Lumbar puncture for the generalist

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ABSTRACT

The safe and successful performance of a lumbar puncture demands a working and yet specific knowledge as well as competency in performance. This review aims to aid understanding of the knowledge framework, the pitfalls and complications of lumbar puncture. It includes special reference to three dimensional relationships, functional anatomy, imaging anatomy, normal variation and living anatomy. A lumbar puncture is a commonly performed procedure for diagnostic and therapeutic purposes. Epidural and spinal anaesthesia, for example, are common in obstetric practice and involve the same technique as a lumbar puncture except for the endpoint of the needle being in the epidural space and subarachnoid space respectively. The procedure is by no means innocuous and some anatomical pitfalls include inability to find the correct entry site for placement of the lumbar puncture needle and lack of awareness of structures in relation to the advancing needle. Headache is the most common complication and it is important to avoid traumatic and dry taps, herniation syndromes and injury to the terminal end of the spinal cord. With a thorough knowledge of the contraindications, the regional anatomy and rationale of the technique and adequate prior skills practice, a lumbar puncture can be performed safely and successfully.
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Introduction

In the United Kingdom the landmark paper, 'Tomorrows Doctors' [1] focuses strongly on the acquisition of practical skills. Similarly, the Association of American Medical Colleges [2] has stated, that before graduation, a student should have demonstrated to satisfaction the ability to perform routine technical procedures including the following *minimum*: venepuncture, inserting an intravenous catheter, arterial puncture, thoracocentesis, lumbar puncture, inserting a nasogastric tube, inserting a Foley's catheter and suturing lacerations. The General Medical Council [3] has also stated that one of the duties of a registered doctor is to keep his/her professional knowledge and skills up to date. Reid *et al.*,[4] alluded to the procedural skills of generalists regarding a range of invasive procedures in South Africa. Kneebone [5] points out that confidence in performing a procedure comes from a knowledge base, of knowing what to expect. Similarly, Wigton [6] mentions that the most important elements of procedural competency are the cognitive aspects.

This article reviews the clinical skill of a lumbar puncture. It starts with a step-by-step description of the procedure and focuses on the pitfalls and complications associated with its performance. It is hoped that it will be useful to generalists and medical students.

Step by step procedure

Step 1. Position

- Lateral recumbent position: The patient should be positioned in the lateral recumbent position with the back flexed as far as possible. Ask the patient to try to touch the flexed knees with his/her chin [7] . This is to overcome the lumbar lordosis which narrows the interspace between adjacent spinous processes and laminae. The coronal plane of the trunk should be at a right angle to the floor with one hip exactly above the other. The needle is passed horizontally, i.e. parallel to the floor. This ensures that the needle stays in the midline.
- Sitting position: The patient is seated with the neck and back fully flexed. Flexion facilitates the course of the needle through the widened gaps between adjacent lumbar spinous processes. For an unexperienced doctor the sitting position is much easier to determine the correct site of insertion.

Figure 1a: Sagittal section of the lumbar vertebrae illustrating the course of the lumbar puncture needle through skin

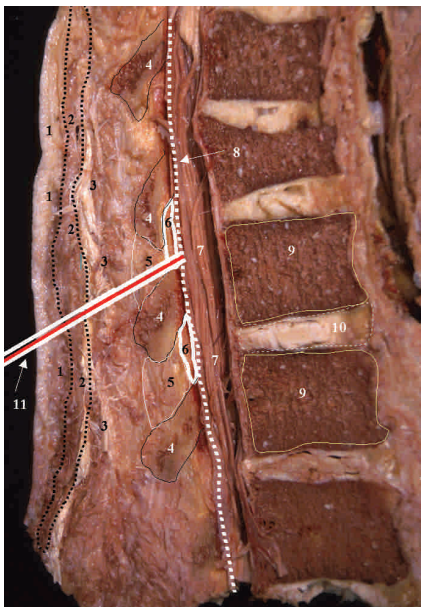
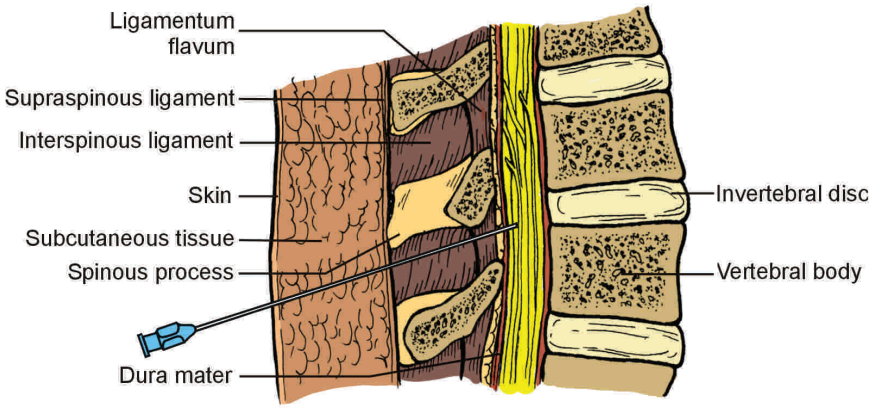


Figure 1b: Line drawing of sagittal section of the lumbar vertebrae with course of lumbar puncture needle.



(**1**) Subcutaneous tissue (**2**) supraspinous ligament (**3**) interspinous ligament (**5**) between the spinous processes (**4**), ligamentum flavum (**6**), dura mater (**8**), into the subarachnoid space and between the nerve roots of the cauda equina (**7**), (lumbar vertebral bodies (**9**), intervertebral disc (**10**) and lumbar puncture needle (**11**).

Figure 2a: Horizontal section at the level of L3 illustrating the course of the lumbar puncture needle through skin

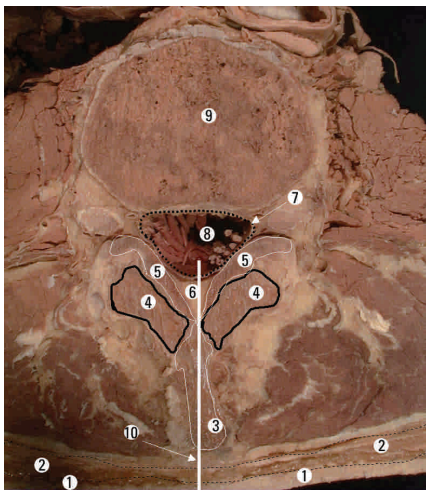
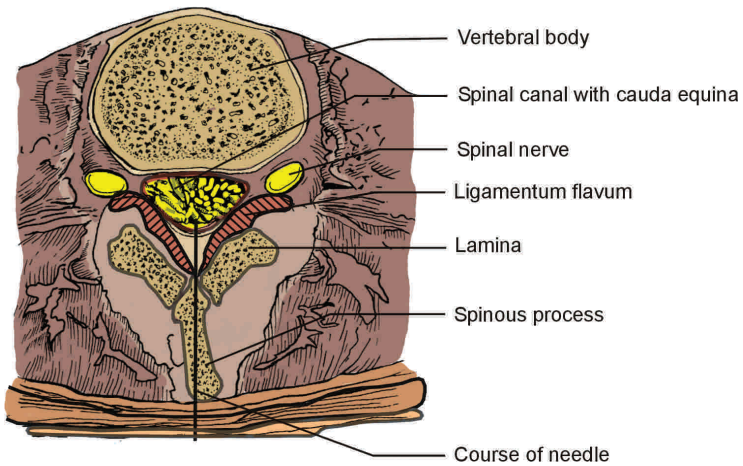


Figure 2b: Line drawing of horizontal section at L3 with the course of the lumbar puncture needle.



(**1**), subcutaneous tissue (**2**), between the spinous processeses (**3**) and laminae (**4**), ligamentum flavum (**5**), epidural space (**6**), dura mater (**7**), into the subarachnoid space and between the nerve roots of the cauda equina (**8**), (lumbar vertebral body (**9**) and lumbar puncture needle (**10**).

Step 2. Determine site of insertion

- A line joining the most superior part of both iliac crests (Tuffier's line) will intersect the midline at the L4 spinous process or L4/L5 interspace[7,8].
- The space above L4 is therefore L3/L4 and below L4/L5 [9] .
- Both these spaces are below the termination of the spinal cord at L1/L2 in the majority of adults [7] and both these spaces may be used as the site of insertion [9].
- The L4/L5 or L5/S1 interspace should be used in children as the spinal cord ends at L3 [7,9].

Step 3. Infiltrate

- Infiltrate only subcutaneously, deeper structures are less pain sensitive and increased volume may distort the tissues and make the procedure more difficult.

Step 4. Insertion of needle

- A pencil-point (or Sprotte-) needle (22-27 gauge) is indicated for spinal anaesthesia. For diagnostic purposes a slightly larger gauge bevelled needle (18, 20 and 21 standard gauge needles; 22 gauge, 3.5cm long needle for neonates and a 20 gauge 5 cm long needle for children) should be used for collection of cerebrospinal fluid (CSF). However, the higher gauge (smaller) needle, the lesser chance of a postspinal headache.
- Insert the needle at the superior aspect of the spinous process that lies inferior to the space to be entered.

Aim for the umbilicus (15 degrees cephalad) if the L4/L5 interspace is used [10].

- The bevel should be in the sagittal plane so as not to cut the longitudinal fibers of the dura mater, diminishing injury to the dura mater by separating the fibers of the dura, rather than cutting through them. This will reduce leakage of CSF.
- Pass the needle through the supraspinous ligament, which connects the spinous processes and the interspinous ligaments which connect adjacent borders of the spinous processes. Pass the needle through the ligamentum flavum, which may feel as a sudden yielding sensation or give as it is penetrated, often referred to as a 'pop'. If the needle is exactly in the midline, it may pass through the gap between the right and left ligamentum flavum [11], which span the space between the laminae of adjacent vertebrae. Practical experience as well as observations by CT [11] shows that the needle is usually not perfectly in the midline, and therefore passes through either the left or right ligamentum flavum to a site in the lateral epidural space, before piercing the dura. In older patients the ligament may provide significant resistance since it is often calcified. This resistance is being felt at a depth of 4-7 cm.
- After entering the ligamentum flavum, remove the stylet at each 2 mm intervals of needle advancement to check for flow of CSF.
- A second 'pop' represents penetration of the dura mater into the subarachnoid space. If bone is encountered – withdraw the needle partially to the subcutaneous tissue. Repalpate the back to make sure the needle is in the midline and try again.

The lumbar puncture needle pierces in order: skin, subcutaneous tissue, supraspinous ligament, interspinous ligament, ligamentum flavum, epidural space containing the internal vertebral venous plexus, dura, arachnoid and finally the subarachnoid space.

Clear fluid will appear if the subarachnoid space is penetrated. If not, it is worth rotating the needle through 90 degrees as the opening at the end of the needle may be obstructed by a nerve root [12]. CSF drips directly into the specimen tube. Never aspirate with a syringe for a small amount of negative pressure can cause subdural hemorrhage or herniation. The amount of fluid collected for diagnostic purposes should be restricted to the smallest volume of CSF necessary. For children this is typically 0.5 ml per tube and not more than 3 ml in total. Various analyses can be done on CSF, including bacteriological and virological cultures, differential cell counts and cytology, protein, glucose, immunoglobulins etc. Different specimen tubes are available for different tests. The three standard investigations include, glucose, biochemistry as well as microscopy, culture and antibiotic sensitivity.

Pitfalls and complications

1. Injury to the end of the spinal cord

Adults: The vertebral level at which the spinal cord terminates varies widely from T12 to the L3/L4 intervertebral disc [13]. The spinal cord extends to the L1-2 disc in 51% of people and to the L2-3 disc or below in 12% [8]. In a recent MRI study of 136 adult scans, MacDonald *et al.*, [14] showed that the median level of termination of the spinal cord for both males and females was the middle one-third of the first lumbar vertebra, a higher level than usually stated. This ranged from the middle one-third of T11 to the middle one-third of L3. Only 25% of cords ended below the disc between L1 and L2. Puncture is usually performed at either the L3/L4 or L4/L5 interspace [9]. Reynolds [15] also strongly advised not to insert a spinal needle above L3, for in a study on injury to the conus medullaris following spinal anaesthesia, seven cases (of which 5 were performed for spinal anesthesia for cesarean sections) were described with neurological damage when the needle was introduced at the L2-L3 interspace. The injury (fluid collection seen on MRI, intramedullary haemorrhage and small infarcts) was followed by neurological symptoms (foot drop, numbness, sphincter disturbance, weakness) associated with more than one nerve root. Five of the seven cases went to litigation. During insertion, the spinal needle is directed somewhat superiorly, which as Reynolds [15] has illustrated convincingly, may be the reason for injuring the conus medullaris in 4-20% of people when using the L2/L3 interspace. Wall *et al.,* [16] has demonstrated that a web of arachnoid membrane holds the nerve roots together at the level of the conus medullaris with the nerve roots forming a peripheral rim around the cord.

Infants: The spinal cord ends at L3. Needle placement should therefore be at L4/5 or L5/S1 [7,9]. The differences between adults and children are due to differential longitudinal growth of the spinal canal and the cord. At six months of fetal life, the lowest limit of the spinal cord lies at the level of S1 [17]. At birth the conus medullaris is mostly found at the level of L3 [18].

2. Headache

Headache is the most common complication of dural puncture [19] , occurring in up to 36.5% of spinal taps [20]. Usually it starts 48 hours after the procedure [21] (probably due to the continued leakage of CSF through the dural puncture site) and may last up to 1 to 2 days or even two weeks. Sometimes it is accompanied by nausea, vomiting, vertigo, tinnitus, diminished hearing and blurred vision. The headache is due to leakage of CSF through the dural puncture site into the epidural and paravertebral spaces faster than the production rate of CSF [22]. The incidence of headache after lumbar puncture is directly related to the size of the needle used at the dural puncture site. Headache is more common with a large needle because of a larger leakage of CSF through the inflicted puncture of the dura. Also less headaches are seen with pin-point needles are seen as compared to cutting needles. A dural puncture with leakage of CSF leads to low CSF pressure, absolute reduction of CSF volume below the cisterna magna with resultant downward movement of the brain and traction on pain-sensitive structures in the cranial cavity, especially the pain-sensitive basal dura [21]. The fact that CSF volume decreases during lumbar puncture seems to decrease the brain's supportive cushion and may also explain the headache. The amount of fluid collected for diagnostic purposes should be restricted to the smallest volume of CSF necessary.

Infants have a total of 40-60 ml of CSF, young children about 60-100 ml and adults 120-150 ml. Although less total CSF, children below 15 kg have approximately twice the volume of CSF per kilogram body weight (4ml/kg) than adults (2ml/kg). In an adult the removal of 10 ml of CSF is replaced in 30 minutes at the normal rate of CSF production of 0.3 ml/min. A child produces CSF at an approximate same rate [23].

Associated risk factors are: female, lower body mass index, young age, large needle size, beveled needle type compared with pencil-point needle of same size, bevel of needle cutting longitudinal dural fibers [24] and multiple punctures. The pencil-point needle separates, rather than cuts, through the dural fibers, giving a significantly lower incidence of post-spinal headaches [25]. The pencil-point needle (22-25 gauge) is indicated for spinal anaesthesia, but not for diagnostic

use, as it does not allow free flow of CSF with resultant difficulty, in obtaining sufficient CSF. The smallest possible atraumatic needle with a stylet should be used for spinal anaesthesia and multiple punctures should be avoided. For diagnostic use a larger bevelled gauge needle (18, 20 and 21 standard gauge needles with a short needle for children) should be used for collection of CSF [12].

Traumatic tap

A traumatic tap (defined as a tap containing macroscopic blood) usually occurs due to the needle being placed too far laterally or advanced too far anteriorly [26]. The internal vertebral venous plexus in the epidural space may be involved in a traumatic tap. A traumatic tap should be distinguished from a subarachnoid hemorrhage. Fluid generally clears after the first and second tubes in a traumatic tap. The presence of a clot in one of the tubes strongly favors a traumatic tap. Clotting does not occur in a subarachnoidal hemorrhage due to defibrinated blood being present in the CSF. Entry to the internal vertebral venous plexus, poses a slight risk of neurological symptoms, as clots may compress the spinal nerve roots or nerves [10].

Dry tap

A dry tap [10] is usually due to incorrect positioning of the patient and consequent misdirection of the needle. The needle is often advanced on to bony structures. This is often due to inappropriate, usually too superior, direction of the needle, with obstruction by the lamina or spinous process of the superior or inferior vertebra. If the needle is directed too laterally, an inferior or superior articular process may provide obstruction and may also injure the spinal nerve root in the intervertebral foramen. The back may also not be fully flexed, with the gaps between the lumbar spinous processes not widened [7] . If only one iliac crest is used to locate L4, 30% of needles are misplaced at L2-3. This high misplacement figure is diminished to 4% if Tuffier's line is used to determine L4, as determined by a cadaveric study [8]. Tuffier's line is defined as a line joining the iliac crests on the left and right and is usually found on the lower border of the spinous process of L4 to the L4-5 interspace [15]. The level indicated by Tuffier's line may vary from L3-4 to L5-S1. In a study [27] to determine the success of identification of lumbar interspaces by using Tuffier's line, correct identification was only seen in 29% of cases and the correct space was one space higher in 51% of cases. It is therefore recommended to rather go for one space lower, as the identified space is likely to be at least one interspace higher.

Difficulty in finding landmarks

It may be difficult to find the landmarks in obese patients. Access to the spinal canal may be impeded in patients with osteoarthritis or suffering from ankylosing spondylitis, kyphoscoliosis or previous lumbar spine surgery [7]. Broadbent *et al.*, [27] showed that the accurate identification of the correct lumbar interspace was significantly impaired by obesity. In young patients the vertebral anatomy is well defined, consistent and amenable to easy localization of the epidural and subarachnoid space [28]. The midline approach is usually used for lumbar puncture, where the needle is directed in a slightly cephalad direction in the midline between two spinous processes towards the umbilicus. To reach the epidural space and thereafter the subarachnoid space, the needle must pass through the opening formed between adjacent laminae, the interlaminar area. There is evidence that the interlaminar area reduces with increasing age, which may make lumbar puncture more difficult. In a study by Boon *et al.*, [29] measurements performed on antero-posterior lumbar spine radiographs in different age groups showed that measurements of the interlaminar area significantly diminished with increasing age at L3/L4, L4/L5 and L5/S1.

Many factors such as osteoarthritis, ankylosing spondylitis, kyphoscoliosis, previous spinal surgery, degenerative disc disease with collapse of the intervertebral space and other vertebral diseases may cause problems during any approach for spinal and or epidural blockade [7]. Such factors may lead to technical difficulties in performing the procedure. Cousins and Bromage [30] suggest the paramedian approach if needle access is difficult in the presence of the above-mentioned conditions.

Pain referred to the lower limb

If the patient complains of a shooting pain down a leg during the procedure, a nerve root may have been hit. The needle was probably angled away from the midline towards the side of the pain. If this happens, the needle should be withdrawn completely and the procedure started again, although this may already have caused nerve damage [15]. Samsoon and Grewal [31] considered the spinal insertion technique of great importance to avoid the risk of nerve trauma. The risk of nerve injury increases when plunging through the dura when uncontrolled pressure is applied.

Possibly the best technique for avoiding uncontrolled plunging through the dura, is the technique described by Bromage *et al.* [32]. It provides safety to the underlying spinal cord by signalling the precise moment to stop the spinal needle. The needle is gripped with a gloved left hand (in case the operator is right handed) between the thumb and the proximal phalanx of the second finger, with the metacarpal heads against the patient's back. Highly controlled pushing of the needle is now possible with a gloved right hand, without repositioning the left hand on the needle. In this way while the right hand pushes the needle in a controlled way, the left hand, guides and stabilizes the needle in the correct direction as well as halts the needle. The advancement of the needle can be halted at the very moment of the observation of cerebrospinal fluid. Advancement of the needle until a dural 'pop' is experienced should be discouraged and a periodical stop and check method (2 mm at a time) for cerebrospinal fluid whether a dural 'pop' has been felt or not seems to be safer. The reason for this is that with atraumatic pencil point needles, no 'pops' may be experienced when passing through the different tissue layers. The plunger of a syringe should not be withdrawn if it is attached to the needle or when injecting anesthetic solution. The negative pressure may pull a spinal nerve root against the needle tip and produce paresthesia, pain or injury [10]. Disk herniation has been reported due to the needle passing beyond the subarachnoidal space (needle advanced too far) into the annulus fibrosus, with resultant herniation of the nucleus pulposus [12]. Multiple attempts may lead to paraspinal muscle spasm, presenting as backache.

Herniation syndromes

Large pressure gradients occur between the cranial and lumbar compartment in supratentorial mass lesions. When the pressure in the spinal compartment is lowered by a lumbar puncture, transtentorial and foramen magnum herniation may occur. Duffy [33] reported on 30 patients with post-lumbar puncture herniation syndromes of whom half lost consciousness immediately after the lumbar puncture. Pre-existing tentorial herniation is a contraindication to a lumbar puncture. This can be diagnosed by findings of pupillary and oculomotor fixation, quadriparesis, postural and respiratory changes.

Interspinal epidermoid tumor

This complication usually arises due to the failure to use a stylet [34] and constitutes

a mass of desquamated cells containing keratin, arising from viable epithelial cells introduced into the spinal canal by the spinal needle. Skin tissue can easily be detached by a hollow needle and implanted into the subarachnoid space. The stylet should not be removed until the needle tip has passed the skin and unstyletted lumbar puncture needles should be avoided.

Hypoxia and ventilation-perfusion mismatches in children

Gleason *et al.*,[35] demonstrated that performing a lumbar puncture on an ill, premature baby using the traditional recumbent position with neck flexion, may result in significant respiratory ventilation-perfusion imbalance leading to hypoxemia. Beware of too long a period of flexion of the neck while positioning the child, for this may produce dangerous airway obstruction. Positioning is best accomplished by an assistant holding the child and maintaining the spine maximally in a flexed position by holding the child behind the shoulders and knees. Weisman *et al.*,[36] compared the grade of hypoxemia in three different positions. The sitting and lateral position without knees-to-chest position experienced less hypoxemia than those in the lateral knees-to-chest position. The neck is best maintained in the neutral position.

Conclusion

This paper focuses on the various pitfalls and complications of a lumbar puncture. In the absence of contraindications, a thorough knowledge of the anatomy and technique as well as adequate prior skills practice, a lumbar puncture can be performed safely and successfully. Lumbar puncture remains a very common procedure performed in various specialities. Not only for diagnostic purposes, but also for therapeutic indications like spinal anaesthesia which is gaining popularity in obstetric anaesthetic practice. Although difficulties and complications are encountered and should be overcome (the procedure is by no means an innocuous procedure), the procedure is widely practiced, remains an essential procedure in the armamentarium of generalists, and is usually safely and successfully performed without complications.

Multimedia resources

Internet sites:

- www.rch.unimelb.edu.au/clinicalguide/pages/lumbar.php
- http://medmic02.wnmeds.ac.nz/groups/rmo/lp/lp_toc.html

CD ROM:

Boon JM, Abrahams PH, Meiring JH, Welch T. 2002 CD ROM: The Virtual Procedures Clinic, **Primal Pictures Ltd: London** ISBN 1904369006

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