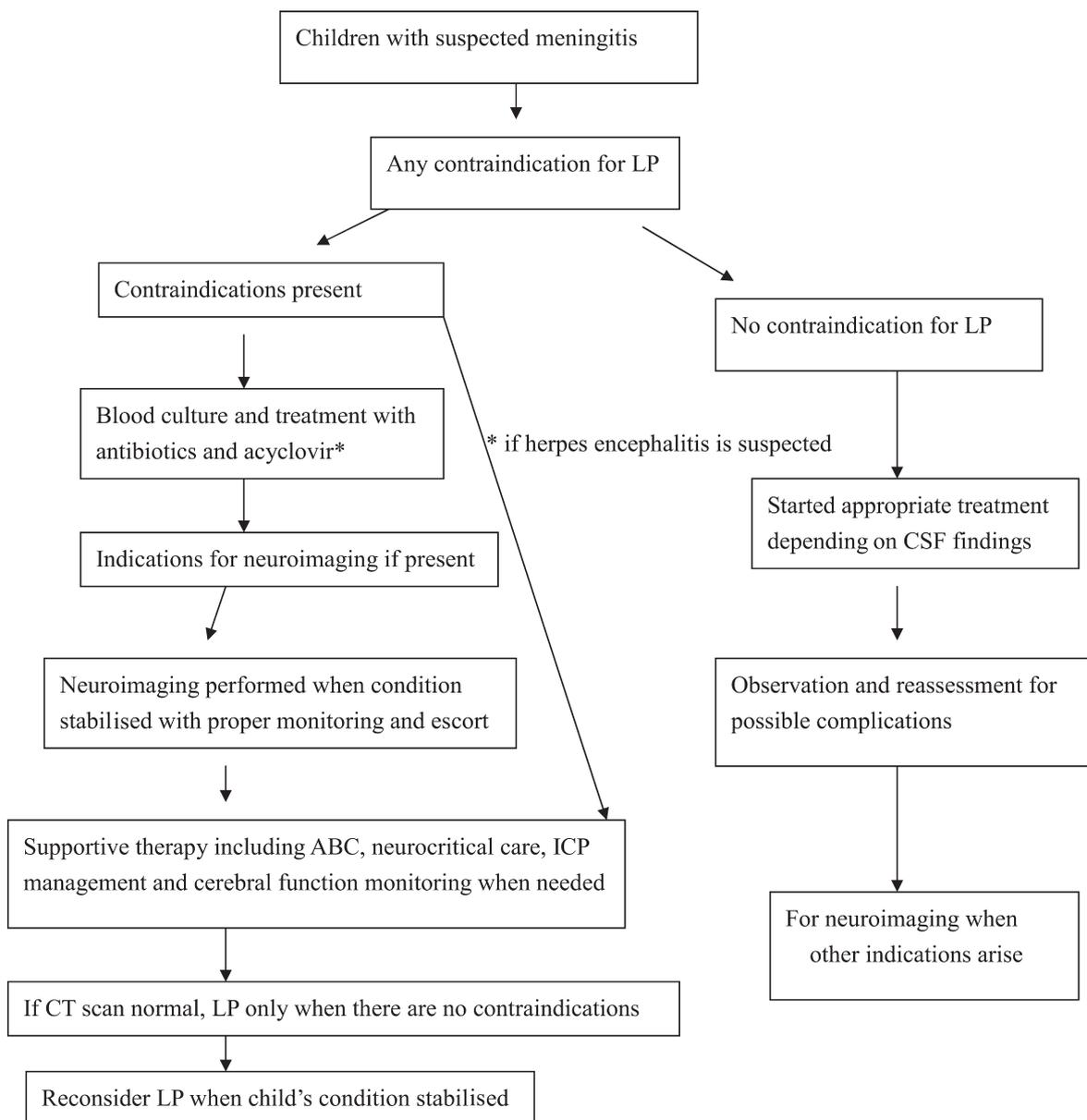


Figure 1 Management algorithm for children with suspected CNS infection, in particular, meningitis.^{1,4,5,13,23}

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