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. 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. 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. 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. This can be plotted as a ‘learning curve’. 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. 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.

In the 1980s, Kolb developed a four stage cycle model to explain how adults learn a skill. 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. 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

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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...
Lumbar Puncture

As part of the diagnostic process:
- Central nervous system infections (meningitis, encephalitis)
- Subarachnoid haemorrhage
- 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

Box 1. Indications for lumbar puncture.

Box 2. Equipment required for lumbar puncture.

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.

Needles should not be inserted through infected skin.

Studies have explored which needle size gives both enough for use in older people with calcified ligaments. 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.

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

Needles with atraumatic tips theoretically part, rather than cut, the elastic fibres in the dura, thus allowing them to close 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).

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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$_2$O) 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 adult is less than 20 cmH$_2$O. If the pressure exceeds 25 cmH$_2$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.
of post-LP headache. 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.

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, 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.

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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, 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.1,2

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. The patient (worse on sitting or standing and eased by lying down) 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.

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.13 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.

References


Further resources

1. The New England Journal of Medicine has a collection of fantastic videos on-line for the common practical procedures, including lumbar puncture.