How to use… lumbar puncture in children

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ABSTRACT

Lumbar puncture (LP) is a useful diagnostic tool in a wide spectrum of paediatric clinical situations. A common indication is to rule out a serious intracranial infection in a febrile child. Success rate can be optimised by proper positioning, appropriate technique and enhanced operator's skill in performing the procedure. The purpose of this review is to explore the indications and contraindications for performing paediatric LP, to describe the anatomical and physiological knowledge required to maximise success rates and to describe complications and their management. We will also provide advice on requesting various cerebrospinal fluid studies, interpretation of results and clinical situations in which LP may be indicated.

INTRODUCTION

Worldwide, central nervous system infections in children are associated with significant morbidity and mortality. Early recognition and treatment is paramount for improving outcomes. Lumbar puncture (LP), the most common method for obtaining cerebrospinal fluid (CSF), has been employed for over a century to diagnose and aid the management of such infections. The role of LP now extends to diagnosing and treating a range of paediatric central nervous system disorders making it an essential skill for paediatricians to acquire.

Thomas Willis first described the role of CSF in disease in 1664 when he noted on postmortem examination of patients with 'epidemic fever' the consistency of the 'liquid around the brain' was turbid. In the 19th century, Francois Magendie hypothesised that CSF suspended, nourished and protected the brain and spinal cord. In 1891, Heinrich Quinke presented his technique for LP to the German Congress of Medicine. By 1912, CSF composition in health and disease was described by William Mestretaz providing the basis for the diagnostic use of LP.[1]

PHYSIOLOGICAL AND ANATOMICAL BACKGROUND

CSF bathes, nourishes and protects the brain and spinal cord. The adult choroid plexus produces CSF at a rate of 14–36 mL/h;[2] in neonates the rate is approximately 25 mL/day.[3] Circulating CSF volume of a neonate is approximately 50 mL[3] with this volume increasing with age until the adulthood volume of approximately 150 mL.[2] CSF circulates through the ventricles, subarachnoid space, perivascular space and the central canal of the spinal cord and is reabsorbed into the bloodstream by arachnoid villi in the superior sagittal venous sinus. CSF and serum differ most dramatically in their protein concentration; in the healthy state CSF protein content is negligible. The blood-CSF barrier maintains this difference. In neonates, however, CSF protein concentration is higher due to immaturity of the blood-CSF barrier.[3] Moreover, a value of up to 10 white cells/mm^3 in the CSF is generally accepted in neonates.

The lumbar region is the safest location from which to sample CSF. Here, there is a large CSF-filled space containing only nerve roots, as the spinal cord terminates around the level of L1–L2, whereas the subarachnoid space extends to the lower border of S2 (figure 1). In neonates, the spinal cord reaches L3. LP should therefore be attempted between L3–L4 or L4–L5 to avoid trauma to the spinal cord. The anatomical layers pierced during LP are shown in figure 1.

TECHNICAL BACKGROUND

Prior to the procedure discussion with parents, and the child if appropriate, is important. They should be informed of

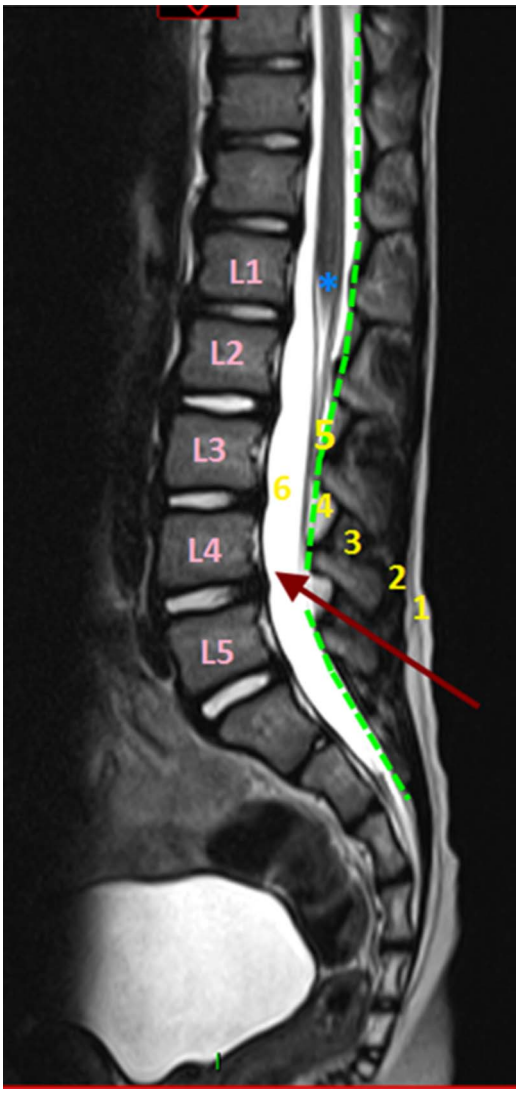

Figure 1 Sagittal T2-weighted image of the thoracolumbar spinal cord in a 7-year-old. The asterix denotes the spinal cord termination at the level of L1 vertebrae. The arrow demonstrates the position of a spinal needle passaging between L4/L5. Layers penetrated are: (1) skin/subcutaneous tissue; (2) supraspinous ligament; (3) interspinous ligament; (4) ligamentum flavum; (5) dura mater (dashed line) and (6) subarachnoid space. A slight 'pop' may be felt as needle penetrates ligamentum flavum; a second 'pop' marks passing the dura mater.

the indications, complications and how the procedure is performed. Consideration should be given to the use of sedation, local anaesthesia and analgesia. Conscious sedation (often with a benzodiazepine such as midazolam) is safe and effective in reducing parental and patient anxiety and reducing procedural pain. Self-administered nitrous oxide and oxygen mixture can also be helpful in the cooperative child. Topical anaesthetic agents such as eutectic mixture of local anaesthetic (EMLA) cream or tetracaine 4% (Ametop) gel should be used. EMLA is effective in significantly reducing pain in neonates.[4] In paediatric practice, bevelled 22-gauge Quincke spinal needles are commonly used. Distance from skin to subarachnoid space

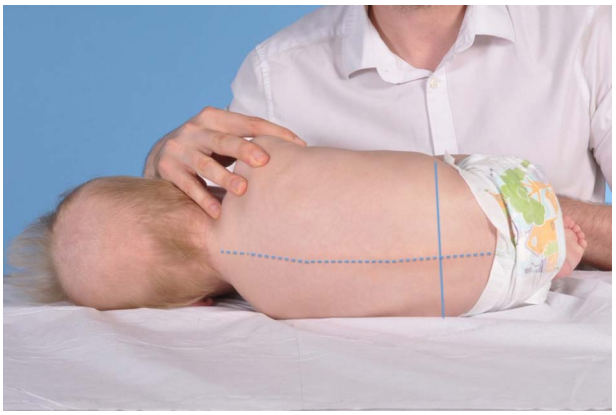

Figure 2 Infant in the left lateral position, hips maximally flexed. Solid line represents Tuffier's line, dashed line the spinal cord. These intersect at L4.

increases with weight and is estimated using the formula: Depth (in millimetres)=0.4×weight+20.[5] Use of a non-stylet needle should be avoided for concern that skin epithelial cells could be transplanted into the subarachnoid space, leading to formation of an epidermoid tumour.

Inappropriate positioning and poor anatomical knowledge are the primary reasons LPs fail, leading to increased procedure duration and morbidity. For children, the left lateral position, with hips fully flexed is recommended. This reverses the natural lumbar lordosis, opening the spaces between spinous processes and their adjacent laminae. A recent study suggests a sitting position with legs flexed at the hip should be considered for neonatal LP, as this maximises the interspinous space and causes less hypoxaemia.[6]

Tuffier's line, which joins the most superior aspect of both iliac crests, crosses the midline over the L4 spinous process as illustrated in figure 2. A space inferior to this is safe for performing LP (see figure 1). A wide aseptic field is mandatory.

Twenty drops of CSF equate to 1 mL. A minimum total sampling volume of 1.5–2 mL is routinely needed (table 1). Commonly, collection is in three universal containers plus a fluoride-containing tube for CSF glucose. Certain investigations require advanced preparation and liaison with the laboratory. CSF samples for neurotransmitters screen, for example, must be snap-frozen in dry ice or liquid nitrogen for immediate specimen transportation. Common LP technical issues and their remedy are presented in table 2.

COMPLICATIONS

LP is generally a safe procedure. Significant complications such as cranial neuropathies or meningitis are rare. A summary of individual complications is described in box 1.

INDICATIONS FOR LP

CSF analysis can be used to diagnose a variety of infective, inflammatory, metabolic and genetic nervous

Table 1 Routine cerebrospinal fluid (CSF) studies

	Test	Minimum CSF volume	Comments
Biochemistry	Glucose (absolute value and CSF: Plasma ratio)	0.25 mL (5 drops)	▶ Send in a fluoride-containing tube ▶ Requires paired plasma sample before procedure is undertaken
	Protein	0.25 mL (5 drops)	▶ Send in a universal tube
Microbiology	Gram staining, culture and sensitivity plus cell counts	0.5 mL (10 drops)	▶ First drops to be collected (unless neurotransmitters required) ▶ Collect in sterile universal tubes ▶ If blood-stained send first and third bottles to the laboratory ▶ Must reach lab within 6 h
	Bacterial DNA PCR	0.25 mL (5 drops)	▶ Especially useful if partially treated meningitis suspected
Virology	PCR (eg, Herpes simplex virus (HSV), enterovirus)	0.5 mL (5 drops)	▶ Samples collected within 72 h from symptoms onset may be falsely negative in HSV infection

Table 2 Common practical problems during lumbar puncture and their remedy

Problem	Likely explanation/s	Remedy
Difficulty getting the child in the proper position	▶ Poor communication with the team (and child) ▶ Analgesia and sedation not considered ▶ Deep infiltration of the local anaesthetic if used (not necessarily needed and may increase discomfort) ▶ Occasionally midazolam, if used, causes a paradoxical reaction	▶ Get help from experienced nurses, play therapists, etc, as available ▶ Clear instructions to the person/s holding the child ▶ Offer explanation and reassurance for the older child ▶ A parent's presence may help ▶ Consider conscious sedation or (rarely) a general anaesthetic in certain circumstances
Physiological instability during procedure (eg, hypoxia)	▶ Neck flexion when child is held ▶ Prolonged procedure time (eg, multiple attempts) ▶ Child is significantly unwell	▶ Ensure neck is in the neutral position. Neck flexion is not necessary ▶ Seek senior help ▶ Postpone procedure if necessary and treat appropriately (eg, oxygen, fluids, antibiotics, etc)
Resistance felt and needle cannot be advanced further	▶ Most likely obstruction is bone	▶ Needle can be partially withdrawn, the angle adjusted, and then reattempted ▶ Needle should remain in the midline, parallel to the floor
CSF is slow-flowing or seems to be stopping	▶ A nerve root is obstructing the flow of CSF	▶ Rotate the needle anticlockwise by 90° facing the bevel towards the direction of CSF flow[16] ▶ Never use a syringe to withdraw CSF (risk of herniation and haemorrhage)
CSF is *still* slow-flowing or seems to be stopping	▶ Blood clot in the needle lumen	▶ Reintroduce stylet fully and withdraw again
'Dry' tap despite needle being advanced adequately	▶ Insertion point in the sacral area ▶ Insertion point above or below horizontal plane	▶ Withdraw needle completely ▶ Reposition patient if necessary ▶ Reidentify landmarks ▶ Reattempt with a new needle
Traumatic tap	▶ Puncturing of a nerve root blood vessel ▶ Penetration of epidural veins when needle is inserted too deep	▶ Withdraw needle back slightly and check if CSF clears as it flows ▶ Reinsertion of needle may be required, with removal of stylet every few millimetres

CSF, cerebrospinal fluid.

Box 1 Complications of lumbar puncture

Brain herniation
- Due to an increase in the pressure differential between the cranial and spinal compartments when the lumbar compartment pressure is lowered by penetration of the needle.
- Herniation following lumbar puncture (LP) occurred in 5% of patients with bacterial meningitis in one review,[7] although this may represent disease progression and not iatrogenic herniation.
- Clinical signs include decerebrate posturing, unresponsiveness, dilated pupils and vomiting.

Infection
- Extremely rare when a sterile technique is used.
- Vertebral osteomyelitis, discitis, epidural abscess and bacterial meningitis have been reported.

Bleeding (intraspinal or intracranial)
- Rare.
- Presentation of spinal bleeding is with severe low back or radicular pain soon after LP with paresis and sensory loss in a saddle distribution along with loss of sphincter control.

Transient dysaesthesia
- Symptoms of abnormal lower limb sensations.
- Occurs during the procedure if the needle makes contact with cauda equina nerve roots.
- Resolve immediately with needle repositioning.
- Permanent nerve damage is rare.

Backache
- Rare.
- Likely to be reported after multiple attempts.

Post-LP headache
emsp;See relevant clinical question

system disorders. The National Institute for Health and Care Excellence guidelines recommend that all children with a suspicion of meningitis should undergo LP, in the absence of contraindications.[8] Important other clinical situations where LP is considered for diagnostic purposes are presented in tables 3 and 4.

LP and CSF removal may also aid in managing idiopathic intracranial hypertension. Therapeutic agents including antibiotics (eg, vancomycin) and chemotherapy (eg, methotrexate) can also be delivered via LP. Special training is required.

CONTRAINDICATIONS TO LP

Current National Institute for Health and Care Excellence guidelines state that CT scanning is unreliable to determine raised intracranial pressure in the assessment of patient's suitability to undergo LP.[8] Despite this mixed evidence, CT scanning is still recommended prior to LP if signs of raised intracranial pressure (ICP) are present, although it cannot exclude raised ICP definitively. Clinical examination should therefore guide appropriateness of LP. Box 2 summarises contraindications to LP.

CLINICAL QUESTIONS

In children undergoing LP, what preventive measures are most effective in reducing incidence of post-LP headache?

Post-LP headache is thought to arise due to persistent CSF leak from the puncture site. When the rate of leakage exceeds CSF production the volume of the cushion supporting the brain is reduced and the consequent gravitational forces on the innervated meninges result in pain. The headache is exacerbated by upright posture and typically lasts less than a week. Incidence is reported to be 32%.[9]

Preventive measures include:
- Using smaller gauge needles; this is supported by adult practice studies,[9] although a recent paediatric study found little corroborating evidence.[10]
- Orientating the needle bevel parallel to the spine rather than inserting perpendicularly (7.9% headache rate vs 19.3%).[11] Employing this technique separates rather than dissects longitudinal collagen dura mater fibres.[11]
- Reinserting the stylet before withdrawing the needle (5% incidence vs 16% when not reinserted).[12] Replacing the stylet is thought to prevent threading of arachnoid strands through the defect, which can prolong CSF leakage.
- Some studies have shown that use of a blunt (atraumatic) needle can reduce post LP headache. These needles are thought to separate the dural fibres and cause minimal tearing of the dura which results in less CSF leak.

It is often advised that post-LP headache can be avoided by lying flat afterwards, however a Cochrane review found little supporting evidence.[13] Good hydration, analgesia and antiemetics have a supportive role, though the majority of post-LP headaches resolve without specific treatment. In prolonged or severe post-LP headache, epidural blood patching can be undertaken.

In children with suspected meningitis, can CSF lactate distinguish bacterial from viral causes?

In bacterial meningitis, CSF lactate is produced by bacterial anaerobic metabolism. It can therefore be useful in differentiating bacterial and viral meningitis, which may be difficult based on initial CSF results. In enterovirus meningitis, for example, CSF parameters can mimic those in bacterial meningitis. This results in unnecessary antibiotic administration in viral meningitis. One systematic review and meta-analysis of 25 studies examining CSF lactate in bacterial and viral meningitis concluded that CSF lactate is a good single differentiator, and is in fact better when compared with conventional markers such as CSF glucose and cell count.[14]

Unlike CSF glucose, which requires a paired serum sample, CSF lactate does not. A CSF lactate level >3.5 mmol/L is indicative of bacterial meningitis.[15]

Table 3 Diagnostic utility of LP in non-infective conditions in neonates and infants

Clinical scenario	Suspected diagnosis	CSF studies	Comments
A neonate with lethargy, refractory-to-treatment prolonged seizures and hypothermia. *Or* An infant with new onset seizures (including infantile spasms) with developmental concerns.	Pyridoxine (or pyridoxal phosphate)-dependent epilepsy	▶ Pipecolic acid: Moderate elevation ▶ Amino acids: abnormal profile (eg, elevated threonine)	▶ LP not always necessary ▶ Elevated urinary α-AASA excretion has more sensitivity and specificity
A neonate with hypotonia, poor feeding, hiccups, apnoeas and seizures. EEG or cerebral function analysis monitor (CFAM) shows burst-suppression pattern.	Non-ketotic hyperglycinaemia	▶ Amino acids: elevated glycine ▶ Increased CSF-to-plasma glycine ratio	▶ Always request with a paired plasma sample. ▶ Avoid CSF contamination with blood (high CSF proline is a sensitive marker of contamination)
An infant with low birth weight, congenital microcephaly, irritability, feeding difficulties, cataracts, developmental delay, seizures and evolving hypertonia.	Serine deficiency disorders	▶ Amino acids: low serine level	▶ CSF level is diagnostic as it is not affected by meals or fasting. ▶ Plasma serine is low or borderline. Urinary levels are not helpful.
An infant (or older child) with slow head growth, developmental delay, different types of seizures that are drug-resistant and a complex movement disorder.	Glucose transporter type 1 deficiency syndrome	▶ Glucose: Low absolute value and ratio to plasma is less than 0.6 (typically less than 0.4) ▶ Lactate: low or normal	▶ Fasting for 4–6 h before LP is recommended ▶ *SLC2A1* gene testing is confirmatory however slightly less sensitive than CSF glucose

AASA, amino adipic semialdehyde; CSF, cerebrospinal fluid; LP, lumbar puncture.

Antibiotic treatment in many cases precedes LP; this often results in negative CSF bacterial cultures. A meta-analysis concluded that pretreatment with antibiotics reduces the clinical accuracy of CSF lactate.[16] Diagnostic utility of a postantibiotic CSF lactate level is retained when considered in conjunction with clinical findings and laboratory tests.

In febrile infants under 3 months old with proven urinary tract infection, should LP routinely be performed?

Urinary tract infection (UTI) affects one in six febrile infants younger than 30 days old.[17] Up to 2% of infants less than 3 months with UTI have coexisting meningitis.[18] The febrile infant under the age of 3 months can be difficult to assess, as pain and pyrexia can cause irritability, clouding the clinical picture. In these infants there is evidence suggesting LP should be performed to look for coexisting meningitis.

One retrospective study assessed the risk of UTI and meningitis coinciding. Only 2 patients of 735 had UTI and meningitis; both were under 1 month old. The conclusion was febrile neonates should have LP performed, regardless of whether UTI is diagnosed.[19]

In neonates with an elevated C reactive protein, should LP be routinely performed?

Neonates often have blood taken at less than 24 h of age for a variety of reasons, including asymptomatic babies with maternal risk factors for infection. C reactive protein (CRP) in such babies is often elevated and practice on how to manage this often differs between hospitals and clinicians.

CRP crosses the placenta in very low quantities, so an elevated CRP in a neonate always represents endogenous synthesis. However, an elevated CRP can be a physiological response to the stress of delivery, peaking at 13 mg/L on the 2nd day of life.[20] CRP can also be raised in non-infection conditions such as intraventricular haemorrhage. Studies have suggested that serial CRP measurements have a higher sensitivity for sepsis than one-off measurements.[20] One study considered babies who had full septic screens (including LP) for maternal risk factors. Of these babies 3423 were asymptomatic; none had meningitis. Of 11 cases of meningitis, all were symptomatic.[21] This suggests that in asymptomatic neonates with elevated CRP, monitoring CRP trends and reserving LP for symptomatic infants is reasonable. If there is clinical suspicion of meningitis or sepsis, a septic screen including LP should be performed.

In paediatric idiopathic intracranial hypertension (IIH), does LP and removal of CSF reduce the symptoms?

As previously mentioned, CSF is produced continuously. One study examined CSF production by measuring external ventricular drain losses in

Table 4 Diagnostic utility of LP in non-infective conditions in preschool and older children

Clinical scenario	Suspected diagnosis	CSF studies	Comments
A child presents, following a recent infection, with progressive weakness in an ascending manner with an associated limbs and back pain. There is loss of deep tendon reflexes over lower limbs.	Guillain-Barré Syndrome	▶ Protein: high ▶ White cell count: WBC typically normal or <50 mononuclear cells/mm^3	▶ Likelihood of finding elevated protein increases with time from symptoms onset ▶ Nerve conduction studies confirm the diagnosis but may not be well tolerated and results can be difficult to interpret in preschool children.
A child presents, following a recent infection, with altered consciousness, behavioural changes and fever. Examination demonstrates pyramidal signs. Brain MRI shows multifocal white matter changes.	Acute disseminated encephalomyelitis (ADEM)	▶ Protein: normal or slightly high ▶ White cell count: normal or minimal lymphocytosis ▶ Oligoclonal bands (OCBs) usually negative	▶ LP is often necessary acutely to exclude CNS infection ▶ OCBs are present if two or more bands of CSF immunoglobulins are seen on isoelectric focusing. This is compared with a serum sample taken simultaneously and if a distinct pattern is seen this will be indicative of intrathecal synthesis. Positivity commonly associated with multiple sclerosis.
A child with acute seizures, altered consciousness, abnormal behaviour and an acute movement disorder. EEG shows slow abnormal background. Neuroimaging is normal.	Autoimmune encephalitis (eg, anti N-methyl D-aspartate receptor (NMDAR) antibodies encephalitis)	▶ Protein: normal or high ▶ White cells: normal count or slight lymphocytosis	▶ LP is often necessary to exclude infection ▶ NMDAR antibodies can be positive in CSF and serum. ▶ High CSF protein is common in Hashimoto's encephalopathy
A child presenting with pallor, bruising and 'bone pains'. Full blood count shows high white cell count with blast cells on the peripheral film.	Acute lymphoblastic leukaemia	▶ Cytocentrifugation (cytospin): presence of blast cells signifies CNS involvement	▶ LP is essential in the initial evaluation and for monitoring especially if relapse is suspected.
A child with developmental regression and abnormal eye movements. Brain MRI shows abnormal T2 signal in the basal ganglia and brainstem.	Leigh's disease	▶ Lactate: high ▶ Pyruvate: high ▶ Lactate: pyruvate ratio: <20 ▶ Amino acids: high alanine	▶ High CSF lactate is more specific than blood lactate in mitochondrial disorders affecting the CNS
An obese teenage girl who has daily headaches and reduced visual acuity. Papilloedema is the only sign on neurological examination.	Idiopathic Intracranial Hypertension	▶ Opening pressure: high ▶ Other routine CSF tests: normal	▶ LP only after satisfactory negative neuroimaging. ▶ Values for high pressure are generally accepted if ≥25 cm H_2O in non-obese and non-sedated children or ≥28 cm H_2O in obese or sedated children. This is applicable across all age groups. ▶ LP is diagnostic and therapeutic

CNS, central nervous system; CSF, cerebrospinal fluid; LP, Lumbar puncture; WBC, white blood cells.

children with hydrocephalus. Output increased logarithmically with age and body weight and output rates ranged from 0.1mL/h to 26.5 mL/h.[22] Reducing intracranial pressure via LP by removing some CSF may provide temporary symptom relief which is usually short-lived. However, there is no evidence from research suggesting how much should be removed or even supporting this practice.

With continuous production of CSF, pressure can return to pretap concentrations within 1–2 h. Repeated taps are distressing, painful and run a theoretical risk of developing an intraspinal epidermoid tumour. Other treatments for IIH are therefore preferred.[23]

Box 2 Contraindications to performing immediate lumbar puncture

- Signs suggesting raised intracranial pressure:
  - Reduced or fluctuating consciousness (Glasgow Coma Scale (GCS) score <9 or a drop of 3 or more)
  - Cushing's triad in any combination: bradycardia, hypertension and irregular breathing
  - Focal neurological signs (eg, unequal pupils, a cranial nerve palsy or limb/s weakness)
  - Abnormal posture (decerebrate/decorticate posturing)
  - Papilloedema
  - Abnormal 'doll's eye' movements
- Shock
- After convulsions until stabilised
- Coagulation abnormalities ((discuss with haematology prior to lumbar puncture (LP) and reverse abnormalities)
  - Abnormal coagulation screen
  - Platelet count $<40\times10^9$/L
  - On anticoagulants
- Local superficial infection at LP site
- Respiratory insufficiency

In traumatic LP, how is CSF pleocytosis diagnosed?

In healthy children and adults, a CSF white cell count of up to 5 cells/mm^3 in the presence of up to 5 cells/mm^3 of red cells is normal. When CSF is contaminated with blood, interpretation of the actual white cells count can be difficult. Very few studies have addressed this issue and the validity of the formulas currently recommended is debateable. Pragmatically, the ratio of the total white cell to the red blood cell counts on the peripheral full blood count done around the time of the LP can be used as a rough

Clinical bottom line

- Paediatric lumbar puncture (LP) is a safe procedure that is helpful in diagnosing a wide array of central nervous system disorders.
- LP should be performed in all patients with suspected intracranial infection in the absence of contraindications, and in all clinically septic infants under 3 months old.
- Best positioning for LP is achieved by maximally flexing the hips without necessarily flexing the patient's neck. Where possible, the sitting position is recommended in neonates.
- A methodical approach to performing LPs, coupled with anatomical and pathophysiological knowledge, significantly improves the diagnostic utility of this investigation.
- Ultrasound-guided LP is a promising technique.

Test your knowledge

1. Which of the following statements are true?
   A. Cerebrospinal fluid (CSF) protein levels are physiologically higher in neonates than in older children.
   B. A higher vertebral space should be used for lumbar puncture (LP) in neonates.
   C. EMLA is effective in neonates.
   D. A normal CT scan eliminates the risk of iatrogenic brain herniation.
   E. To reduce post-LP headaches, the needle bevel should face the patient's top side on insertion.
2. For which of the following tests should the first drops of CSF be collected:
   A. Viral PCR.
   B. Lactate.
   C. Cells count.
   D. Neurotransmitters.
   E. Glucose.
3. Which of the following statements are true?
   A. Antibiotics should be withheld until LP has been performed in cases of suspected bacterial meningitis to obtain sensitivities.
   B. CSF lactate is not diagnostically useful without a paired serum sample.
   C. An opening pressure of 29 cm H_20 in a normal weight child is considered high.
   D. CT head scan should be requested prior to LP for a patient with a GCS of 8.
   E. A CSF result of normal cell count and high protein is consistent with a diagnosis of Guillain-Barré syndrome.
4. A lumbar puncture is helpful in the following clinical situations:
   A. A ventilated preterm baby with a rising C reactive protein and a negative blood culture.
   B. A 7 year-old with acute onset of unsteady gait and weak lower limbs.
   C. A 4 year-old with a temperature of 39°C and decorticate posturing.
   D. A 6 week-old boy with fever and a positive urine culture.
   E. A 10 day-old with intractable seizures and a 'burst-suppression' background on EEG.
5. The following are true in the interpretation of CSF results:
   A. CSF lactate is helpful in differentiating between viral and bacterial meningitis.
   B. Increased CSF protein is indicative of a neuroinflammatory disorder.
   C. CSF oligoclonal bands are present in a wide range of paediatric neurological disorders.
   D. Blood glucose is not usually required in interpreting CSF values.
   E. High CSF glucose is consistent with glucose transporter type 1 deficiency syndrome.

Answers are at the end of the references.

guide. If the ratio in the CSF is higher, then CSF pleocytosis is likely to be present.

TOPICS FOR FURTHER RESEARCH

For the majority of diagnostic procedures in modern clinical practice, radiological guidance is used to maximise the safety and efficacy of the procedure. However, the vast majority of LPs occur 'blind', with anatomical landmarks used to identify the puncture site. There is some evidence from the adult literature to suggest ultrasound guidance is beneficial, especially for difficult procedures. Small trials have suggested higher success rate when ultrasound guidance is used routinely.[24] There is limited paediatric evidence, with the majority of research looking at using ultrasound to assess spinal anatomy, and not to guide the procedure itself. A few small trials suggest it is feasible,[25] however larger randomised trials are needed.

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ANSWERS

1. A, C, E
2. C, D
3. C, D, E
4. A, B, D, E
5. A, B

How to use… lumbar puncture in children

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