Fluoroscopically Guided Lumbar Puncture

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OBJECTIVE. The objective of this article is to detail the indications, techniques, risks, and benefits of fluoroscopically guided lumbar puncture (LP).

CONCLUSION. Familiarity with the details of fluoroscopically guided LP can aid in the work flow, increase the success rate, and minimize the complications of the procedure.

Fluoroscopically guided lumbar puncture (LP) is performed in the department of radiology, often by members of the division of diagnostic neuroradiology. Although there are many articles that discuss the technique of LP, few discuss the procedure from the radiologist's perspective. The goal of this article is to review the methods of fluoroscopically guided LP and discuss the general indications and the risks of the procedure.

LP was introduced to diagnostic medicine by the German physician Heinrich Quincke in 1891 [1], and with the exception of image guidance, the technique has not significantly changed since its introduction. LP is an invasive procedure requiring experience and skill. The procedure is more difficult to perform in obese patients, patients with congenital anomalies, and patients with extensive postsurgical or degenerative changes of the lumbar spine. Image guidance increases the success rate of LP, although the presence of extensive osteoarthritis or bony ankylosis can occasionally foil even image-guided procedures.

Indications for Lumbar Puncture

Image-guided LP in the radiology department is performed for one of four reasons.

To Obtain CSF for Laboratory Analysis

Image-guided LP is performed to obtain CSF for laboratory analysis (i.e., for cytology) to evaluate for subarachnoid hemorrhage or for markers for demyelinating disease.

To Obtain an Opening CSF Pressure

Image-guided LP is performed to obtain an opening CSF pressure. This information is often requested for the evaluation of patients with idiopathic intracranial hypertension (pseudotumor cerebri) or normal-pressure hydrocephalus. A high-volume tap (40 mL) may be requested as part of a diagnostic evaluation.

To Obtain Access for Intrathecal Chemotherapy Infusion

Image-guided LP is performed to obtain access for intrathecal chemotherapy infusion and is ordered by the hematology or oncology department.

To Inject Contrast Material for Diagnostic CT Myelography

Image-guided LP is performed to inject contrast material for diagnostic CT myelography. Diagnostic CT myelography is typically performed as a surgical planning tool as an alternative to MRI if there is a contraindication to MRI or if the neurosurgeon or orthopedic surgeon prefers it; sometimes diagnostic CT myelography is performed in addition to MRI.

Indications for Fluoroscopic Guidance

The principal indication for an image-guided LP is a failed bedside attempt or the belief that a bedside attempt will be unsuccessful. Ordering providers may not be adequately trained in LP technique or may have not sought credentialing, opting to send the patient for an image-guided procedure. Occasionally patients request image guidance. Typical factors contributing to a failed bedside procedure are obesity, severe degenerative disk disease, or scoliosis.

In the current health care climate, it is important to note that LP is a procedure with

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low reimbursement and that scheduling a procedure room with fluoroscopic guidance and a dedicated radiology technician comes at considerable cost over the bedside procedure. Fluoroscopic image guidance can add several levels of complexity to the procedure of LP, requiring proper placement of the order with the radiology department, communication of the order to the staff member who will perform the procedure, scheduling of the procedure room, and transport of the patient. Because LP is poorly reimbursed, hospitals rarely have dedicated facilities for this procedure, and LP cases may compete with complex neurointerventional cases for access to expensive angiography suites. Alternatively, fluorography room time must be negotiated with other divisions of the radiology department. Finally, fluoroscopy entails a radiation dose, which may be unnecessary. For these reasons, the bedside procedure remains the first line of approach, and the radiology department typically requires that a bedside attempt be made before the image-guided procedure is undertaken.

Fluoroscopically guided LP entails a review of the patient's medical history and coordination of a significant number of hospital personnel. Completion of a preprocedure checklist (Appendix 1) can expedite preparation and can ensure a safe procedure.

Medically unstable patients such as patients receiving mechanical ventilation should be accompanied by emergency radiology or ICU personnel who can monitor vital signs. Outpatients should have someone available to drive them home after they have been released from the postprocedure recovery area. In-house staff are generally aware that patients should take nothing by mouth 2 hours before LP, and outpatients should be contacted by radiology support staff with procedure guidelines, which includes asking standard questions regarding major medical conditions, medications, and allergies.

Absolute Contraindications to Lumbar Puncture

Uncorrected Coagulopathy and Anticoagulants

Uncorrected coagulopathy will put the patient at risk for bleeding as a consequence of the procedure, with the possibility for neurologic damage as a sequela. The risk of a spinal hematoma is clearly higher in a patient with coagulopathy [2]. Spinal epidural and subarachnoid hemorrhages have been reported [3, 4]. Although both types of hemorrhage can result in spinal cord compression and myelopathy, subarachnoid hemorrhage is thought to be more dangerous in part because of blood being in direct contact with the nerve roots; however, imaging cannot always definitely reveal the compartmental location of a hematoma [3]. Some authors distinguish between subarachnoid hemorrhage and subarachnoid hematoma because "hematoma" implies a blood clot with mass effect and a greater potential for nerve damage [3].

As one will note from virtually any encounter with the medicine service, the international normalized ratio (INR) and coagulation issues are complex and controversial. Frequently, the guidelines differ among departments, and varying guidelines are found in the literature. Although many use the same platelet minimal value of 50,000, based on spontaneous bleeding below 40,000, some choose a higher platelet minimum value of 75,000, particularly in the setting of corrected thrombocytopenia [3, 5]. In patients with some hematologic conditions, the platelet value may be technically adequate, but platelet function may still be abnormal, raising a question about following platelet counts as a principal measure of coagulation status. Some practitioners believe that an INR of less than 1.5 is adequate. Others rely more on the prothrombin time (PT) and partial thromboplastin time (PTT) parameters with INR as an additional consideration. In addition, coagulation may not be the same in patients with hepatic dysfunction, and other parameters are considered important to evaluate. Radiology departments oftentimes establish global department policies to avoid miscommunication and ongoing debate. In complex cases, a hematology consult may be appropriate.

Concerns arise when the radiologist is asked to perform a procedure that he or she believes falls into the marginal zone for safety. As with other areas of medicine, the responsibility falls to the physician performing the procedure, and a risk-benefit assessment may be necessary in patients whose coagulation profiles are questionable. A dialogue with the ordering physician will help to clarify the issue, and the dialogue should be documented in the patient record. In these cases, one should avoid multiple puncture attempts that will further increase the risk of bleeding. With a simple traumatic tap, the amount of blood in the CSF should decline during the CSF collection. If the amount of blood remains concerning, alerting the ordering provider and suggesting supplemental fresh frozen plasma (FFP) and regular neurologic checks may be appropriate.

Inpatients are often on a subcutaneous heparin protocol for deep venous thrombosis prophylaxis. The risk of bleeding as a result of LP is reported to be negligible below a total dose of less than 10,000 U [6]. When there is a question regarding heparin status, obtaining the activated PTT value may be prudent [7]. The prolonged use of heparin raises the risk of heparin-induced thrombocytopenia, and the platelet count should be assessed in this setting [8].

Spinal hematomas after LP in the absence of coagulopathy are extremely rare but have been reported [3, 4], and the incidence is increased if anticoagulation therapy is started immediately after LP; this increased incidence suggests that anticoagulation therapy should be delayed for at least 1 hour after LP [9]. The incidence of a traumatic tap is reduced with image guidance [10], and the likelihood of other complications is probably reduced as well. Spinal hematoma with nerve root or cord compression is an emergency because pressure on the spinal cord can result in irreversible ischemic injury and because outcomes appear to worsen with delays in diagnosis and treatment [4, 11].

Intracranial subdural hemorrhage is a rare complication of LP. Risk factors are thought to include coagulopathies and cranial abnormalities such as cranial vault deformities, shunts, meningiomas, and cerebral atrophy [12]. Intracranial subdural hematoma may be a late consequence of a spinal fluid leak and intracranial hypotension [13, 14] and should be considered in a patient with unremitting headache after LP [13, 14].

The risk of hematoma is generally considered to be higher and coagulopathy should be corrected before attempting the procedure if INR is greater than 1.4 or if platelets are less than 50,000.

Anticoagulants should be discontinued before LP according to the following guidelines. If the patient is receiving a therapeutic dose of heparin, discontinue 6 hours before the examination and hold routine prophylactic dosing for the day of the procedure. If the patient is receiving aspirin, discontinue 7 days before the examination; however, low-dose aspirin (80 mg) can be continued. If the patient is receiving warfarin (Coumadin, Bristol-Myers Squibb), discontinue for 2 days before the procedure and follow the INR to less than 1.4 and the PTT to less than 40. If the patient is receiving clopidogrel bisulfate (Plavix, Bristol-Myers Squibb), discontinue for 7 days before the procedure. If the patient is receiving enoxaparin sodium (Lovenox, Sanofi-Aventis), discontinue for 12–24 hours before the procedure. For patients who are receiving thrombolytic therapy, guidelines have not been established [7, 15].

In many cases, the hospital or radiology department will have a policy or set of guidelines for procedures that includes a list of contraindications for LP and the radiologist should be familiar with those guidelines.

Elevated Intracranial Pressure or Clinical Findings That Suggest an Obstruction to CSF Flow

Patients who are obtunded, are comatose, are of altered consciousness, have focal neurologic deficits, or have papilledema should undergo head imaging, either CT or MRI, to assess for obstructive hydrocephalus, signs of elevated intracranial pressure (ICP), or an intracranial mass. Elevated ICP cannot be directly determined noninvasively, but obstructive hydrocephalus, cerebral edema, or a mass lesion, which could result in downward herniation as a result of removal of CSF, are contraindications to LP. If there is possibility of an intracranial mass or other cause for obstructive hydrocephalus, head imaging is mandatory. Any evidence of an obstruction to CSF flow should raise concern about the safety of LP (Fig. 1). Relatively subtle findings such as an obstructive colloid cyst or a Chiari I malformation may pose a risk for herniation as a result of LP [16, 17].

Removal of spinal fluid below an obstructive cord lesion or a complete block to CSF flow can create a pressure differential that can cause shifting of the position of the spinal cord and can result in cord compression, cord ischemia, or both—a phenomenon that has been termed “spinal coning” [18, 19]. Although the performance of an LP in the setting of a complete block to CSF flow is rare, the incidence of spinal coning is this setting is thought to be significant [20]. Therefore, LP below the level of a spinal block is not advised, and spinal coning should be considered in a patient with neurologic deterioration after an LP because there is the possibility of a block to spinal fluid flow within the spinal canal.

Low-Lying Conus, Tethered Cord, and Myelomeningocele

These conditions can preclude LP. In cases in which LP is critical, cervical puncture can be performed, usually by an interventional neuroradiologist.

Relative Contraindications

Lack of Informed Consent

An invasive procedure such as LP requires written patient consent. If consent cannot be obtained because of the patient’s mental status and if obtaining consent from the health care proxy is not possible, the procedure can be performed if deemed medically necessary. A note documenting the medical necessity of LP should be written by the ordering provider and be included in the patient’s medical chart.

Patient Is Medically Unstable or Is Unable to Cooperate With the Necessary Positioning

Patient sedation may be necessary to optimize procedure success. Sedation can range from a prescription sedative to full anesthesia coordinated with the anesthesia department.

Infection

LP in the presence of epidural abscess creates a risk for the spread of infection into the subarachnoid space; therefore, a diagnostic LP should not be performed when there is a known abscess [3]. A superficial infection is also thought to be a contraindication for LP because of an increased risk of carrying the infection into the CSF with the LP needle [21]. As I discussed earlier, a risk-benefit assessment should be performed on case-by-case basis. Careful antiseptic preparation of the skin and avoiding the site of infection if possible should serve to minimize the risk of infection tracking into and seeding along the line of puncture. Like patients with anatomic abnormalities, patients with infections can undergo cervical puncture as an alternative to LP.

Pregnancy

Women of child-bearing age should have a pregnancy test before any procedure involving radiation. If the test is positive, the risks to the fetus must be discussed with the ordering physician and the patient.

Contraindications to an Image-Guided Procedure

The only contraindication to image guidance is a patient weight greater than the table limit. A fluoroscopy table with a hydraulic lift mechanism can be damaged by exceeding the weight limit of the table, which is usually approximately 350–400 lb (158–180 kg).

Risks of Lumbar Puncture

Cerebral Herniation

Cerebral (uncal) herniation due to a pressure differential secondary to a mass lesion or obstructive hydrocephalus is a rare but potentially devastating complication of LP.

Cord Compression

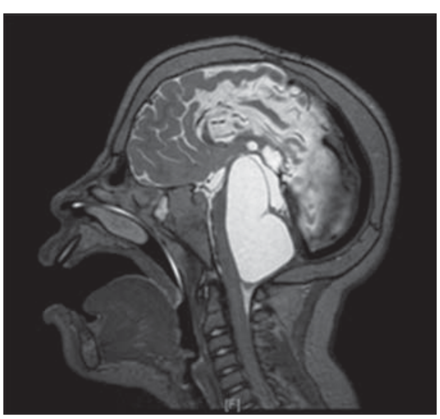
Hemorrhage into the epidural or subarachnoid space can result in cord compression and irreversible nerve damage.

Nerve Injury

A low-lying conus can increase the risk of nerve injury, or direct injury to a lumbar nerve root can occur as a result of LP. Back pain and radicular symptoms after LP typically resolve.

Infection and Meningitis

Infection and meningitis as a result of LP are unusual and can be avoided with proper technique.



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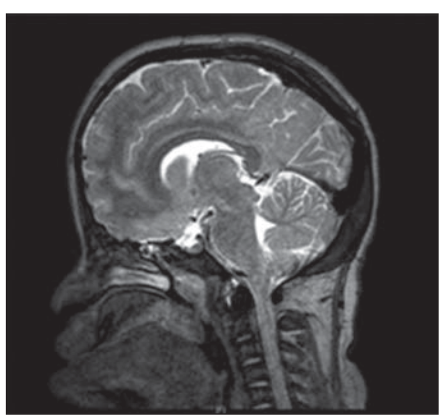


B

Fig. 1—Request for lumbar puncture (LP) is not appropriate in some patients; completion of preprocedure checklist shown in Appendix 1 will help identify these patients.
A, 12-year-old boy with multiple medical problems. LP was requested to obtain CSF for laboratory assessment of meningitis. Patient had previous brain MRI study that showed arachnoid cyst and obstructive hydrocephalus. LP was not performed.
B, 9-year-old boy with pyknodysostosis, craniosynostosis, and papilledema. Review of recent brain MRI study showed sulcal effacement and crowding of foramen magnum; these findings prompted concern for obstruction to CSF flow at level of foramen magnum. LP was not performed.

Headache

The typical post-LP headache is reported to occur in approximately one third of patients [22]. There are mixed opinions about the best ways to prevent and treat a post-LP headache. Caffeine is recommended [22]. Although it seems intuitively obvious that bed rest and hydration would decrease the incidence of headache or help to treat a headache once it occurs, evidence-based reports contradict this intuition [23, 24]. Further, neither the volume of CSF taken nor the opening pressure is correlated with post-LP headache [23, 25, 26]. Headache is largely attributed to LP technique, including the needle gauge, bevel orientation, and number of LP attempts [22]. Postprocedural bed rest seems to remain the standard of care. Persistent headache, which is rare, is treated with a blood patch, a procedure that is usually performed by members of the anesthesia department.

Epidermoid Tumor of the Thecal Sac

Epidermoid tumor of the thecal sac is a rare long-term sequela that can occur from inclusion of skin tissue into the spinal canal [27].

Myelography

Diagnostic myelography remains a procedure performed only by a diagnostic neuroradiologist. An intrathecal contrast injection is followed by CT of the spine in the area of interest (Fig. 2). The diagnostic study is generally interpreted by the radiologist who performed myelography.

In the absence of metallic interference, MRI is superior to myelography for the visualization of the contents of the spinal canal because MRI allows direct visualization of the spinal cord and nerve roots. Myelography is an invasive technique and offers little image detail or soft-tissue contrast. Therefore, MRI is generally the imaging modality of choice, and myelography is used only to address very specific questions.

Indications for Myelography

In the emergency setting, myelography is typically requested to rule out cauda equina in a patient who has a contraindication to MRI. Myelography is used to evaluate for lower cord or nerve root compression, which is seen as a block to contrast flow. Contraindications to MRI can include a pacemaker, cochlear implant, or metallic hardware that cannot be removed and that has a risk of movement or heating in the magnetic field.

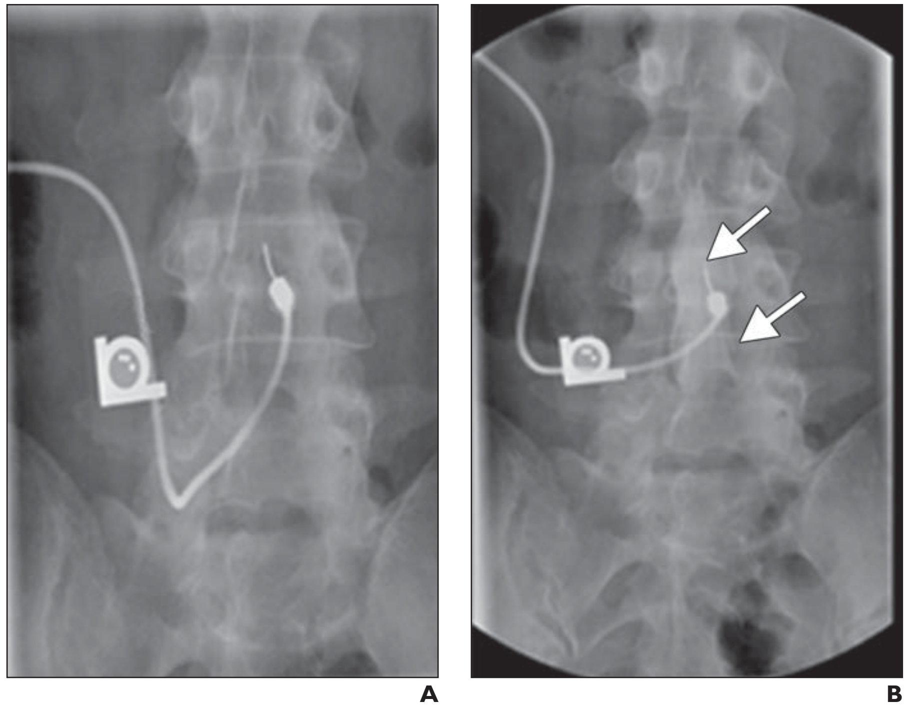


Fig. 2—80-year-old man who presented for lumbar puncture as part of radiation therapy planning.
A, Myelogram obtained with prone oblique approach at L3–L4.
B, On myelogram, contrast material around needle (*upper arrow*) should outline thecal sac and individual nerve roots of cauda equina should be evident (*lower arrow*).

Neurosurgeons sometimes request myelograms for presurgical planning, typically to gain a better understanding of the bony landmarks relative to the neural structures. Myelography can also be used to evaluate the flow of contrast material within the spinal canal to define structures, such as arachnoid cysts, to learn whether they communicate with the intrathecal CSF. CSF leaks can also be investigated using myelography or cisternography. The interested reader is referred to general reviews of myelography [28–30].

Risks of Myelography

The introduction of myelographic contrast material adds additional procedural risks because of possible reactions to the contrast material. Myelographic contrast material is a water-soluble contrast agent that comes in different iodine concentrations, and care should be taken to familiarize oneself with the information in the packaging and package insert. These agents are a clear liquid, and care must be taken to keep all syringes and containers clearly labeled. Contrast reactions to myelographic contrast material have been reported [30]. Commonly the contrast material can cause headache that usually occurs and subsides more rapidly than a post-LP headache. Headache may be caused by changes in osmolarity or some other property of the contrast material that is clearly worse when the contrast agent traverses more readily into the cranium, as can happen with cervical myelography. The slow administration of contrast material—with the patient's head and shoulders slightly elevated after the procedure—should minimize this type of headache in lumbar myelography. Most authors agree that bed rest and hydration are helpful in the prevention and treatment of the headache associated with myelographic contrast material [28, 31]. Myelographic contrast agents have been reported to cause seizure as a rare occurrence [32, 33]. CT myelography and the use of myelographic contrast agents are further detailed by the American College of Radiology and American Society of Neuroradiology in a dedicated guideline [32].

Intrathecal Chemotherapy

Risks of Intrathecal Chemotherapy

As with myelography, chemotherapy intended for the intrathecal space can be accidentally administered into the epidural or subdural space. This error is thought to occur in 10% of the cases and to result in ineffective administration of chemotherapy [34]. The return of CSF should ensure proper needle positioning. A small amount of contrast material administered and visualized under fluoroscopy may also help to confirm subarachnoid positioning before chemotherapy administration.

Review of Spine Imaging, Patient Preparation, and Local Anesthesia

A review of existing spine imaging studies is important if there is a suspicion of low-lying conus, mass lesions, or infection in the lumbar area or if the patient has a history of spinal surgery. For routine cases, a review of spine imaging studies may be helpful to identify the optimal level or approach for the puncture. The target spinal level is identified before beginning the sterile procedure. Once an optimal target site is identified, the point of approach is marked on the patient's skin with a marker. The area is then prepared and draped for sterile procedure. Lidocaine is used for local anesthesia. Because nerve endings are primarily at the skin, a wheal of subcutaneous lidocaine (≈ 2 mL) with a tuberculin or a small-gauge needle is usually sufficient. Both latex and lidocaine allergies have been reported, and appropriate precautions should be taken when indicated.

The Mechanics of Fluoroscopic Guidance

Older fluoroscopy equipment often has one fixed overhead camera. Imaging in radiology is best performed with two orthogonal views: one to assess the target and the other to assess depth. The fixed overhead camera can be complemented by adding a second camera that allows a lateral view or by equipping the facility to obtain a cross-table lateral view. Newer facilities offer a biplane camera, which can greatly facilitate the ability to assess a lateral view. State-of-the-art angiography suites can have multiple biplane cameras and large imaging screens. Generally, however, diagnostic radiologists are not familiar with advanced angiography facilities, and the basic biplane camera is adequate for fluoroscopic guidance of LP.

Several different approaches are common for fluoroscopically guided LP and are often a matter of preference [35]. With any approach, proper patient positioning is necessary to optimize the likelihood of procedure success. The invasive portion of the procedure should not be attempted until the patient is stably and comfortably positioned and the target for access to the spinal canal is clearly identified on fluoroscopy. Time and effort invested in optimal patient positioning can greater simplify the invasive portion of the procedure.

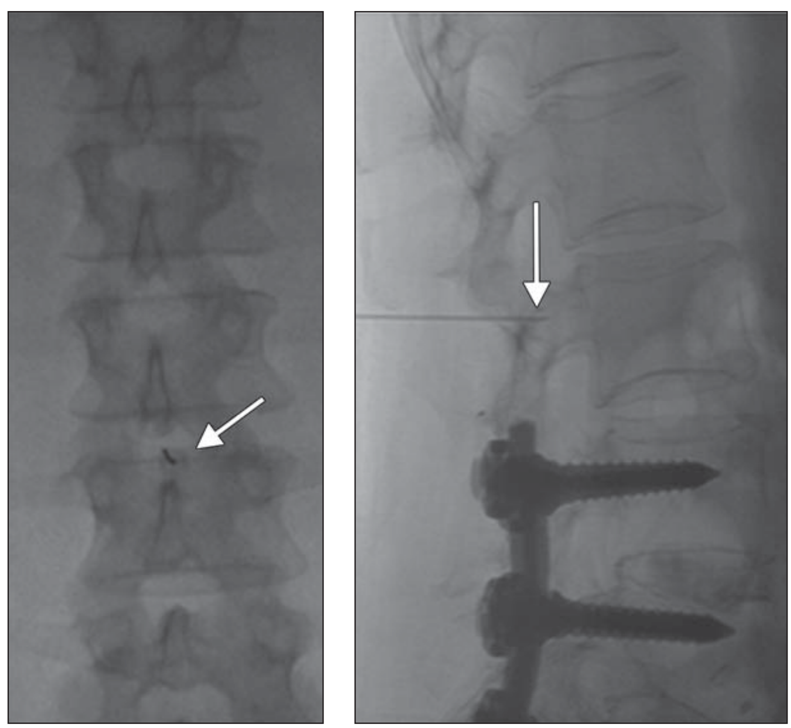
The Prone Midline Approach

For the prone midline approach, the patient should be exactly centered on the fluoroscopy table. Pillows placed under the patient centered at the target level (usually L2–L3 or L3–L4) will serve to reverse the normal lumbar lordosis and to mimic the decubitus positioning that would be used at bedside with a sitting or a lateral approach. The needle will traverse between the spinous processes at midline and serves to widen the space between the spinous processes. As the patient is positioned, the target site should be assessed with the fluoroscope to determine the optimal target level.

The advantage of the prone midline approach is that if the needle hub is kept directly over the needle tip and if the needle is directly in the center of the imaging screen, all parallax is removed and the needle trajectory is very clear at imaging. One should not hesitate to obtain a lateral view to determine the depth of the needle tip relative to the spinal canal (Fig. 3). This information about needle depth is most readily obtained using a biplane camera, which can be rotated, but can also be obtained using a conventional cross-table lateral camera. The disadvantage of the midline approach is that midline intraspinous and supraspinous ligaments can be very strong or can be calcified and resistant to needle penetration and can cause the needle to be deflected from accessing the spinal canal.

The Prone Oblique Approach

The prone oblique approach may be more comfortable for the patient, and this off-midline approach allows avoidance of strong midline ligaments and midline bridging osteophytes (Fig. 4). The disadvantage of this approach is that the obliquity complicates evaluation of the exact trajectory, and establishing a true lateral view is also complicated by patient positioning. Nevertheless, many radiologists prefer this approach.



A B

Fig. 3—Lumbar puncture (LP).
A, 30-year-old woman who presented for LP to obtain opening pressure. Posteroanterior myelogram obtained using midline approach shows needle (*arrow*) is positioned at midline, between spinous processes at L2 and L3.
B, 50-year-old man who presented for LP to obtain CSF for routine laboratory evaluation. Lateral myelogram shows needle tip (*arrow*) in anterior spinal canal. Posterior fusion hardware is also noted.

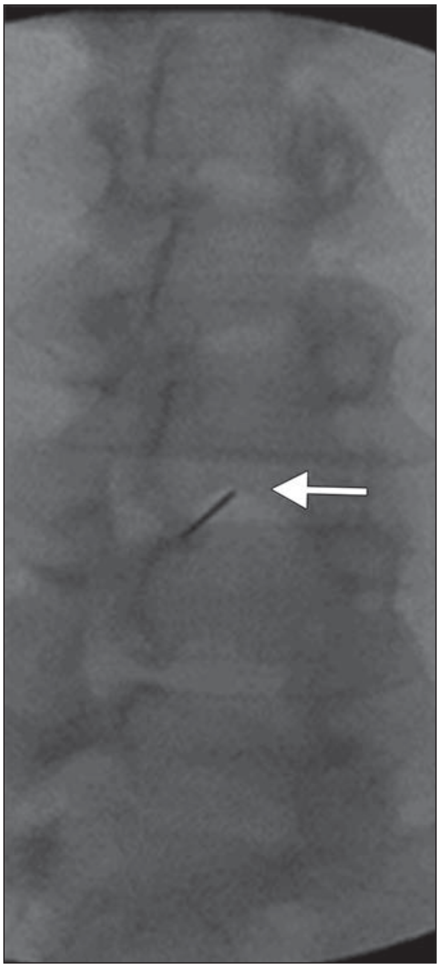


Fig. 4—29-year-old woman who presented for lumbar puncture to obtain opening pressure. Myelogram obtained using prone oblique approach shows patient is slightly oblique to right. Needle (*arrow*) enters lateral to spinous processes at L2–L3 level.

Older data suggest that the oblique or paramedian approach results in a lower incidence of post-LP headache than the median or midline approach [36], although another study makes the opposite claim [37]. A large cohort double-blinded randomized controlled trial conducted with 75 patients in each group reported no significant difference in the incidence of post-LP headache between the two groups [38]. Patients generally find positioning for the paramedian approach to be more comfortable, and the paramedian position is advocated for older patients with osteoarthritis or a hip injury [38].

The Lateral Approach

The lateral approach is more typically reserved for a biplane unit or angiography suite because the camera has the flexibility to rotate into line with the laterally positioned needle. Here again patient positioning is critical to the success of the procedure because constant retargeting will be required in the uncomfortable or moving patient. The patient may be belted into position on the narrow table to limit movement. Although a biplane unit has the advantage of being able to rotate to the patient's obliquity, the use of a biplane unit and of the lateral approach requires practice, and biplane and camera controls on newer machines can be complicated. Prone oblique positioning or lateral decubitus positioning with a biplane camera may be necessary in patients who cannot tolerate prone positioning.

Choices for Level and Needle

A target for puncture access is chosen to be below the conus tip, but the canal narrows toward the sacrum and the distance from the skin to the thecal sac increases. The conus tip is typically at the L1 level but can be verified by assessing previous imaging studies if any are available. Given these factors, the optimal levels are L2–L3 and L3–L4. Ultimately the level is chosen by fluoroscopic inspection as the level that appears most unobstructed by osteophytes, degenerative loss of disk height, or changes from previous surgery. The ideal level has a vertebral body as the "backstop" rather than a disk, and the bone ensures that the needle tip is not positioned too deeply.

LP is difficult for the patient but requires patient cooperation. Patients who are fearful or hesitant may require sedation. Patients who move during the procedure can pose risk to both themselves and the physician performing the procedure. I find that a continued dialogue with patients can be reassuring to them. The feeling of loss of control can be disturbing to patients, and it may be helpful to reassure anxious patients that they can choose to discontinue the procedure if they wish to do so.

Needle options are generally 20- and 22-gauge. A standard needle is 3.0 inches (7.6 cm) long; LP of obese patients may require a longer needle (5.5 inches, 14.0 cm). Smaller-caliber needles have been shown to result in a lower incidence of post-LP headache; needles of higher gauge than 22-gauge are easily bent during LP and are not typically used [39]. The tip of the needle has a bevel that can be used to help steer the needle. The stylette should always be fully in place when advancing or removing the needle to prevent cutting a nerve root or creating a suction to the nerve root when the needle is removed.

Radiation Exposure

Efforts should be made to minimize the fluoroscopy radiation dose to the patient and health care personnel. Studies in the literature report a wide range of radiation dose values for LP, showing radiation doses from LP to be comparable to those from lumbar CT, but these radiation values are no doubt on the high end because they are reported for obese patients [40]. In addition, a wide range of fluoroscopy times have been reported [40, 41].

Certainly a number of techniques can serve to dramatically reduce fluoroscopy time and radiation dose. First, use imaging only to guide the procedure. Avoid continuous fluoroscopy; instead, use spot images. If possible, use the Screen Capture mode so that the image is retained on the screen after fluoroscopy has ended.

Second, cone the image to the necessary FOV. Magnification can be helpful but increases the radiation dose to the smaller area that is irradiated.

Third, remember that recording an image for the PACS requires increased radiation, so use discretion when obtaining stored images.

Fourth, some older machines have an incandescent light (i.e., white light) directly overhead within the gantry. If prone positioning is used, this light can be helpful because the needle will cast a shadow. When the hub of the needle is in line with the tip, there is no shadow. Once the target is confirmed with fluoroscopy, the fluoroscope may be used only sparingly and observing the needle shadow may be sufficient to guide the needle.

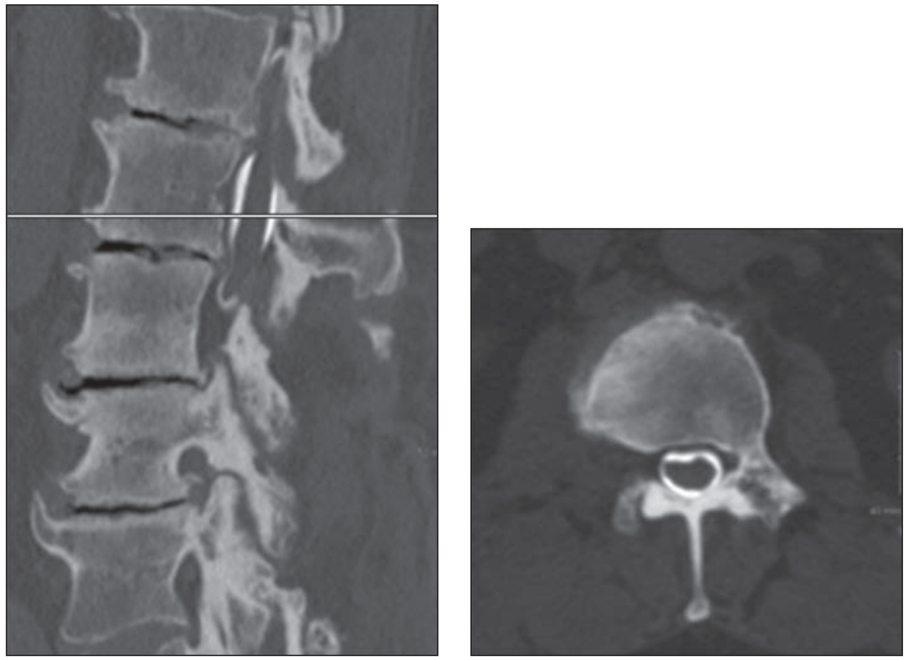
Fifth, currently most machines report a total procedure fluoroscopy time and dose delivered (in mGy and mGy · cm^2). In a straightforward procedure, the fluoroscopy time can be approximately 0–0.3 minutes, and the dose delivered can be 20–25 mGy and 4000–5000 mGy · cm^2. These values are comparable to the dose from a single chest radiograph [42].

Troubleshooting

If a puncture is proving difficult, alternative approaches may be helpful. Changing the level of approach or trying an alternative approach, such as prone oblique, can be productive. One should avoid making multiple passes through the thecal sac if possible because this increases the risk of hematoma, dural tear, and CSF leak. Proper intrathecal positioning of the needle tip is confirmed with the flow of the CSF. Occasionally the needle is in the correct position, but the CSF does not flow because of low CSF pressure or a local obstruction to flow. If a lateral view confirms that the needle is in the proper position, very subtly advancing or withdrawing the needle or rotating the needle may solve the problem. Injecting a small amount of myelographic contrast material and visualizing the contrast material with the fluoroscope can be informative. It is possible for the needle to puncture the dura and tent the thecal sac, resulting in a subdural injection into the potential space (Fig. 5), and contrast material will accumulate at the site of injection and will not highlight the lumbar nerve roots. A venous plexus is found anterior to the vertebral bodies, and venous blood may be seen if the needle has passed through the posterior dura.

A review of previous spinal imaging studies should precede choosing a plan of action. Additional imaging may be helpful, and the requesting provider might be contacted to order CT of the lumbar spine, which can better show the bony landmarks and possible points of access than fluoroscopy. Cases that are unsuccessful using fluoroscopy with a single overhead camera may be scheduled in a biplane suite to be performed by a diagnostic neuroradiologist or interventional neuroradiologist. When one radiologist is unsuccessful in performing LP, another may have a slightly different technique that results in success. In refractory cases in which the tap is critical, CT guidance is an option [35, 43]. Although an uncommon technique, cervical puncture is occasionally used for myelography or CSF collection [44].

Complicated cases, such as patients with scoliosis or a history of spinal surgery, may require a more detailed review of previous imaging studies or a request for CT of the lumbar spine before the procedure. Scoliotic patients can have extremely strong lumbar musculature and fascia that may require a larger-gauge needle to prevent bending of the needle, and the prone oblique approach may be required. Previous bone removal surgery such as laminectomy should facilitate the puncture; however, if the surgery was remote, strong scar tissue can cover the laminectomy site and can be difficult to puncture. Again, a larger-gauge needle may be needed in these cases.



A **B**

Fig. 5—70-year-old man who presented for myelography. Purpose of myelography was to aid with presurgical planning.
A and **B,** Sagittal (**A**) and axial (**B**) CT scans show that contrast material has been accidentally injected into subdural space. This area is potential space, but needle can cross dura and tent thecal sac. Injected contrast material should not flow freely from injection site and will not show lumbar nerve roots. Line in **A** shows level of cross-sectional image in **B**.

Obtaining an Opening Pressure

An opening pressure may be requested for the evaluation of idiopathic intracranial hypertension or normal-pressure hydrocephalus, among other conditions. It is generally accepted that an accurate pressure requires the patient to be in the lateral decubitus position [35]; however, this position can pose a problem when using older fluoroscopy equipment with a single overhead camera because the patient needs to be repositioned after needle placement. Repositioning the patient with the needle in place can be difficult, and there is a possibility of losing CSF access or widening the dural puncture location, thus potentially increasing the risk of bleeding or CSF leak. Patient positioning for obtaining an accurate opening pressure has been discussed given that ordering physicians have historically recorded opening pressures from a lateral decubitus position, but the constraints of many fluoroscopy units necessitate recording the pressure while the patient is in a prone position. One recent study reported no significant difference in opening pressure values as a function of patient position [45], and another study reported a small increase in recorded pressure values when patients were in the prone position [46]. It is important to remember that the "zero" point of the manometer is roughly at the level of the heart. If the opening pressure is measured with the patient in prone position, the distance from the zero point of the manometer and the heart must be estimated and added. Free flow of CSF can be verified by elevating and lowering the manometer to verify that the CSF meniscus within the manometer rises and falls appropriately. A normal pressure ranges from 60 to 200 mm H_2O in patients older than 8 years and up to 250 mm H_2O in obese patients [47]. Opening pressures of greater than 250 mm H_2O are diagnostic of intracranial hypertension [48].

For diagnostic LP, laboratory orders should be in place for the studies requested by the ordering physician. With a standard diagnostic LP, CSF is collected in four tubes, for a total volume of 8–15 mL [15]. The common practice is to put 3 mL of CSF in each of the first three tubes and to put 5 mL of CSF in the last tube. CSF from the plastic tubing connected to the needle can be retained in the last tube.

A high-volume tap (removal of > 30 mL of CSF) generally implies the diagnostic use of CSF removal to assess improvement of symptoms, as might be seen in idiopathic intracranial hypertension or normal-pressure hydrocephalus [49]; however, a high-volume tap has been shown to be of limited therapeutic value in patients with idiopathic intracranial hypertension [50]. A closing pressure may be requested and may be helpful to the ordering physician in determining the volume of the CSF reservoir [51]. A closing pressure can also be helpful in determining the volume of CSF removed. A conversation with the patient's neurologist before the procedure can help to optimize the diagnostic value of a high-volume tap.

Postprocedure Guidelines

The patient is typically advised to remain horizontal for the remainder of the day after LP; this position is thought to give the puncture a chance to heal, although no advantages of bed rest have been found in a number of randomized controlled trials [39]. The patient should not engage in strenuous activity for at least 24 hours after LP. If the patient is to return home, it is advisable that someone who can drive him or her home after a short stay in postprocedure recovery be available. Dehydration can exacerbate a post-LP headache, so hydration is advised through the day after the procedure. Alcohol causes dehydration, so refraining from alcohol consumption is also advised through the day after the procedure. Further details for the management of post-LP headache are discussed in a recent online review [39].

Managing Complications

If hemorrhage is suspected, the patient's history may suggest the most immediate logical course of action. A patient with borderline coagulation panel results or with corrected coagulopathy may best be treated with immediate supplemental FFP and close clinical follow-up including attention to lower extremity neurologic status. A suspected hematoma in a patient with abnormal clinical findings might be confirmed using MRI. If the patient has a contraindication to MRI, myelography may be necessary. The value of unenhanced CT in this setting should not be underestimated. Although unenhanced CT offers little soft-tissue contrast, a spinal hematoma may prove conspicuous even in the presence of hardware. Correction of coagulopathy and surgical decompression are the standard of care for patients with symptomatic spinal hematoma because it is generally believed that the extent of irreversible damage to the spinal cord or nerve roots is a function of the duration of the compression [4]. Better neurologic outcomes are reported in patients who undergo surgery within 12 hours of symptom onset than in those who undergo surgery later [11]; however, an increasing number of reports describe the resolution of spinal epidural hematoma with nonoperative management [52].

Conclusion

LP is a common and necessary procedure that sometimes requires fluoroscopic guidance. Familiarity with the indications for LP, methods of fluoroscopic guidance, and potential complications of LP can optimize the safety and success of this procedure.

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APPENDIX 1: Preprocedure Checklist for Inpatients Scheduled to Undergo Fluoroscopically Guided Lumbar Puncture (LP)

1. What is the patient's name and medical record number?
2. What is the name of the contact person or team member who requested LP?
3. What is the indication for LP?
4. Why is fluoroscopic guidance needed in this case? Has someone else already attempted LP at bedside in this patient?
5. What is the patient's coagulation profile? Is the patient taking any anticoagulant medication (i.e., heparin, warfarin [Coumadin, Bristol-Myers Squibb], aspirin, or newer anticoagulants)?
6. How much does the patient weigh? Is the patient's weight more than the weight limit for the fluoroscopy table?
7. Is the patient medically stable?
8. Can the patient provide consent for the procedure? If the consent form needs to be signed by a guardian or health care proxy, can that person be contacted to provide consent?
9. If there is any chance that the patient could be pregnant, has there been a recent pregnancy test?
10. Will the procedure require patient sedation or anesthesia? If so, who will coordinate the procedure time slot with the anesthesia personnel?
11. Are previous head imaging examinations available for review?
12. Are previous spinal imaging examinations available for review?"
13. Have all the absolute and relative contraindications for LP been reviewed?