Research, Audit and Clinical Practice

# Lumbar Puncture

N Cooper

#### Key points

- Educational theory helps us understand how best to both teach and learn a practical procedure
- Diagnostic lumbar puncture is generally a safe procedure, but it does have complications
- Potential complications can be avoided by the use of correct equipment and procedures

### Abstract

Most junior doctors learn common practical procedures, like lumbar puncture, on the job. This usually involves unstructured observation, demonstration and then supervised practice. Thus, most doctors have learned to perform a lumbar puncture without studying the theory of the procedure in any detail. The result is that patients experience less than optimal care, and more complications than necessary.<sup>1,2</sup> This article first outlines some educational principles with regard to teaching and learning practical procedures and then describes the theory of diagnostic lumbar puncture.

### Introduction

Mastering any procedural skill involves four processes that learners need to go through in order to learn successfully.<sup>3</sup> This need not start at any point, but includes theory, coaching (which could include simulation), 'real life' activity and reflection.

Without supervision, learners show a higher complication rate than experienced practitioners. However with appropriate supervision, the complication rate among learners remains comparable to that seen in the hands of an experienced person.<sup>4</sup> The key to maintaining patient safety is therefore *proper supervision*, so that the learner can learn, while the patient remains safe.

# **Educational theory**

Educational theory and observation tell us that it takes many repetitions of a skill to become proficient at it. There is no predetermined number of times that a procedure should be performed, and trainees vary in the rate at which they become competent. When starting to learn a procedure, the success rate is often low, with a rapid improvement over the next 20 or so procedures, and further improvement over the next  $100.^{5}$  This can be plotted as a 'learning curve'.<sup>6</sup>

Research has shown that confidence and competence are not the same thing. When trainees are rated on their confidence in performing a practical procedure and then observed doing so, the two do not correlate.<sup>7</sup> Thus, simply asking trainees whether they can perform a lumbar puncture before letting them get on with it is not adequate 'proof' that they are indeed competent. Acute Medicine trainees are required to have objective evidence of their competence in performing common practical procedures. However, there is plenty of evidence to suggest that Consultants (termed Faculty in the USA) have significant deficiencies in clinical skills themselves and fail to detect substandard performance in observation exercises.<sup>8</sup>

In the 1980s, Kolb developed a four stage cycle model to explain how adults learn a skill.<sup>3</sup> In effect, Kolb's learning cycle says that effective learning occurs when we get involved in a learning experience (concrete experience), have to think about the experience (reflective observation), theorise and assimilate this with what we already know (abstract conceptualisation) and practise or experiment with this new knowledge (active experimentation). His idea was that learning is a process and that effective learning occurs when people spend time in each part of the cycle.

The observation that people tend to spend more time in some steps of this cycle rather than others led to the concept of learning styles, expanded by Honey and Mumford.<sup>9</sup> Figure 1 illustrates these two models combined.

### Diagnostic lumbar puncture

With this 'bigger picture' in mind, there are six key stages in performing a lumbar puncture (LP). These are:

- The decision to perform a lumbar puncture
- Assembling the correct equipment
- Positioning and preparation of the patient
- Correct needle insertion
- Measuring the opening pressure and specimen collection
- Dealing with challenges and trouble-shooting during the procedure

# © 2011 Rila Publications Ltd.

# Nicola Cooper

FAcad MEd FRCPE Clinical Lead for Acute Medicine The Leeds Teaching Hospitals NHS Trust St James's University Hospital Leeds, LS9 7TF Email: nicola.cooper@ leedsth.nhs.uk

### Acute Medicine 2011; 10(4): 188-193

Lumbar Puncture



In this diagram, the cycle represents the process of learning. For example, imagine you are given the task of teaching a small group of doctors how to perform a lumbar puncture. The cycle helps to explain the process that learners need to go through in order to learn successfully. This process need not start at any point, but includes theory, coaching (which could include simulation), 'real life' activity and reflection.

At every stage, there will be people who prefer to learn in a certain way. Some will prefer theory whereas others will prefer practice. *The reality is they need all stages to learn effectively*. This model can be applied to almost any subject, not just practical procedures.

Figure 1. The learning cycle and learning styles (based on Kolb<sup>3</sup> and Honey & Mumford).<sup>9</sup>

Complications of lumbar puncture and their management will be discussed separately.

## Deciding to perform a lumbar puncture

A common indication for lumbar puncture on the Acute Medical Unit is an admission with severe headache. Taking a headache history, and proper clinical examination of the patient requires knowledge and skill. On the one hand there are several primary care conditions that present with headache plus photophobia and/or neck stiffness (eg migraine, tonsillitis) that do *not* require a lumbar puncture. On the other, patients with meningitis or subarachnoid haemorrhage can appear completely well, without meningism. There are other indications for lumbar puncture, listed in Box 1. Sometimes the decision to perform a lumbar puncture can be difficult; it is the author's opinion that the decision to perform a lumbar puncture should always be discussed with a senior doctor (registrar /consultant) without delay. Computed tomography (CT) of the head is not required before lumbar puncture when the history is typical of meningitis and there are no 'red flags' suggestive of raised intracranial pressure (ie altered level of consciousness or confusion, seizures, focal neurological signs, papilloedema).

The patient's platelet count and clotting screen should be checked before lumbar puncture, chemical thromboprophylaxis should not have been given in the preceding 12 hours, and the risks versus benefits should be considered and explained to the patient (and/or carers). Ideally, written informed consent should be obtained. If a written consent form is not used, a thorough account of the consent process must be documented in the medical notes.

# Equipment

All practical procedures require attention to a strict aseptic technique. In the case of lumbar puncture, this means

© 2011 Rila Publications Ltd.

### 190

# *Lumbar Puncture*



- Subarachnoid haemorrhage
  Inflammation in the central nervous system eg multiple
- Inflammation in the central nervous system eg multiple sclerosis
- Cancers eg leptomeningeal carcinomatosis, lymphomatous
   /leukaemic meningitis

### For treatment: • Spinal anaesthesia

Intrathecal chemotherapy /antibiotics

# For diagnosis and treatment:

- Idiopathic intracranial hypertension
- Normal pressure hydrocephalus



thoroughly washed hands, a sterile trolley, a sterile operative field, sterile gloves and gown. Some operators also wear a surgical mask. Long hair must be tied back. Needles should not be inserted through infected skin.

Box 2 lists the equipment required to perform a lumbar puncture.

Smaller needles give less risk of post-LP complications, but may not allow cerebrospinal fluid (CSF) to flow freely enough to measure pressure accurately, or may not be rigid enough for use in older people with calcified ligaments. Studies have explored which needle size gives both optimum CSF flow with the least post-LP complications.<sup>10,11,12</sup> Typically a 20-22G needle, 3.5 inches (8.9cm) long is used for adults. A 22G 'atraumatic' needle is probably the best for diagnostic lumbar punctures in adults. Needles with atraumatic tips theoretically part, rather than cut, the elastic fibres in the dura, thus allowing them to close

- Dressing pack (or LP pack)
- Extra gauze swabs
- Iodine or chlorhexadine for skin
- 10 ml 1% lignocaine
- One green needle and one blue/orange needle
- 10 ml syringe
- Sterile gloves
- Large sterile towel with window (or several sterile towels)
- Sterile gown +/- surgical mask
- At least 2 x 22G LP needles
- · CSF manometer to measure pressure
- Sterile sample containers
- A sterile procedure trolley



on withdrawal and minimising any CSF leak, thus reducing the chance of post-LP complications (Figure 2). A needle with a stylet must be used, to avoid the complication of formation of a subarachnoid epidermal cyst.

The CSF opening pressure *must* be measured in all diagnostic lumbar punctures, so a manometer is also an essential part of the kit. The reason for this is that some serious conditions present with either gradual onset or thunderclap headache and CT and CSF appearances can be normal but the CSF pressure will be raised (eg cerebral venous sinus thrombosis).



1) Quincke (bevelled) tip with a cutting edge

2) Whitacre and 3) Sprotte needles have atraumatic tips with the hole in the side **Figure 2.** Types of spinal (LP) needle.

### Positioning and preparation

Lumbar puncture can be performed either with the patient sitting upright or lying in the left lateral position. The latter is preferred, as it reduces the risk of post-LP complications and allows an accurate measure of CSF opening pressure.

For the left lateral position, ensure the hips and shoulders are square – in line with each other and perpendicular to the bed. Then flex the spine as much as possible (foetal position) to open up the gaps between the spinous processes. The line that connects both posterior superior iliac spines (Tuffier's line) is level with L4. Midway along this line is the space between L3 and 4 which is most commonly used for lumbar puncture and easily accessed.

If the lumbar puncture is being performed with the patient in a sitting position, ensure he is leaning forward and perpendicular to the bed /trolley. Put the patient's feet on a low stool with elbows resting on the thighs – this opens up the gaps between the spinous processes. Figure 3 illustrates the correct positions.

Lumbar puncture is performed at the level of L3-L4 or L4-L5. An anaesthetic cream may be administered topically in advance of the procedure. With the patient correctly positioned and comfortable, remove any topical anaesthetic, and palpate the anatomical landmarks. You may prefer to use a skin marking pen to draw an arrow pointing towards the right spot, as insertion of local anaesthesia can make anatomical landmarks harder to identify later. (Do not insert the LP needle through an ink dot as this can lead to tattooing).

After donning sterile gloves and gown and preparing the sterile procedure trolley, the skin should be cleaned with appropriate skin disinfectant using a pattern of widening concentric circles. The area should then be covered with sterile drapes. Identify the landmarks again before introducing local anaesthetic and inserting the LP needle.

The maximum safe dose of lidocaine without epinephrine (adrenaline) in an adult is 3-5mg/kg. A 1% solution means 1000mg in 100ml (or 10mg/ml). Based on a maximum dose of 3mg/kg in a 70 kg adult, up to 210mg of lidocaine may be used. That is 21 ml of 1% lidocaine, or if a 2% solution is used then that is 10.5ml lidocaine.

### Acute Medicine 2011; 10(4): 188-193

191



### Needle insertion

After allowing time for local anaesthetic to be effective, the LP needle should be inserted with the stylet firmly in place. The needle should be inserted in the chosen space in the midline, directed at a slight angle (around 15 degrees) to the left, as if aiming towards patient's umbilicus. If using a bevelled needle rather than an atraumatic one, *it should be orientated so that the bevel aligns with, rather than cuts across, the dural fibres* which run parallel to the spinal axis (from the patient's head to toe).

If properly positioned, the lumbar puncture needle should pass through the skin and subcutaneous tissue, the supraspinous ligament, interspinous ligament, ligamentum flavum, the posterior epidural space (that includes the internal vertebral venous plexus), the dura and in to the subarachnoid space. Figure 4 illustrates this.

As the needle passes through the ligamentum flavum, a characteristic 'popping' sensation is often felt by the operator. After this, the LP needle should be advanced in 2mm increments, and the stylet withdrawn to look for CSF flow. The stylet must always be re-inserted fully before advancing the needle again. If bone is encountered, the needle should be withdrawn to the level of the subcutaneous tissue without exiting the skin, and re-directed appropriately.

# **Opening pressure and specimen collection**

The CSF opening pressure (measured in  $cmH_2O$ ) can only be accurately measured in the lateral recumbent position. Once CSF flow is seen, the manometer is attached and the CSF allowed to rise and settle. Normal CSF pressure in an

© 2011 Rila Publications Ltd.

adult is less than 20  $\text{cmH}_2\text{O}$ . If the pressure exceeds 25  $\text{cmH}_2\text{O}$ , the patient should be monitored closely for signs of cerebellar herniation and the cause of the raised intracranial pressure determined.

The operator's assistant should be briefed beforehand regarding the sterile nature of the procedure. CSF should always be allowed to drip in to collection tubes and must never be aspirated – even a small negative pressure could precipitate an intracerebral haemorrhage. 3-4 mls in each sample container is sufficient for analysis, and fluid from the manometer should be used as well.

CSF samples are usually sent for:

- Protein and glucose (to biochemistry) note that most labs require CSF glucose to be analysed in a glucose blood tube
- Microscopy, culture and sensitivities (to microbiology)
- Xanthochromia if a subarachnoid haemorrhage is suspected

A contemporaneous blood glucose sample should also be requested. In certain situations (eg suspected multiple sclerosis, cancer) samples are sent for specialist tests, as directed by a neurologist.

The stylet should be firmly replaced in the needle before the needle is withdrawn. Replacing the stylet before withdrawing the needle is thought to push back any strands of tissue and helps to minimise the dural puncture site. Studies have shown that replacing the stylet before withdrawing the needle significantly reduces the incidence

# *Lumbar Puncture*



**Figure 4.** Anatomy. If correctly inserted, the lumbar puncture needle should pass through 1) the skin and subcutaneous tissue, 2) supraspinous ligament, 3) interspinous ligament, 4) ligamentum flavum, 5) posterior epidural space, that includes the internal vertebral venous plexus, 6) dura, and in to the subarachnoid space.

of post-LP headache.<sup>14</sup> A small dressing is placed over the needle entry site, and the patient can be advised to drink plenty of fluid and 'take it easy' for a few hours. Randomised controlled trials have not found any difference in the incidence of post-LP headache when comparing gentle mobilisation with bed rest.<sup>15</sup> All sharps must be disposed of correctly, and details of the procedure recorded in the medical notes.

### Challenges and trouble-shooting

A common challenge when performing a lumbar puncture is patient obesity, when key landmarks can be difficult to identify. Osteoarthritis, kyphoscoliosis, previous spinal surgery, and degenerative disc disease also pose problems. In these cases, consider asking an experienced physician, anaesthetist or interventional radiologist to perform the procedure.

After inserting the LP needle, if CSF is encountered but there is poor flow, a nerve root may be obstructing the opening of needle. Rotating the needle by 90 degrees often improves matters. If clotted blood is seen in the LP needle, the procedure should be started again, using a new needle and a new interspace.

Lumbar puncture is an anxiety-producing procedure, so having a member of staff in front of the patient to explain what is happening is helpful. In well adults who are particularly anxious, an anxiolytic 'pre-med' such as 10mg oral temazepam an hour before the procedure can be used. If intravenous sedation is required, a separate doctor who is trained in safe sedation practice should administer this and monitor the patient throughout the procedure.

© 2011 Rila Publications Ltd.

# Complications and their management

Lumbar puncture is commonly complicated by headache after the procedure. At least 30% of patients will suffer a post-LP headache when a 20G bevelled needle is used,<sup>16</sup> commonly found on medical wards in the UK. Young age, female sex and obstetric patients are most susceptible, hence this has been an area of extensive research in anaesthesia. Surveys have revealed that doctors who perform lumbar punctures on wards tend not use the correct needle size and type, thus increasing the risk of post-LP complications.<sup>1,2, 17</sup>

Post-LP headache can be incapacitating. It should not be forgotten that rare neurological complications can also occur, such as subdural haematoma and cranial nerve palsies. It is thought that a hole is left in the dura after the LP needle has been withdrawn. This hole allows CSF to leak further, lowering CSF volume and causing discomfort through traction of the dural membranes when the patient is upright. This theory is supported by many studies that have looked at ways to try and reduce the size of the hole, by the clinical presentation of post-LP headache and by the efficacy of its treatment – extradural blood patch.

Classically, post-LP headache is related to posture (worse on sitting or standing and eased by lying down), is throbbing in nature and varies in severity. It usually presents 24-48 hours after lumbar puncture. The patient

### References

- Broadley SA and Fuller GN. Audit of LP practice in UK neurology centres. J Neurol Neurosurg Psychiatry 1997; 63: 266.
- Broadley SA nad Fuller GN. Lumbar puncture needn't be a headache [editorial]. Br Med J 1997; 316: 1324–5.
- 3. Kolb DA. Experiential learning experience as the source of learning and development. Prentice-Hall 1984, Englewood Cliffs, New Jersey.
- Titley OG, Bracka A. A 5 year audit of trainees experience and outcomes with two-stage hypospadias surgery. *British Journal of Plastic Surgery* 1998; 51: 370 –375.
- Prasad S. Phaco-emulsification learning curve. Journal of Cataract and Refractive Surgery 1998; 24: 73 – 77.
- Kestin IG. A statistical approach to measuring the competence of anaesthetic trainees at practical procedures. *British Journal of Anaesthesiology*. 1995; **75**: 805 – 809.
- Barnsley L, Lyon PM, Ralston SJ, et al. Clinical skills in junior medical officers: a comparison of self-reported confidence and observed competence. *Medical Education* 2004; **38**: 358-367.
- Holmboe ES. Direct observation by Faculty (chapter 9). In: Holmboe ES and Hawkins RE [Eds]. Practical guide to the evaluation of clinical competence. Mosby Elsevier, Philadelphia, 2008.
- 9. Honey P and Mumford A. The manual of learning styles. Peter Honey 1982, Maidenhead.
- Vilming ST, Schrader H, Monstad I. Post-lumbar puncture headache: the significance of body posture. A controlled study of 300 patients. *Cephalalgia* 1988; 8: 75–8.

may be unable to mobilise because of the headache. In theory, abdominal compression can be used to confirm the diagnosis.<sup>18</sup> With the patient sitting and symptomatic, the waist is slowly squeezed from behind. This compresses the inferior vena cava, causes the epidural veins to become engorged and displaces CSF in to the head, relieving the headache.

Although patient characteristics cannot be changed, there are three key things that the operator can do to reduce the incidence of post-LP headache:

- Use the optimum needle size and type
- If using a bevelled needle, ensure the bevel of the needle is in the saggital plane (aligned with the dural fibres)
- Reinsert the stylet before withdrawing the needle

Conservative management is usually effective for post-LP headache: bed rest, analgesia and increased fluids. The headache often settles over a few days. However, some cases are severe. For severe cases (having excluded a subdural haematoma), the most effective treatment is an autologous extradural blood patch.<sup>19</sup> 10-20 ml of the patient's own blood is withdrawn and injected in to the extradural space by an experienced anaesthetist. 90% of headaches are relieved after the first patch and up to 98% after two.

- Kleyweg RP, Hertzberger LI, Carbaat PA. Significant reduction in post lumbar puncture headache using an atraumatic needle. A double blind controlled clinical trial. *Cephalalgia* 1998; 18(9): 6355-7.
- Braune HJ and Huffman G. A prospective double blind clinical trial comparing the sharp Quincke needle (22G) with an 'atraumatic' needle (22G) in the induction of post lumbar puncture headache. *Acta Neurol Scand* 1992; 86: 50-54.
- Carson D and Serpell M. Choosing the best needle for diagnostic lumbar puncture. *Neurology* 1996; 47: 33-37.
- Strupp M, Brandt T, Muller A. Incidence of post lumbar puncture syndrome reduced by reinserting the stylet: a randomised prospective study of 600 patients. *J Neurol* 1998; 245: 589-92.
- Spriggs DA, Burn DJ, French J, et al. Is bed rest useful after diagnostic lumbar puncture? Postgrad Med J 1992; 68: 581-3.
- Kuntz KM, Kokmen E, Stevens JC, et al. Post lumbar puncture headaches: experience in 501 consecutive procedures. *Neurology* 1992; 42: 1884-7.
- Muller B, Adelt K, Reichmann H, et al. Atraumatic needle reduces the incidence of post-lumbar puncture headache. J Neurol 1994; 241: 376-80.
- Reynolds F. Dural puncture and headache avoid the first but treat the second. BMJ 1993; 306: 874-6.
- Hardman JG and Gajraj NM. Epidural blood patch. Br J Hosp Med 1996; 56: 268-9.

#### Further resources

 The New England Journal of Medicine has a collection of fantastic videos on-line for the common practical procedures, including lumbar puncture. 2. www.nejm.org/multimedia/medical-videos (Accessed 24/11/11).