Perils and pitfalls of lumbar puncture in the emergency department

Anna Holdgate and Karyn Cuthbert
Department of Emergency Medicine, St George Hospital, Sydney, New South Wales, Australia

Abstract

Lumbar Puncture is a procedure commonly performed in the emergency department. It provides important diagnostic information but has a significant number of limitations and complications. This article reviews the role of lumbar puncture in the emergency department based on an extensive review of the current literature, focusing on the recognized contraindications and complications of the procedure and how they can be minimized. The interpretation of diagnostic tests performed on cerebrospinal fluid is also examined, highlighting those tests most commonly ordered from the emergency department.

Key words: cerebrospinal fluid, headache, lumbar puncture, meningitis.

Introduction

Lumbar puncture (LP) was first described as a diagnostic test by Quincke in 1891. This procedure is commonly performed in the emergency department (ED) but has associated limitations and morbidity which should be considered prior to LP. This article aims to review the indications, contraindications and complications of this test based on an extensive literature review. The prevention and management of complications and the interpretation of cerebrospinal fluid (CSF) findings will also be discussed.

Indications

The major role for LP in the ED is the diagnosis of infection or bleeding within the central nervous system (CNS). It may also have a role in the diagnosis of CNS malignancy, multiple sclerosis, Guillain–Barre syndrome and other demyelinating CNS disorders.

Since the advent of computed tomography (CT) scanning the use of LP as a diagnostic test has fallen significantly and it is now used predominantly for the investigation of potential CNS infection and as a second-line test for possible subarachnoid haemorrhage.

In the context of meningitis, early LP is helpful (but not essential) to confirm the diagnosis, identify the responsible microorganism and determine antibiotic sensitivities. In patients who have been partially treated with antibiotics or who are immunosuppressed, the clinical features of meningitis may be more subtle and there should be a lower threshold for performing LP in this group. Lumbar puncture is often used as a test of exclusion in the presence of febrile seizures in children, and fever and delirium in the elderly; although the diagnostic yield in these situations is low in the absence of other supportive clinical parameters.
Contraindications

Raised intracranial pressure

The major contraindication to LP is the presence of raised intracranial pressure (ICP), however, most conditions for which LP is undertaken frequently cause elevated ICP and the degree of elevation is often only recognized when the LP is performed. The main risk with LP in the presence of elevated ICP is worsening neurological state due to uncal or cerebellar herniation which may precipitate cardiopulmonary arrest (coning). Numerous case reports of catastrophic deterioration following LP appear in the literature; conversely, there are several large case series of patients with known raised ICP, with or without papilloedema, who underwent LP with only 1–5% of these patients subsequently deteriorating. In most of these studies it is unclear whether deterioration was directly related to LP, and many of the patients had clinical signs highly suggestive of mass lesions and would almost certainly have had a CT scan prior to LP had CT been available at the time.

The necessity of CT scanning prior to LP has been a controversial issue in the past two decades, particularly in the context of possible bacterial meningitis. When the diagnosis of serious CNS infection is clinically suspected, antibiotics should be given prior to both CT and LP. Most patients with suspected meningitis do not require CT prior to LP except in certain clinical situations. Lumbar puncture should be delayed or avoided altogether in patients with focal neurological signs, papilloedema or a significantly altered level of consciousness. Computed tomography scanning should precede LP in patients who have a slowly progressive headache (days to weeks), are immune compromised or have focal craniofacial infection such as sinusitis or otitis (increased risk of cerebral abscess). A normal CT scan does not prove that ICP is also normal. Up to 50% of patients with elevated CSF pressure will have normal CT scans, and a significant number of those with mass lesions on CT will have normal CSF pressure. Specific CT findings which indicate unequal pressures between intracranial compartments and thus indicate a risk of herniation following LP are listed (Table 1). The presence of any of these findings is an absolute contraindication to LP.

Although the presence of papilloedema is considered an absolute contraindication to LP in the context of CNS infection, the absence of papilloedema does not prove that CSF pressure is normal. In acutely raised intracranial pressure, papilloedema is said to be absent in 50% of children and at least 15% of adults; the exact time frame for the development of papilloedema is unclear. Papilloedema is rarely seen in patients with acute bacterial meningitis. In one large case series of patients with acute bacterial meningitis, papilloedema was found in only 2.5% of patients although over 40% had documented elevated CSF pressure. Many of the case reports of coning following LP occurred in patients without papilloedema and in the pre-CT era there were many reports of patients with documented papilloedema who underwent uneventful LP. Despite this, LP should not be performed in the presence of papilloedema, except where the clinical picture is that of benign intracranial hypertension and the CT scan is normal. As the absence of papilloedema does not indicate that CSF pressure will be normal, the other clinical contraindications to LP should be assessed prior to proceeding to LP.

Other contraindications

The other major contraindications to LP are the presence of localized infection at the puncture site, a coagulopathy or a platelet count of less than 50,000. The complications of LP in the presence of these findings will be discussed in the following section.

Complications

Bleeding

Local haemorrhage due to injury to spinal and peri-vertebral veins is a well recognized complication of LP. There are several case reports of spinal canal haematoma following LP, most of these occurred in the presence of thrombocytopenia or anticoagulation therapy. A significant number of cases had neurological impairment which did not improve with surgical evacuation.

<table>
<thead>
<tr>
<th>Table 1. Computed tomography findings that contraindicate lumbar puncture.</th>
</tr>
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<tbody>
<tr>
<td>• Lateral shift of midline structures.</td>
</tr>
<tr>
<td>• Loss of suprachiasmatic or basilar cisterns.</td>
</tr>
<tr>
<td>• Obliteration of fourth ventricle.</td>
</tr>
<tr>
<td>• Obliteration of superior cerebellar/quadrigeminal plate cisterns with sparing of ambient cisterns.</td>
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</tbody>
</table>
Lumbar puncture in ED

Local trauma

Trauma to local structures such as ligaments, periosteum and the intervertebral disc can produce localized back pain and disc herniation. Neurological injuries due to direct damage to the spinal cord or entrapment of nerve roots in the LP needle have also been reported. Although the spinal cord is usually described as terminating at the lower border of the L2 vertebra, this occurs in only 94% of adults with the remainder terminating as low as the middle of the body of L3. Thus, to avoid direct injury to the spinal cord, LP should be performed at the L3–L4 interspace (indicated by a line between the iliac crests) or lower. In neonates the spinal cord terminates at the lower border of L3. Reinsertion of the needle stylet prior to withdrawal should prevent accidental entrapment of nerve roots or arachnoid membrane.

Blood stained CSF due to a ‘traumatic’ tap can cause diagnostic confusion. This will be discussed later. There is no evidence that the use of local anaesthetic increases the risk of a traumatic tap.

Implantation of epidermal cells

Epidermoid tumours are usually rare congenital lesions but can be acquired following LP with a non-styletted needle. Needles without a stylet can introduce a core of epithelial tissue into the spinal canal which subsequently grows to become an encapsulated mass of keratinous cells. This causes a syndrome of back and lower limb pain that develops years after LP and usually requires surgical excision.

Infection

Localized infections such as epidural abscess, discitis and osteomyelitis can occur following LP and the presence of overlying skin infection increases this risk. Central nervous system infections, such as meningitis and encephalitis can develop as a result of LP through infected tissues. Children with bacteremia at the time of LP are also at risk of subsequently developing meningitis; however, suspected bacteremia is not a contraindication to LP because delay in diagnosis of meningitis is a more serious risk than the chance that LP will cause meningitis.

Headache

Post-dural puncture headache (PDPH) is the commonest complication of LP, occurring in up to 46% of patients. Post-dural puncture headache is due to gravity-dependent traction on pain sensitive intracranial structures due to low CSF pressure which occurs when CSF leak at the puncture site is greater than the rate of CSF production. As well as headache, other symptoms of low CSF pressure and stretch of intracranial structures include upper cranial nerve dysfunction such as diplopia, vertigo and hearing loss.

Post-dural puncture headache usually develops within 48 h, but 25% begin more than 3 days after the LP. Most will resolve spontaneously in less than a week, although occasionally the headache may persist for months. The headache is characteristically related to vertical posture and relieved by lying flat; it occurs more commonly in women and in younger adults but infrequently in children.

There are two major factors that determine the frequency of PDPH: the size of the needle and the shape of the needle. Numerous studies have examined the effect of needle size on the incidence of PDPH and all have demonstrated a reduction in the rate of headache when smaller needles are used. The approximate incidence of PDPH for a range of needle sizes is illustrated (Table 2). In vitro studies have also demonstrated a significant reduction in CSF leakage after dural puncture with smaller needles compared with larger needles.

There are two different types of LP needle: those with a sharp beveled cutting tip (Quincke) and those with a round, pencil-point tip with a side hole (Sprotte or Whitacre). In theory, the pencil-point tip is less traumatic as it parts rather than cuts the dural fibres. Several studies looking at the clinical effect of the different needle types have found varying results, most studies show a small reduction in the incidence of PDPH with the atraumatic needle but the impact of the type of needle is much less important than the size of the needle.

<table>
<thead>
<tr>
<th>Needle size</th>
<th>Headache (%)</th>
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<tbody>
<tr>
<td>20 g</td>
<td>30</td>
</tr>
<tr>
<td>22 g</td>
<td>20</td>
</tr>
<tr>
<td>25 g</td>
<td>10</td>
</tr>
<tr>
<td>26 g</td>
<td>5</td>
</tr>
<tr>
<td>29 g</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>

The orientation of the needle bevel parallel (rather than perpendicular) to dural fibres is also important in reducing the likelihood of PDPH. In theory, the parallel orientation parts, rather than cuts, the dural fibres. Clinical and in vitro studies have shown reduced PDPH and reduced CSF leak when the bevel is parallel, although microscopic examination indicates that the dural fibres are cut with both parallel and perpendicular bevel puncture.40,47

Although smaller needles have lower incidence of PDPH, technical difficulties with these needles may make them unsuitable for use in the ED. Most of the studies on smaller needles have been in anaesthetic practice where the purpose of the LP is to gain access to the subarachnoid space for administration of anaesthetic agents. However, in the ED the purpose is to extract CSF for diagnostic purposes in patients who are more likely to have abnormal CSF and less likely to be able to lie still for a prolonged procedure. Smaller (25 g and 26 g) needles are technically more difficult to insert and are more likely to have to be manipulated after insertion to maintain CSF flow.42 Cerebrospinal fluid takes significantly longer to appear in the hub of a 26-g needle compared with a 22-g needle.47 Although CSF pressure measurements are still possible with normal CSF through small needles, the acquisition of CSF is slower and if the CSF has increased viscosity due to inflammation or blood it may be difficult to obtain diagnostic samples.42,47 For these reasons, a 22-g needle would seem an appropriate compromise although the incidence of PDPH is still high. Similarly, although atraumatic needles are associated with a lower incidence PDPH, they are technically more difficult to use and have a higher rate of failed LP and therefore may not be suitable for use in the ED.49

Bed rest for between 4 and 24 h has been recommended traditionally following LP to reduce the incidence of PDPH; however, the effect of bed rest on the incidence of PDPH remains unproven with conflicting results in different studies. Limited or prolonged bed rest, and bed rest in the supine, prone, horizontal or head-down position, have not shown consistent reductions in the incidence, duration or severity of PDPH.4,44,50–54 One study suggested that early mobilization may in fact reduce the incidence of PDPH.50 The maintenance of good hydration with oral or intravenous fluids has also never been shown to be beneficial48 but is recommended to avoid further lowering of CSF pressure by dehydration.48 Autologous epidural blood patch is a well-established treatment for PDPH with a greater than 90% success rate in experienced hands, provided it is not performed within 24 h of the original LP.41,43 Intravenous caffeine benzoate has also been reported as a successful treatment.46

**CSF interpretation**

The purpose of LP in the ED is to acquire CSF for diagnostic evaluation, therefore a thorough understanding of CSF interpretation is a prerequisite to performing an LP. Although there are hundreds of tests which can be performed on CSF, this discussion is limited to those results generally available within the first few hours in the ED.

**Bedside findings**

Important information is available at the bedside as soon as the LP is performed. Normal CSF pressure in a horizontal patient is 5–20 cm H2O with 5–10 cm variation with deep respiration; straining may cause spurious elevation.4,56 Elevated pressure is found in the presence of space-occupying lesions and obstruction to CSF flow or absorption. Low pressure is associated with severe dehydration, spinal block to CSF flow or CSF leak.56

The macroscopic appearance of normal CSF is clear and colourless; abnormal CSF may be cloudy, bloody or pigmented. A white cell count (WCC) of greater than 400 white blood cells (WBC)/mL causes macroscopic turbidity while a red cell count (RCC) greater than 500 red blood cells (RBC)/mL causes pink discolouration. Turbidity may also be due to the presence of microorganisms or extremely elevated CSF protein. Grossly bloody CSF is seen when there are greater than 6000 RBC/mL.56 Other causes of pigmentation in the CSF are listed (Table 3).

**Biochemistry**

Cerebrospinal fluid protein levels are normally about 200-fold less than blood protein levels, normal levels are laboratory dependent but in the range of 30–45 mg/dL. Elevated CSF protein is associated with infective and malignant meningitis, neurofibromas, haemorrhage, CNS tumours, Guillain–Barre syndrome and is seen occasionally in myxoedema and diabetic neuropathy. Grossly elevated CSF protein (> 500 mg/dL) is classically found in tuberculous meningitis, arachnoiditis and spinal block and may cause clotting of the CSF. Cerebrospinal fluid protein is reduced in normal CSF through small needles, the acquisition of CSF is slower and if the CSF has increased viscosity due to inflammation or blood it may be difficult to obtain diagnostic samples.42,47 For these reasons, a 22-g needle would seem an appropriate compromise although the incidence of PDPH is still high. Similarly, although atraumatic needles are associated with a lower incidence PDPH, they are technically more difficult to use and have a higher rate of failed LP and therefore may not be suitable for use in the ED.49

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benign intracranial hypertension, hyperthyroidism and hypervitaminosis A.2,8,56–58
Cerebrospinal fluid glucose is normally approximately 65% of serum glucose; however, in severe hyperglycaemia the CSF glucose may be as low as 30% of the serum level. Elevated CSF glucose is usually secondary to hyperglycaemia; low CSF glucose is associated with a number of pathological conditions (Table 4).

Table 3. Cerebrospinal fluid pigments

<table>
<thead>
<tr>
<th>Pigment</th>
<th>Colour</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxyhaemoglobin</td>
<td>Red/pink</td>
<td>Red cell lysis in CSF prior to LP</td>
</tr>
<tr>
<td>Bilirubin</td>
<td>Yellow</td>
<td>Red cell lysis in CSF prior to LP, and/or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Severe systemic jaundice (poor correlation with serum bilirubin), and/or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gruelly elevated CSF protein &gt; 150 mg/dL</td>
</tr>
<tr>
<td>Methaemoglobin</td>
<td>Brown/orange</td>
<td>Old blood in CSF (e.g. encapsulated subdural haematoma)</td>
</tr>
<tr>
<td>Melanin</td>
<td>Black</td>
<td>Metastatic melanoma</td>
</tr>
<tr>
<td>Carotene</td>
<td>Yellow/orange</td>
<td>Hypercarotenemia</td>
</tr>
</tbody>
</table>

CSF, Cerebrospinal fluid; LP, lumbar puncture.


Table 4. Causes of reduced cerebrospinal fluid glucose

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacterial meningitis</td>
<td>Approximately 50% patients</td>
</tr>
<tr>
<td>Tubercular and fungal meningitis</td>
<td>Almost universal</td>
</tr>
<tr>
<td>Mumps and herpetic meningitis*</td>
<td>Approximately 25% patients</td>
</tr>
<tr>
<td>Sarcoidosis</td>
<td></td>
</tr>
<tr>
<td>Central nervous system tumours</td>
<td></td>
</tr>
<tr>
<td>Systemic lupus erythematosus,</td>
<td></td>
</tr>
<tr>
<td>rheumatoid meningitis</td>
<td></td>
</tr>
</tbody>
</table>

*Other viral meningitis have normal cerebrospinal fluid glucose.

Cerebrospinal fluid glucose is normally approximately 65% of serum glucose; however, in severe hyperglycaemia the CSF glucose may be as low as 30% of the serum level. Elevated CSF glucose is usually secondary to hyperglycaemia; low CSF glucose is associated with a number of pathological conditions (Table 4).2,56–58 In acute bacterial meningitis, CSF glucose is depressed in only 50% of patients while elevated CSF protein is seen in 95% of patients.2,4

Microscopic examination and detection of microorganisms

A WCC greater than 5 WBC/mL is abnormal, a count greater than 10 WBC/mL indicates definite CSF pathology.2,4,56,57 The presence of any neutrophils is also considered pathological; neutrophils usually indicate bacterial meningitis or early viral meningitis, although small numbers (< 10/mL) of neutrophils can be seen in non-infective conditions such as infarction, trauma and post-myelography.2,56,57 Bacterial meningitis is usually associated with WCC in the range of 100–5000 WBC/mL, although up to 10% of patients will have WCC less than 10 WBC/mL and approximately one quarter of patients will have counts in excess of 5000 WBC/mL.16 Occasionally a predominantly lymphocytic pleocytosis may be seen in bacterial meningitis.2 Extremely high neutrophil counts should raise the possibility of a cerebral abscess.4 Viral infections characteristically show a CSF monocytoysis or lymphocytosis, often preceded by an initial granulocytosis. Elevated eosinophils are classically seen in parasitic infections and may also be found in tuberculosis (TB), neurosyphilis, subarachnoid haemorrhage, lymphoma and post-myelography. Fungal infections and TB classically show a predominance of lymphocytes.8,56,57 White cell counts need to be done promptly because white cell lysis begins within 1 h at room temperature and up to 40% cells may be lysed by 2 h; refrigeration will slow lysis.57 In the presence of a traumatic tap, a correction of 1 WBC per 700 RBC/mL allows estimation of the true WCC in the absence of significant anaemia or leucocytosis in the peripheral blood.57 A more accurate calculation can be made using the formula:4

\[
\text{True WCC}_{\text{CSF}} = \frac{\text{WCC}_{\text{measured}} \times \text{RCC}_{\text{CSF}}}{\text{RCC}_{\text{blood}}}
\]

Gram staining of CSF may identify specific bacteria prior to culture results. Centrifugation of CSF prior to staining increases the sensitivity by concentrating organisms; cytocentrifugation can be used for small samples and this further increases the sensitivity compared with conventional centrifuge smears.36 India ink staining is positive in approximately 50% of patients with cryptococcal meningitis, culture and antigen testing have a sensitivity of up to 90%; however, samples from multiple LP may be required to isolate the organism.
Similarly, acid fast stains for TB have poor sensitivity (approximately 25%), while culture sensitivities are 75–90%, but may take weeks to become positive.1,2 Administration of antibiotics prior to LP decreases the yield from Gram staining and culture in an unpredictable manner depending on the particular organism and time elapsed between bacterial administration and LP. However, antibiotic therapy should not be withheld once the diagnosis is clinically suspected as the organism may still be identified in the CSF or by blood culture and CSF antigen testing.3-6 The classical findings of high protein, low glucose and neutrophil pleocytosis will often persist for several days.6,13,24,50-62

Cerebrospinal fluid antigen testing using latex agglutination (LA) has been heralded as a useful adjunct to bacterial identification, particularly when antibiotics have been administered prior to LP. Latex agglutination antigen testing has approximately 70–90% sensitivity for Neisseria meningitides, 85% for Haemophilus influenzae and 60% for Streptococcus pneumoniae; the sensitivity of Gram stain for these organisms is at least the same if not higher.8 Latex agglutination testing in developed countries has failed to demonstrate any benefit over Gram staining in either detection or rapidity of identification of the organism, even in patients treated with antibiotics prior to LP.63 Other means of antigen testing such as latex coagglutination, counter-immunoelectrophoresis and enzyme linked immunosorbent assay may have slightly different sensitivities but all methods of antigen testing are time consuming, expensive and give no information on antibiotic sensitivities.2,8,24,63

Xanthochromia

The utilization of LP as a diagnostic test in subarachnoid haemorrhage (SAH) has fallen significantly since the widespread availability of CT scanning. However, LP is an important second-line investigation, with RBC in the CSF indicating haemorrhage into the subarachnoid space. Xanthochromia describes the yellowish discolouration of CSF, but is often used more specifically as a term to define the pigmentation of CSF by degraded haem products. The presence of xanthochromia is used to distinguish blood in the CSF due to a traumatic tap from blood in the CSF due to SAH. Computed tomography scans performed on third-generation scanners within 12 h of onset of headache have nearly 100% sensitivity for SAH.64-66 However the sensitivity of CT scan falls as the time from onset of headache increases, particularly in the presence of a normal neurological examination, whereas xanthochromia may persist for several weeks after the initial bleed.64-69 Regardless of the timing of CT, all patients with a normal CT and a clinical history suggestive of SAH should be considered for LP to avoid missing this potentially devastating diagnosis.69,70 Traumatic bloody taps are estimated to occur in up to 20% of LP and both the timing of LP and the method of assessment for xanthochromia are important in this setting.69

Blood in the subarachnoid space may take up to 4 h to reach the lumbar thecal sac.58 Red blood cells in the CSF are broken down to oxyhaemoglobin, bilirubin and methaemoglobin only after time-dependent activation of enzymes by circulating macrophages which have to migrate to the meninges. For these reasons, it is recommended that LP should be delayed for 12 h after the onset of headache in those patients with a normal CT scan to allow adequate time for the formation of xanthochromia.65,67,71

Detection of xanthochromia by visual inspection of CSF supernatant is less sensitive than spectrophotometric assessment using a wavelength spectrum which includes oxyhaemoglobin, methaemoglobin and bilirubin.68,69 Visual inspection is commonly used but may not detect up to 50% of xanthochromia.77 Xanthochromia does not absolutely exclude a traumatic tap because extremely bloody taps (>12,000 RBC/mL) can cause xanthochromia within 30 min and repeat LP done several hours after a traumatic tap will also demonstrate xanthochromia.57,73

Small studies looking at the role of D-dimer, lactate and ferritin levels in distinguishing traumatic tap from SAH are promising but inconclusive.78-80 The presence of erythropoietic macrophages which have ingested RBC in the CSF increases the likelihood of SAH, but their absence is not helpful in excluding the diagnosis.81 The use of a diminishing red cell count in sequential tubes is non-specific and a traumatic tap and SAH may coexist.57,80

Conclusion

Lumbar puncture is a useful test in the ED in specific clinical situations, especially the diagnosis of meningitis and as a second line investigation for SAH. It is not without risk but awareness of the contraindications and adherence to proper technique with the smallest practical needle should minimize the complications. There are a limited number of tests on CSF which are
immediately useful in the ED but a thorough understanding of these tests is essential to derive maximum clinical benefit from each lumbar puncture performed.

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References