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Lumbar puncture: considerations, procedure, and complications

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Lumbar puncture is an important technique used to obtain cerebrospinal fluid, administer medications, and monitor intracerebral pressure. As essential invasive approach to diagnosing and treating central nervous system disorders, clinicians should be familiar with lumbar puncture. This review includes the considerations, contraindications, procedures, and complications of lumbar puncture.

Keywords: Spinal puncture, Cerebrospinal fluid, Post-dural puncture headache, Complications

Introduction

Cerebrospinal fluid (CSF) is critical in the homeostasis of the central nervous system (CNS) and provides important information for diagnosing neurological diseases and disorders. Lumbar puncture is a commonly used neurological technique. Since being developed by Heinrich Irenaeus Quincke in 19th century, this procedure has been the gold standard for obtaining CSF for chemical evaluations of the CNS. Its indications include CNS infection, inflammation, stroke, neoplasm, sleep disorder, and intrathecal administration for spinal anesthesia or chemotherapy [1]. In addition, lumbar puncture can provide a channel for intracranial pressure measurement and CSF drainage.

"Spinal tap" is another well-known name for lumbar puncture since this medical procedure is performed on the individual's back with a fine needle to obtain CSF. Despite major advances in non-invasive evaluation techniques such as neuroimaging, lumbar puncture remains a basic skill of clinicians and an essential diagnostic tool in neuroscience. It is a procedure that can be used in virtually all fields of medicine, except for several contraindications. In this review, the considerations, procedure, and complications of lumbar puncture will be discussed to enable a thorough understanding.

Procedure

In real-world practice, informed consent must be obtained prior to procedures. Written informed consent includes making patients aware of potential complications since lumbar puncture is an invasive procedure. The patient's ideal position is the lateral recumbent position with the knees and the neck flexed, or the seated position with the neck flexed. The lateral recumbent position is preferred to the sitting position. The opening pressure of the lateral recumbent posture is more reliable than that of the sitting position, and lowering the position of the head may reduce the risk of post-dural puncture headache (PDPH). The proper position and posture of the patient are critical to the success of the lumbar puncture procedure [2]. The needle will miss the route if the individual's back is misaligned due to the shoulder or pelvis being tilted. In addition, if the patient provides insufficient flexion of the neck and back, the approach becomes more difficult.

The ideal points of needle insertion are either L3-4 or L4-5.

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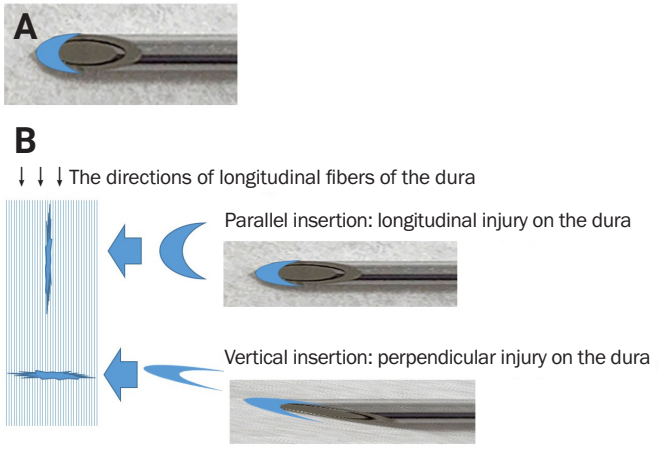
This "ideal" location is derived from the level of the conus medullaris, which the spinal needle should not injure. There are reasonable grounds for the level of safe practice. In adults, the spinal cord ends with wide variability, ranging from T12 to L3 [2,3]. The level is higher than L1-2 in half of the population, while the conus medullaris extends to the L2-3 level in 6% [2]. However, there should be consideration of clinical landmarks. Tuffier's line, also known as the intercristal line, refers to a transverse line that connects both iliac crests and intersects the spine at L4-5. Tuffier's line has been a reliable landmark for finding the spinal level; however, the application of this method can be challenging. Location of this landmark has an accuracy of 30% to 60% depending on the user [4-6]. Half of the total attempts do not match the target level [7]. Caution is needed as the Tuffier's line cannot guarantee an accurate spinal level, and the needle may enter one level higher than intended. This is why the L3-4 or L4-5 level is ideal for lumbar puncture.

To begin a lumbar puncture, the skin around the needle insertion point should be thoroughly cleaned. Using the classic concentric circular fashion with a cleaning agent such as povidone-iodine is recommended. The lumbar puncture should be performed after the skin has been cleansed and sterile drapes have been applied. An aseptic procedure is obligatory to avoid iatrogenic infection. Local anesthesia remains optional.

The spinal needle should be inserted at the midline with the stylet. Although there is still controversy [8], it is common sense to keep the bevel parallel to the direction of the dural fiber to reduce trauma at the dura (Fig. 1). Let the needle gently proceed toward the patient's umbilicus. The human body structures through which the needle breaks are as follows: skin, subcutaneous tissue, supraspinous ligament, interspinous ligament, ligamentum flavum, epidural space including internal vertebral venous plexus, dura mater, arachnoid, and subarachnoid space. The spinal needle will be inserted 2/3 (4–5 cm) of its length to reach the subarachnoid space [2,9,10]. During the procedure, the patient may experience pain when the needle pierces the skin and when the needle contacts bony structures or spinal nerve roots.

The route of the needle should be a single direction. If the needle contacts a bony structure without obtaining CSF, redirection of the needle is required. In this case, the needle should be withdrawn without removal from the skin, and then redirected. A traumatic puncture may occur when the needle damages the venous plexus. Due to the clotted blood at the puncture site, the procedure should be repeated at another site with a new needle. There may be a "pop" when the needle reaches the subarachnoid space, and CSF can be observed in the needle's hub. If the CSF does not flow, the needle can be advanced by 1 to 2 mm or can be rotated 90º. The stylet must be in place as the needle moves forward and backward (Fig. 2). If a strand of arachnoid flows into the needle hub and can stick out with its movement, the arachnoid may remain outside the dura to cause a protracted CSF leak [11]. The stylet will fill the hollow caused by the spinal needle to prevent this situation (Fig. 3).

Figure 1 The tip of the spinal needle and schema of injury to the dura



(A) The sharp tip marked in blue makes an opening in the dura. **(B)** Note that the direction of the bevel can lead to differences in the direction of injury to the dura.

Once the CSF begins to flow, passive drainage is ideal for obtaining the CSF. Aspiration can be dangerous. The speed of CSF flow depends on the gauge of the spinal needle, but gentle pressure applied to the patient's abdomen can reduce the time needed to collect CSF. Do not forget to replace the stylet before the needle is removed. Apply a dressing with sterile gauze at the puncture site, and cover with gentle pressure. Vague pain around the puncture site, such as stiffness or discomfort, is common and may last for days or weeks.

Contraindications

There are several contraindications that must be excluded prior to performing lumbar puncture. Underlying diseases such as Arnold-Chiari malformation and vertebral abnormalities should be considered. In real-world practice, clinicians

Figure 2 The spinal needle and the stylet

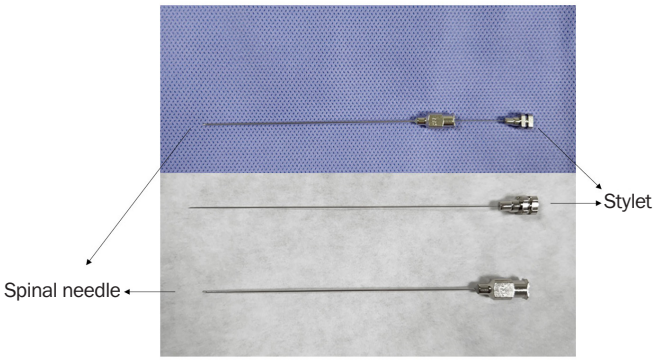
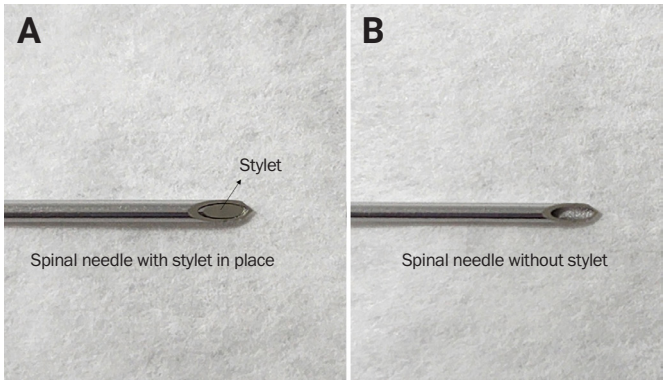


Figure 3 The tip of the spinal needle with and without the stylet



The Quincke spinal needle, which has an angular and sharp tip, with **(A)** and without **(B)** stylet. Note that the stylet fills the hollow created by the spinal needle (annotation).

usually order brain computed tomography or magnetic resonance imaging (MRI) before lumbar puncture to exclude increased intracranial pressure. Neuroimaging is highly recommended when the clinician finds symptoms or signs that suggest increased intracranial pressure, such as altered level of consciousness, focal neurologic deficit, immunocompromised state, new-onset seizure, and malignancy [2,12-14]. The clinician's due diligence is paramount.

Soft tissue infection near the target site of lumbar puncture is another contraindication, because the lumbar puncture through the infected tissue may result in new-onset CNS infection [15], and the CSF findings would become less reliable. Developmental abnormality such as myelomeningocele also is a contraindication. A recent study suggested that a platelet count under 40,000 /mm3 and prothrombin time international normalized ratio (PT INR) over 1.5 are contraindications [15-17]. The platelet count and PT INR should be greater than 50,000/mm^3 and less than 1.5, respectively [2,14]. Clinicians should beware of anticoagulant and antiplatelet agent administration, which are relative contraindications, although supporting data are lacking [16,18].

Traumatic Tapping

Traumatic tapping refers to release of a mixture of CSF and peripheral blood when the needle damages the blood vessels during approach to the subarachnoid space. Traumatic tapping can confound the clinician. Pleocytosis cannot differentiate a false positive from CNS infection, while a high red blood cell (RBC) count may lead to a false positive for subarachnoid hemorrhage (SAH). Previous studies showed that the cutoff for traumatic tapping was ≥400 or ≥1,000 CSF (RBCs)/mm^3 [19-21]. The incidence of traumatic tapping has been reported to range from 10.1% to 16.0%, depending on the definition [20-23]. Risk factors include thrombocytopenia [23,24], high PT INR [24], operator inexperience [25], large-bore beveled spinal needle [14], and obesity affecting recognition of the vertebral level [20-22].

There are two considerations in traumatic tapping; interpreting pleocytosis and differentiating traumatic tapping from SAH. There are several suggestions for the interpretation of traumatic tapping. A previous study suggested a formula to predict CSF white blood cell (WBC) count: CSF WBC (predicted) = CSF RBC × (blood WBC/blood RBC) [26], and another study suggested the correction formulas of one CSF WBC per 1,000 RBDs [27]. SAH can be excluded if CSF RBC <2000/mm^3 with no xanthochromia [28], and the risk of SAH is nonsignificant if CSF RBC <100/mm^3 [29]. However, it should be kept in mind that the results of traumatic tapping are not reliable for making clinical decisions, and careful consideration based on the clinical information is required when traumatic tapping occurs. Follow-up lumbar puncture is recommended within the next several days.

Complications

Understanding the potential complications and their pathophysiology is essential to improving the quality of lumbar puncture and follow-up.

Post-dural puncture headache

Since the first recognition of PDPH reported by Dr. Bier in 1898 [30], it has been considered a common lumbar puncture complication. PDPH is a specific complication for lumbar puncture and has a particular pattern of headaches and relatively effective treatments. Subsequently, PDPH is recognized as an independent field of headache. The 3rd edition of the International Classification of Headache Disorder described PDPH as follows [31]; the leakage of CSF through the dural puncture results in headaches within several days. Common symptoms include positional headache and neck stiffness. PDPH is usually self-limiting within 2 weeks; however, it may result in a clinically significant situation such as subdural hemorrhage due to the traction effect of veins resulting from the brain being slumped downward [2,15,16,30,32]. It is believed that post-lumbar puncture bed rest may prevent PDPH. The duration of bed rest has been studied, and from four to eight hours is generally recommended [1,14,33]. Prophylactic epidural blood patch is not recommended to prevent PDPH [30].

Spinal hematoma

Due to the post-procedural pain, spinal hematoma may be overlooked or underestimated. Spinal hematoma with no neurological deficit can be self-limiting, but on the contrary, close observation and opportune steps are required if the patient complains of severe persistent back pain, radiating pain, sphincter dysfunction, or new-onset sensory disturbance [15,30]. Although very rare, special cautions for spinal hematoma and close monitoring followed by an MRI scan are paramount. This complication may lead to significant neurological deficits such as permanent paraplegia or sphincter dysfunction.

Conclusions

Lumbar puncture is a double-edged sword as an essential diagnostic tool and invasive procedure. Clinicians should keep the following basic considerations in mind: patient position, puncture site, direction of the needle and its bevel, anatomical structures, and potential complications. These practical details are tremendously important.

In conclusion, lumbar puncture requires the clinician's attention, awareness, and commitment from the preparation stage. We hope that this review will be helpful for practicing clinicians.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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