ACR–ASNR–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF MYELOGRAPHY AND CISTERNOGRAPHY

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The American College of Radiology will periodically define new practice parameters and technical standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing practice parameters and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice parameter and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review and approval. The practice parameters and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice parameter and technical standard by those entities not providing these services is not authorized.

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The purpose of this document is to assist practitioners in achieving this objective.

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1 *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the "ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures (Revised 2008)" sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.*

I. INTRODUCTION

This practice parameter was revised collaboratively by the American College of Radiology (ACR), the American Society of Neuroradiology (ASNR), and the Society for Pediatric Radiology (SPR).

Myelography has been an important diagnostic modality for a wide range of spinal disease processes for more than 80 years. Cisternography using intrathecal contrast media has also been used for many years in the diagnostic evaluation of disease processes involving the basal cisterns and skull base.

These procedures typically involve performance of a lumbar puncture under fluoroscopic guidance followed by the fluoroscopically monitored introduction of a nonionic water-soluble iodinated contrast medium that is appropriate for intrathecal administration into the subarachnoid space. Alternatively, when a lumbar puncture is contraindicated, previously unsuccessfully attempted, or less advantageous, the contrast medium may be introduced into the thecal sac via a C1-C2 puncture, which is described in section V.C.9. In certain clinical situations, water-soluble magnetic resonance imaging (MRI) contrast and MR imaging techniques may be used in a similar fashion for similar indications; however, such media are not presently Food and Drug Administration (FDA) approved for this purpose and such intrathecal administration of gadolinium-based contrast should be considered with caution and full understanding of the potential risks. Following the introduction of intrathecal contrast medium, the lumbar puncture needle is withdrawn.

With the aid of a tilting table, the intrathecal contrast is positioned in the desired region of the spinal subarachnoid space (lumbar, thoracic, or cervical) or in the intracranial basal cisterns, and appropriate radiographic/fluoroscopic (conventional myelogram) and/or computed tomographic (CT) myelogram or cisternogram images are obtained.

Institutions offering myelography should document appropriate training, demonstrated competence, and maintenance of skills for all physicians who receive privileges to perform these procedures.

II. INDICATIONS

Although myelography and cisternography have largely been superseded by the development of high-resolution CT and MRI, there remain numerous indications for these procedures, including but not limited to:

1. Demonstration of the site of a cerebrospinal fluid (CSF) leak (postlumbar puncture headache, postspinal surgery headache, orthostatic headache, rhinorrhea, or otorrhea) [1,2].
2. Symptoms or signs of spontaneous intracranial hypotension [3-7].
3. Surgical planning, especially in regard to the nerve roots.
4. Evaluation of suspected brachial plexus or nerve root injury [8-10].
5. Evaluation of intraspinal arachnoid webs or cysts [11-14].
6. Evaluation of the bony and soft-tissue components of spinal degenerative changes [3,15,16].
7. Radiation therapy planning.
8. Diagnostic evaluation of spinal or basal cisternal disease.
9. Nondiagnostic MRI studies of the spine or skull base.
10. Poor correlation of physical findings with MRI studies.
11. Use of MRI precluded because of:
    A. Claustrophobia
    B. Technical issues (eg, patient size)
    C. Safety reasons (eg, pacemaker)
    D. Surgical hardware
12. Delineation of congenital anomalies (eg, diastematomyelia) when MRI is insufficient.

For the pregnant or potentially pregnant patient, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [17].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A. Physician

Certification in Radiology, Diagnostic Radiology, Interventional Radiology/Diagnostic Radiology (IR/DR), Nuclear Radiology, or Nuclear Medicine by one of the following organizations: the American Board of Radiology (ABR), the American Osteopathic Board of Radiology, the Royal College of Physicians and Surgeons of Canada, or the Collège des Médecins du Québec, and the performance of myelography with acceptable success and complication rates.

or

Completion of a residency or fellowship training program approved by the Accreditation Council for Graduate Medical Education (ACGME), the Royal College of Physicians and Surgeons of Canada, the Collège des Médecins du Québec, or the American Osteopathic Association (AOA) to include evidence of training and competency in myelography. Adequate training should include the performance of a sufficient number of myelographic procedures to become facile in the technique.

and

Instruction in all of the following areas should be substantiated by the director of the training program:

1. Anatomy, physiology, and pathophysiology of the central and peripheral nervous systems.
2. Physics of ionizing radiation, including an understanding of its production, detection, and risks and of techniques to minimize radiation exposure.
3. Pharmacology and dosage of contrast media used in myelography. (Use of only those agents approved for intrathecal use should be emphasized.)
4. Indications for myelography and cisternography, and indications for alternative imaging studies, including MRI.
5. Preprocedural assessment of the patient.
6. Conduct of the myelographic examination. This includes spinal puncture, patient positioning, and fluoroscopic and filming techniques.
7. Conduct of the postmyelogram CT examination. This includes timing, patient positioning, and technical factors.
8. Postprocedural patient management, especially the recognition and initial management of complications.
9. Interpretation of lumbar, thoracic, and cervical myelograms and cisternograms, as well as interpretation of postmyelogram CT scans.
10. Contraindications to myelography.
11. Knowledge of the drugs that can increase the risk of myelographic adverse events.

Maintenance of Competence

Physicians must perform a sufficient number of overall procedures to maintain their skills. Continued competence should depend on participation in a quality improvement program. Consideration should be given to the physician's lifetime practice experience.

Continuing Medical Education

Continuing education should be in accordance with the ACR Practice Parameter for Continuing Medical Education (CME) [18].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

B. Non-Physician Radiology Provider (NPRP)

NPRPs are all Non-Physician Providers (eg, RRA, RPA, RA, PA, NP, ...) who assist with or participate in portions of the practice of a radiologist-led team (Radiologists = diagnostic, interventional, neurointerventional radiologists,

radiation oncologists, and nuclear medicine physicians). The term "NPRP" does not include radiology, CT, US, NM, MRI technologists, or radiation therapists who have specific training for radiology related tasks (eg, acquisition of images, operation of imaging and therapeutic equipment) that are not typically performed by radiologists.

The term 'radiologist-led team' is defined as a team supervised by a radiologist (ie, diagnostic, interventional, neurointerventional radiologist, radiation oncologist, and nuclear medicine physician) and consists of additional healthcare providers including RRAs, PAs, NPs, and other personnel critical to the provision of the highest quality of healthcare to patients. (ACR Resolution 8, adopted 2020).

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

C. Radiologic Technologist

Certification by the American Registry of Radiologic Technologists (ARRT) or unrestricted state licensure is required. In addition, the radiologic technologist should have training in and be skilled in performing fluoroscopic examinations on patients with intrathecal contrast media, including patient positioning, fluoroscopic beam limitation, and methods of applying safe physical restraint during table tilting. Continuing education programs and on-the-job training under the supervision of qualified physicians should be available.

IV. EQUIPMENT SPECIFICATIONS

A. Myelographic Facility

The suggested specifications for the facility are:

1. High-quality radiographic/fluoroscopic imaging equipment with a capability for film or digital recording of selected portions of the examination. A tilt table and a proper support device for securing the patient on it should be available.
2. An adequate selection of spinal needles and appropriate nonionic contrast media approved for intrathecal use.
3. Appropriate facilities and equipment for treating adverse reactions (eg, seizure, vasovagal reaction, and/or cardiorespiratory collapse).
4. Appropriately trained personnel to provide proper patient care and operation of the equipment.
5. A multidetector CT scanner with multiplanar reconstruction capability to perform postmyelogram CT myelographic and/or cisternographic studies.

B. Surgical and Emergency Support

Although serious complications of myelography are infrequent, there should be access to surgical and interventional management of complications.

V. SPECIFICATIONS OF THE EXAMINATION

A. Preprocedural Patient Care

The written or electronic request for myelography should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state scope of

practice requirements. (ACR Resolution 35, adopted in 2006 – revised in 2016, Resolution 12-b)

The clinical history and findings are to be reviewed by the performing physician.

1. Before myelography, any prior pertinent imaging studies, including spinal radiographs, CT, and/or MRI, should be reviewed. If previously acquired imaging is available, when possible, the review should include an evaluation for signs of elevated intracranial pressure and the position of the cerebellar tonsils as well as the position of the conus and for the presence of cervical stenosis, cisternal narrowing or lumbar stenosis, operative hardware, or any other potential hazard before choosing the level for lumbaror cervical puncture for myelography.
2. Appropriate prior medical history should include questions about relevant medications, especially those that can increase risk of adverse events; prior seizures; prior allergic reactions; and clotting ability.
3. Patients who are on anticoagulant therapy (eg, warfarin [Coumadin], heparin, clopidogrel [Plavix], ticlopidine [Ticlid], etc) should discontinue these drugs for a period of time indicated in the consensus guideline of the American Society of Regional Anesthesia and Pain Medicine (see Table 1) [19,20] before undergoing myelography. However, as there are now many marketed anticoagulation medications, each agent has a recommended period for which it should be continued, and if possible, this decision should be made after discussion with the physician who prescribed such medication. If the risks of discontinuing the anticoagulation are deemed greater than the risk of myelography, consideration should be given to bridging with intravenous heparin (if appropriate for the specific therapy) or delaying the myelogram until such time as it is reasonably safe to hold the anticoagulation (eg, patient who has recently undergone coronary artery stenting and is on clopidogrel). Of note, more recently published consensus guidelines are more lenient with respect to the requirements for holding anticoagulant medications before myelography, and there may be variability among the practice patterns of different groups [21].
4. For patients with known hematologic disorders or other conditions affecting blood coagulation, a platelet count and international normalized ratio, prothrombin time, and partial thromboplastin time values within one week of the procedure should be available.
5. Some providers may elect to withhold medications known to decrease the seizure threshold for 48 hours before and 24 hours after myelography [22]. Newer literature has shown the heterogeneity in the practice patterns with regard to withholding medications that decrease the seizure threshold and that continuing seizure threshold–lowering medications during myelography does not increase the risk of seizure [22,23]. Although the contributory role of these medications in the development of seizure after myelography and cisternography has not been established, providers may decide to withhold medications after consideringthe potential risks and benefits. Of note, medications that lower the antiseizure threshold (such as monoamine oxidase inhibitors) and certain antidepressant medications could in theory precipitate a seizure, per the medication's manufacturers, and should be considered carefully if not withheld for an appropriate time to allow adequate clearance (typically at least 24 to 48 hours premyelography). Antiseizure medications should not be withheld because, in theory, they may prevent a seizure or their nontapered absence may make the patient more susceptible to having a seizure secondary to the myelography contrast instillation.
6. Informed consent should be obtained and documented. The risks and benefits of the procedure and of possible alternative procedures that may provide the needed information should be addressed.
7. The patient should be appropriately hydrated both before and after the procedure.
8. If sedation is used, it should be administered in accordance with the ACR–SIR Practice Parameter for Minimal and/or Moderate Sedation/Analgesia [24].

Table 1:

Recommended guidelines for performing spinal procedures in anticoagulated patients	
Warfarin	Discontinue chronic warfarin therapy 4–5 days before spinal procedure and evaluate INR. INR should be within the normal range at time of procedure to ensure adequate levels of all vitamin K-dependent factors.
Antiplatelet medications	No contraindications with aspirin or NSAIDs. Thienopyridine derivatives (clopidogrel and ticlopidine) should be discontinued 7 days and 14 days, respectively, prior to procedure. GP IIb/IIIa inhibitors should be discontinued to allow recovery of platelet function prior to procedure (8 hours for tirofiban and eptifibatide, 24–48 hours for abciximab).
Thrombolytics/fibrinolytics	There are no available data to suggest a safe interval between procedure and initiation or discontinuation of these medications. Follow fibrinogen level and observe for signs of neural compression.
LMWH	Delay procedure at least 12 hours from the last dose of thromboprophylaxis LMWH dose. For "treatment" dosing of LMWH, at least 24 hours should elapse prior to procedure. LMWH should not be administered within 24 hours after the procedure.
Unfractionated SQ heparin	There are no contraindications to neuraxial procedure if total daily dose is less than 10,000 units. For higher dosing regimens, manage according to intravenous heparin guidelines.
Unfractionated IV heparin	Delay spinal puncture 2–4 hours after last dose, document normal aPTT. Heparin may be restarted 1 hour following procedure.

Note:—NSAIDs indicates nonsteroidal antiinflammatory drugs; GP IIb/IIIa, platelet glycoprotein receptor IIb/IIIa inhibitors; INR, international normalized ratio; LMWH, low-molecular-weight heparin; aPTT, activated partial thromboplastin time. *Adapted from:* Horlocker TT, Wedel DJ, Benzon H, et al. **Regional anesthesia in the anticoagulated patient: defining the risks (the second ASRA Consensus Conference on Neuraxial Anesthesia and Anticoagulation).** *Reg Anesth Pain Med* 2003;28:172–97.

(Reprinted with permission from Layton KF, Kallmes DF, Horlocker TT. Recommendations for Anticoagulated Patients Undergoing Image-Guided Special Procedures. Am J Neuroradiol 2006;27:468-470.)

V. SPECIFICATIONS OF THE EXAMINATION

B. Relative Contraindications to Myelography

1. Known space-occupying intracranial process with increased intracranial pressure
2. Historical or laboratory evidence of bleeding disorder or coagulopathy
3. Previous surgical procedure in anticipated puncture site (can choose alternative puncture site)
4. Generalized septicemia
5. History of adverse reaction to iodinated contrast media and/or gadolinium-based MR contrast agents
6. History of seizures (patient may be premedicated)
7. Hematoma or localized infection at region of puncture site
8. Pregnancy

V. SPECIFICATIONS OF THE EXAMINATION

C. Procedure [3]

1. The patient is placed prone or lateral decubitus on the tabletop, and the skin of the lumbar back is prepped and draped in standard sterile technique.
2. Operators should wear a facemask to reduce the chance of causing iatrogenic meningitis.
3. Using the lumbar approach, an interlaminar or interspinous space, ideally below the expected location of the conus, is localized (eg, L3-L4) [25]. Subcutaneous and intramuscular local anesthetic is administered. Generally, diagnostic myelography is performed with a styletted small bore (22–25 gauge) spinal needle introduced through the anesthetized region and directed toward the midline. Smaller needles and pencil point needles are associated with lower risk of bleeding and post–dural puncture headache. Occasionally, because of body habitus or specific pathology, larger-gauge needles may be required. The needle is advanced under intermittent image guidance. If a beveled needle is used, the bevel may be used to control the direction of the needle. When the dura is traversed, a change in resistance is often, but not always, perceived. The stylet is then slowly removed to check for CSF return. At this point, opening CSF pressure can be measured, and/or CSF sampling can be performed before contrast injection. When possible, opening CSF pressure should be measured in the lateral decubitus position because prone positioning can elevate pressures [26].
4. A nonionic iodinated contrast medium is slowly administered intrathecally through the lumbar needle under intermittent imaging. An appropriate amount of contrast is injected, not to exceed the manufacturer's recommendations (ie, maximum of 3 g of organic iodine via myelographic grade contrast medium) [3,27-30].

5. Before removing the needle, imaging may be obtained to document the needle position.
6. The needle is then removed from the back, and the patient is secured to the tabletop by a support device before being tilted into Trendelenburg or reverse Trendelenburg positions.
7. Transforaminal puncture for myelography: recent preliminary reports suggest that a transforaminal puncture (rather than interspinous, interlaminar, or C1-C2 approach) may be used in patients with extremely difficult access, complete posterior fusion, or spinomuscular disorders preventing access. Further experience is needed to evaluate the utility and indications for this technique in a wider array of disorders [31].
8. Using intermittent imaging, table tilting, and patient rotation, anteroposterior, oblique, and cross-table lateral images of the region in question are documented on film or digital media. For lumbar myelography, if the conus medullaris has not been recently visualized by other means, evaluation of that area should be included in the study.
9. For cervical myelography, and, in some instances, thoracic myelography with the patient prone, the head is hyperextended on the neck, thus creating a lordotic "trough," and the table is then gradually and slowly tilted head downward until the opacified CSF "column" flows through the area of interest. The myelographic table must have adequate and secure shoulder support for the patient's safety. The patient's chin is supported in a chin rest to prevent rapid ascent of the contrast into the intracranial basal cisterns. The lead-gloved hands of the technologist may also support the positioning of the patient's head and neck. As in the lumbar region, anteroposterior, oblique, and cross-table lateral images can be documented on film or digital media.
10. If cisternography is requested, with the opacified CSF "column" in the cervical spine canal, the table is restored to the horizontal position, and then the hyperextended head is gradually and slowly lowered (flexed) into a neutral position under image guidance. Imaging for cisternography is typically obtained with CT; conventional radiographic images are not usually obtained [4,5].
11. In the fluoroscopic lateral C1-C2 approach [32], the patient is ideally positioned prone on the table top, and the head is secured in a neutral position. The supine position may be used in situations in which the prone position is not feasible, such as cases involving general anesthesia, sedation, or hardware [33]. Using image guidance, the head and neck are positioned in the true lateral projection, and local anesthesia is administered subcutaneously and intramuscularly in the side of the neck at a point overlying the posterior aspect of the C1-C2 interlaminar space slightly anterior to the spinolaminar junction line and inferior to the arch of C1. If C-arm fluoroscopy or CT fluoroscopy is not available or if the patient is unable to remain in a prone position on the tabletop but can lie quietly and comfortably in a nonrotated lateral decubitus position, lateral C1-C2 puncture can be performed using vertical beam fluoroscopy. Under intermittent image guidance, the spinal needle is advanced incrementally into the subarachnoid space at the posterior margin of the thecal sac behind the posterior margin of the upper cervical spinal cord. Great caution with frequent image monitoring should always be used during needle advancement, as the dura is punctured and as the iodinated contrast medium is cautiously and slowly injected into the posterior cervical subarachnoid space. When this is completed, an image should be documented and permanently retained, and the needle is then withdrawn from the neck. The desired area of the opacified subarachnoid space is then examined and documented.
12. CT can be used as an alternative method for image guidance for needle placement in patients with difficult access, and can be used successfully for both lumbar and cervical punctures.
13. Following completion of the examination as described above, the patient may be transferred to the CT scanner for CT myelographic or cisternographic imaging, when appropriate.
14. For CT myelography, the patient is rolled from side to side to promote uniform diffusion of contrast to completely opacify the region of interest. Imaging is obtained using a multidetector CT scanner with the patient prone and/or supine as needed within the scanner. Image data are acquired helically with thin collimation. Images are reconstructed in the axial, coronal, and sagittal planes and reviewed in soft-tissue and bone windows.
15. For CT cisternography, CT imaging is obtained as soon as possible after positioning of the opacified CSF in the basal cisterns. Thin-section image data may be obtained helically through the area of interest with thin collimation with the patient in both prone and supine positions. Images are reconstructed in the axial, coronal, and sagittal planes and reviewed in soft-tissue and bone windows. For detection of CSF leakage at the skull base, use of a workstation capable of multiplanar and 3-D image reformations has proven value in

localizing and measuring the size of the dural defect [4,5].

16. Pediatric myelography is most often performed under conscious sedation or general anesthesia. Pediatric patients are often kept NPO for 6–8 hours before anesthesia or sedation and may be dehydrated. Patients should be appropriately hydrated before and for several hours after the sedation. Pediatric patients may be at higher risk of adverse events during contrast medium administration, including patients with asthma, sensitivity to medication and/or allergens, congestive heart failure, or serum creatinine level >1.5 mg/dL, or those younger than 12 months of age. However, the incidence of headache, vomiting, and back pain appears to be lower in the pediatric population.

    Before performing myelography in a child, the radiologist should review imaging studies of the brain and spine, if available, to determine if the patient has undergone repair of a posterior dysraphic defect, a low-lying tethered cord, or a lipomeningocele, all of which preclude lumbar puncture. Low-lying cerebellar tonsils and Chiari II malformations with caudal displacement of the hindbrain into the cervical canal are contraindications to lateral C1-C2 puncture. The position of the conus in infants and young children is lower than in older children and adults, and lumbar puncture should be performed at the L3-L4 or L4-L5 level in children younger than 3 years of age, preferably using a higher gauge needle (eg, 24 or 25-gauge). Penetration of the dura may be inapparent. When CSF sampling is needed, collection should be limited to 1–2 cc per vial, especially in infants with small-capacity thecal sacs. Instillation of the contrast medium under intermittent imaging control is recommended. The minimum volume and dose to produce adequate visualization should be used; dosage should be calculated per kilogram of body weight.

16. Delayed CT through the region of interest can be useful in certain situations (eg, to demonstrate opacification of suspected arachnoid cysts that do not opacify on the initial CT, or assess the site of potential CSF leak when not evident on initial images). Delayed images after repositioning a patient to facilitate greater contrast distribution to a particular region of interest can also be useful.
17. In particular situations, recent reports of modifications of fluoroscopic and CT myelography techniques to improve the conspicuity of CSF leaks and CSF-venous fistulas, including digital subtraction, dual energy, and photon counting CT [53] image acquisition with attention to the phase of the respiratory cycle, and ultrafast myelography, have suggested utility but are supported by preliminary results with limited data [34-38]. Inclusion of these techniques herein will await greater experience and definition of specific indications.

V. SPECIFICATIONS OF THE EXAMINATION

D. Postprocedural Care [28-30, 39]

1. The patient should be adequately hydrated.
2. The patient should be observed following the examination for sufficient time to observe for potential complications.
3. If the myelogram is performed on an outpatient basis, the patient should be properly instructed regarding limitations following the procedure (eg, no driving).
4. Instructions regarding postprocedural care, including warning signs of adverse reactions, symptoms, and signs of infection at the puncture site and the possibility of persistent headaches, should be given to the patient by a trained professional. The instructions should include a recommendation that the patient be in the company of a responsible adult for 12 hours following the procedure.
5. A physician should be available to answer questions and provide patient management following the procedure.

VI. MR MYELOGRAPHY AND MR CISTERNOGRAPHY

A. Indications for MR Myelography (MRM)

The intrathecal use of gadolinium has not been approved by the FDA. As a result, noncontrast heavily T2-weighted MRI techniques should be considered before performing MRM. However, the off-label use of

intrathecal gadolinium may be indicated when noncontrasted techniques are insufficient. The decision to use intrathecal gadolinium should weigh the potential unknown risks associated with gadolinium deposition in the brain and be undertaken with an understanding of the rare serious adverse events that can occur with higher concentrations of gadolinium in the intrathecal space [40,41]. Similar to conventional myelography and cisternography, MRM has the following indications, including but not limited to:

1. Demonstrating the location and size of a CSF leak in posttrauma and postsurgical patients and in spontaneous intracranial hypotension.
2. Defining target volume for craniospinal irradiation.
3. Determining the cause of cervical or thoracic myelopathy.
4. Assessing spinal and neural foraminal stenosis in presurgical diagnosis.
5. Assessing brachial plexus or nerve root injuries [9,10,42].
6. Evaluating spinal herniations and extradural defects.
7. Determining the presence of, or flow obstruction by, spinal arachnoid cysts or webs [11].

B. Indications for MR Cisternography (MRC)

Similar to conventional cisternography and with the same caveats as for MRM in terms of the preference of nongadolinium based techniques, MRC has the following indications, including but not limited to:

1. Localization and measurement of skull-base CSF fistulae or leaks. In patients with negative CT myelography or MRM, MRC with gadolinium can be used as a subsequent technique to detect leaks and may employ the use of delayed postcontrast imaging [43,44].
2. Preoperative evaluation of intracranial arachnoid cysts [14].
3. Evaluation of inner ear structures.
4. Evaluation of the facial nerve in patients with hemifacial spasm.
5. Evaluation of the cranial nerves and lesions within the basilar cisterns and intracranial subarachnoid spaces.

C. Equipment Specifications

Please refer to the Equipment Specifications sections of the ACR–ASNR–SCBT-MR–SSR Practice Parameter for the Performance of Magnetic Resonance Imaging (MRI) of the Adult Spine and the ACR–ASNR–SPR Practice Parameter for the Performance and Interpretation of Magnetic Resonance Imaging (MRI) of the Brain [45,46].

D. Myelography Facility (for intrathecal injection of gadolinium contrast)

Please see section IV.A.1-4.

E. Specifications of the Examination (for intrathecal injection of gadolinium)

Please see section V.

F. MRM Technique [7,47,48]

MRM without intrathecal contrast is best accomplished using a heavily T2-weighted pulse sequence (eg, constructive interference in the steady state, fast imaging employing steady state acquisition [FIESTA], or Sampling Perfection with Application optimized Contrast using different flip angle Evolution [SPACE]). These images provide a high degree of contrast resolution, enabling sharp definition between the spinal cord and intrathecal nerve roots and the surrounding CSF. These images are acquired in 3-D, which allow reconstructions in multiple planes. Images are typically obtained in the sagittal and axial planes, although coronal plane images may be specified in particular situations. Leakage of fluid outside the thecal sac, as through a dural tear, can be recognized on noncontrast MRM, although extradural fluid collections that are not derived from an intradural source (eg, a postoperative seroma or a congenital cyst) cannot be

distinguished from intradural leakage. Please refer to the ACR–ASNR–SCBT-MR–SSR Practice Parameter for the Performance of Magnetic Resonance Imaging (MRI) of the Adult Spine [45].

MRM with intrathecal contrast is an off-label use of gadolinium-based contrast agents [48] (ie, these agents are not approved by the FDA for intrathecal injection). MRM with intrathecal contrast should be considered with extreme caution considering the reports of gadolinium deposition in the brain. Therefore, before performing this procedure, the physician must obtain informed consent from the patient. To date, this procedure has primarily been performed to identify the site of CSF leakage and to measure the size of a dural tear. The quantity of contrast agent injected into the subarachnoid space via lumbar puncture is very small (typically 1 mL of 0.05 mM gadolinium-based contrast).MRM with intrathecal contrast is conducted in an entirely analogous manner to the technique used in conventional myelography followed by CT. MR sequences for examining the cervical, thoracic, or lumbar spine typically include sagittal and axial T1- and T2-weighted fast spin echo with fat saturation and short tau inversion recovery. In particular situations, coronal T1- and T2-weighted images may also be of important diagnostic value. MRM with intrathecal gadolinium contrast can help to confirm that an extradural fluid collection represents a CSF leak secondary to a dural tear. In the setting of a CSF leak, gadolinium will extend from the intrathecal space into the extradural collection, resulting in T1 shortening (hyperintensity). This will not occur with other types of extradural fluid collections (eg, seroma).

G. MRC Technique [49,50]

1. MRC without intrathecal contrast is also performed using MR sequences that are heavily T2-weighted with thin-section images acquired in the axial and coronal planes, as described above for MRM. This technique has mainly been used to evaluatefor suspected dural tears at the skull base causing CSF rhinorrhea or otorrhea. MRI examinations in such cases typically also include T1- and conventional T2-weighted images. Reported results indicate a high sensitivity for detecting sites of CSF leakage, comparable to those achieved with CT myelography. Compared with CT cisternography, MRC has the advantages of being noninvasive and having no ionizing radiation exposure. However, definition of thin cortical bony margins (as in the cribriform plate and ethmoid air cell walls) is usually better on CT than on MRI.

2. As with MRM, intrathecal administration of gadolinium contrast for cisternography via lumbar puncture is not FDA approved and should be considered with extreme caution considering the reports of gadolinium deposition in the brain, and the patient must be so informed. Dosage and method of administration are the same as for MRM with intrathecal gadolinium-based contrast agent (see section VI.F above). Thin-section T1-weighted axial and coronal images with fat saturation allow localization of the site of leakage and measurement of its size. Not infrequently, more than one site of leakage is delineated. Although the number of reported studies is still small, the reported results demonstrate good correlation with endoscopic transnasal operative findings.

VII. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [51].

VIII. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, non-physician radiology providers, radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society as a whole, "as low as reasonably achievable" (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary to achieve the clinical objective. All personnel who work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection, application of dose constraints and limits) and the principles of proper management of radiation dose to patients (justification, optimization including the use of dose reference levels). https://www-

pub.iaea.org/MTCD/Publications/PDF/PUB1775_web.pdf

Nationally developed guidelines, such as the ACR's Appropriateness Criteria®, should be used to help choose the most appropriate imaging procedures to prevent unnecessary radiation exposure.

Facilities should have and adhere to policies and procedures that require ionizing radiation examination protocols (radiography, fluoroscopy, interventional radiology, CT) to vary according to diagnostic requirements and patient body habitus to optimize the relationship between appropriate radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used, except when inappropriate for a specific exam. If such technology is not available, appropriate manual techniques should be used.

Additional information regarding patient radiation safety in imaging is available from the following websites – Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org). These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists).

Radiation exposures or other dose indices should be periodically measured by a Qualified Medical Physicist in accordance with the applicable ACR Technical Standards. Monitoring or regular review of dose indices from patient imaging should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry and relevant publications relying on its data, applicable ACR Practice Parameters, NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States or the Conference of Radiation Control Program Director's National Evaluation of X-ray Trends; 2006, 2009, amended 2013, revised 2023 (Res. 2d).

IX. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on QC & Improvement, Safety, Infection Control*, *and Patient Education* on the ACR website (https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards).

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