

ACR Appropriateness Criteria[®]

Imaging of Suspected Intracranial Hypotension

Expert Panel on Neurological Imaging: *Vincent M. Timpone, MD^a, Matthew S. Parsons, MD^b, Daniel J. Boulter, MD^c, Judah Burns, MD^d, Rami W. Eldaya, MD, MBA^e, Jonathan A. Grossberg, MD^f, Alvand Hassankhani, MD^g, Troy A. Hutchins, MD^h, Adam G. Kelly, MDⁱ, Majid A. Khan, MD^j, A. Orlando Ortiz, MD, MBA^k, Christopher A. Potter, MD^l, Vinil N. Shah, MD^m, Richard D. Shih, MDⁿ, Chadwick L. Wright, MD, PhD^o, Bruno Policeni, MD, MBA^p*

Abstract

The clinical syndrome of intracranial hypotension refers to the symptoms caused by cerebrospinal fluid hypovolemia and is primarily characterized by postural headaches, but can be associated with a multitude of other neurological symptoms. Imaging plays a critical role in helping to establish a diagnosis of intracranial hypotension, localize the source of cerebrospinal fluid leak, and assist in directing targeted treatments. Using the best available evidence, this document provides diagnostic imaging recommendations for the workup of intracranial hypotension across various clinical presentations.

^aMayo Clinic Arizona, Phoenix, Arizona.

^bPanel Chair, Mallinckrodt Institute of Radiology, Saint Louis, Missouri.

^cThe Ohio State University Wexner Medical Center, Columbus, Ohio.

^dMontefiore Medical Center, Bronx, New York.

^eWashington University School of Medicine, Saint Louis, Missouri.

^fEmory University School of Medicine, Atlanta, Georgia; American Association of Neurological Surgeons/Congress of Neurological Surgeons.

^gHospital of the University of Pennsylvania, Philadelphia, Pennsylvania.

^hUniversity of Utah Health, Salt Lake City, Utah.

ⁱUniversity of Rochester Medical Center, Rochester, New York; American Academy of Neurology.

^jThomas Jefferson University Hospital, Philadelphia, Pennsylvania.

^kJacobi Medical Center, Bronx, New York.

^lBrigham & Women's Hospital, Boston, Massachusetts; Committee on Emergency Radiology-GSER.

^mUniversity of California San Francisco, San Francisco, California.

ⁿSchmidt College of Medicine, Florida Atlantic University, Boca Raton, Florida; American College of Emergency Physicians.

^oUniversity of Cincinnati, Cincinnati, Ohio; Commission on Nuclear Medicine and Molecular Imaging.

^pSpecialty Chair, University of Iowa Hospitals and Clinics, Iowa City, Iowa. Corresponding author: Vincent M. Timpone, MD, Mayo Clinic Arizona, Department of Radiology, Division of Neuroradiology, 5777 E Mayo Blvd, Phoenix, AZ 85054; e-mail: Timpone.Vincent@mayo.edu.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document. Reprint requests to: publications@acr.org.

Majid A. Khan, MD, reports consulting fees from Stryker Medical, Hyprevention, Medwaves Avecur; payment for expert testimony as an expert witness in medico-legal cases. Matthew S. Parsons, MD, reports leadership roles as Neuroradiology Fellowship Director. Richard D. Shih, MD, reports grants or contracts from The Florida Medical Malpractice Joint Underwriting Association Grant request for applications #2022-01, The Geriatric Emergency Department Fall Injury Prevention Project. Chadwick L. Wright, MD, PhD, reports leadership roles as Board of Director, American Board of Science in Nuclear Medicine—unpaid. The other authors state that they have no conflict of interest related to the material discussed in this article. Jonathan A. Grossberg, MD, is a partner and all other authors are non-partner/non-partnership track/employee.

The ACR Appropriateness Criteria documents are updated regularly. Please go to the ACR website at www.acr.org/ac to confirm that you are accessing the most current content.

Disclaimer: The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

The American College of Radiology Appropriateness Criteria are evidence-based guidelines for specific clinical conditions that are reviewed annually by a multidisciplinary expert panel. The guideline development and revision process support the systematic analysis of the medical literature from peer reviewed journals. Established methodology principles such as Grading of Recommendations Assessment, Development, and Evaluation or GRADE are adapted to evaluate the evidence. The RAND/UCLA Appropriateness Method User Manual provides the methodology to determine the appropriateness of imaging and treatment procedures for specific clinical scenarios. In those instances where peer reviewed literature is lacking or equivocal, experts may be the primary evidentiary source available to formulate a recommendation.

Key Words: Appropriateness Criteria, appropriate use criteria, AUC, CSF leak, CSF-venous fistula, digital subtraction myelogram, dynamic CT myelogram, intracranial hypotension, spontaneous intracranial hypotension

J Am Coll Radiol 2024;21:S396-S412. Copyright © 2024 American College of Radiology

ACR Appropriateness Criteria® Suspected Intracranial Hypotension. Variants 1 to 6 and Tables 1 and 2.

Variant 1. Adult. Orthostatic headache from suspected intracranial hypotension, without recent spinal intervention that could cause CSF leakage. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
MRI complete spine without and with IV contrast	Usually Appropriate	0
MRI complete spine without IV contrast	Usually Appropriate	0
MRI head without and with IV contrast	Usually Appropriate	0
MRI head without IV contrast	Usually Appropriate	0
CT myelography complete spine	May Be Appropriate	⊕⊕⊕⊕⊕
Radiographic myelography digital subtraction complete spine	Usually Not Appropriate	⊕⊕⊕⊕
MR myelography complete spine	Usually Not Appropriate	0
MRI complete spine with IV contrast	Usually Not Appropriate	0
MRI head with IV contrast	Usually Not Appropriate	0
CT head cisternography	Usually Not Appropriate	⊕⊕⊕
CT head with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without IV contrast	Usually Not Appropriate	⊕⊕⊕
CT complete spine with IV contrast	Usually Not Appropriate	⊕⊕⊕⊕
DTPA cisternography	Usually Not Appropriate	⊕⊕⊕
CT complete spine without and with IV contrast	Usually Not Appropriate	⊕⊕⊕⊕
CT complete spine without IV contrast	Usually Not Appropriate	⊕⊕⊕⊕
CT myelography dynamic complete spine	Usually Not Appropriate	⊕⊕⊕⊕⊕

Variant 2. Adult. Orthostatic headache from suspected intracranial hypotension within 72 hours of dural puncture or other spinal intervention that could cause CSF leakage. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiographic myelography digital subtraction complete spine	Usually Not Appropriate	☼☼☼☼
MR myelography complete spine	Usually Not Appropriate	○
MRI complete spine with IV contrast	Usually Not Appropriate	○
MRI complete spine without and with IV contrast	Usually Not Appropriate	○
MRI complete spine without IV contrast	Usually Not Appropriate	○
MRI head with IV contrast	Usually Not Appropriate	○
MRI head without and with IV contrast	Usually Not Appropriate	○
MRI head without IV contrast	Usually Not Appropriate	○
CT head cisternography	Usually Not Appropriate	☼☼☼
CT head with IV contrast	Usually Not Appropriate	☼☼☼
CT head without and with IV contrast	Usually Not Appropriate	☼☼☼
CT head without IV contrast	Usually Not Appropriate	☼☼☼
DTPA cisternography	Usually Not Appropriate	☼☼☼
CT complete spine with IV contrast	Usually Not Appropriate	☼☼☼☼
CT complete spine without and with IV contrast	Usually Not Appropriate	☼☼☼☼
CT complete spine without IV contrast	Usually Not Appropriate	☼☼☼☼
CT myelography complete spine	Usually Not Appropriate	☼☼☼☼☼
CT myelography dynamic complete spine	Usually Not Appropriate	☼☼☼☼☼

Variation 3. Adult. Orthostatic headache from suspected intracranial hypotension without improvement post 72 hours of dural puncture or other spinal intervention that could cause CSF leakage. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiographic myelography digital subtraction complete spine	Usually Not Appropriate	☼☼☼☼
MR myelography complete spine	Usually Not Appropriate	○
MRI complete spine with IV contrast	Usually Not Appropriate	○
MRI complete spine without and with IV contrast	Usually Not Appropriate	○
MRI complete spine without IV contrast	Usually Not Appropriate	○
MRI head with IV contrast	Usually Not Appropriate	○
MRI head without and with IV contrast	Usually Not Appropriate	○
MRI head without IV contrast	Usually Not Appropriate	○
CT head cisternography	Usually Not Appropriate	☼☼☼
CT head with IV contrast	Usually Not Appropriate	☼☼☼
CT head without and with IV contrast	Usually Not Appropriate	☼☼☼
CT head without IV contrast	Usually Not Appropriate	☼☼☼
DTPA cisternography	Usually Not Appropriate	☼☼☼
CT complete spine with IV contrast	Usually Not Appropriate	☼☼☼☼
CT complete spine without and with IV contrast	Usually Not Appropriate	☼☼☼☼
CT complete spine without IV contrast	Usually Not Appropriate	☼☼☼☼
CT myelography complete spine	Usually Not Appropriate	☼☼☼☼☼
CT myelography dynamic complete spine	Usually Not Appropriate	☼☼☼☼☼

Variation 4. Adult. Obtundation with initial brain imaging features of suspected intracranial hypotension. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
MRI complete spine without and with IV contrast	Usually Appropriate	○
MRI complete spine without IV contrast	Usually Appropriate	○
CT myelography complete spine	May Be Appropriate	☼☼☼☼☼
Radiographic myelography digital subtraction complete spine	Usually Not Appropriate	☼☼☼☼
MR myelography complete spine	Usually Not Appropriate	○
MRI complete spine with IV contrast	Usually Not Appropriate	○
DTPA cisternography	Usually Not Appropriate	☼☼☼
CT complete spine with IV contrast	Usually Not Appropriate	☼☼☼☼
CT complete spine without and with IV contrast	Usually Not Appropriate	☼☼☼☼
CT complete spine without IV contrast	Usually Not Appropriate	☼☼☼☼
CT myelography dynamic complete spine	Usually Not Appropriate	☼☼☼☼☼

Variation 5. Adult. Chronic daily headache from suspected intracranial hypotension with negative initial brain and spine imaging, but with history and clinical examination suggesting CSF leakage. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
Radiographic myelography digital subtraction complete spine	Usually Appropriate	⊕⊕⊕⊕
CT myelography dynamic complete spine	Usually Appropriate	⊕⊕⊕⊕⊕
MR myelography complete spine	May Be Appropriate	○
DTPA cisternography	May Be Appropriate	⊕⊕⊕
CT head cisternography	Usually Not Appropriate	⊕⊕⊕

Variation 6. Adult. Rebound headache following epidural blood patch or fibrin glue patch treatment for suspected intracranial hypotension. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiographic myelography digital subtraction complete spine	Usually Not Appropriate	⊕⊕⊕⊕
MR myelography complete spine	Usually Not Appropriate	○
MRI complete spine with IV contrast	Usually Not Appropriate	○
MRI complete spine without and with IV contrast	Usually Not Appropriate	○
MRI complete spine without IV contrast	Usually Not Appropriate	○
MRI head with IV contrast	Usually Not Appropriate	○
MRI head without and with IV contrast	Usually Not Appropriate	○
MRI head without IV contrast	Usually Not Appropriate	○
CT head cisternography	Usually Not Appropriate	⊕⊕⊕
CT head with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without IV contrast	Usually Not Appropriate	⊕⊕⊕
DTPA cisternography	Usually Not Appropriate	⊕⊕⊕
CT complete spine with IV contrast	Usually Not Appropriate	⊕⊕⊕⊕
CT complete spine without and with IV contrast	Usually Not Appropriate	⊕⊕⊕⊕
CT complete spine without IV contrast	Usually Not Appropriate	⊕⊕⊕⊕
CT myelography complete spine	Usually Not Appropriate	⊕⊕⊕⊕⊕
CT myelography dynamic complete spine	Usually Not Appropriate	⊕⊕⊕⊕⊕

Table 1. Appropriateness category names and definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Table 2. Relative radiation level designations

RRL	Adult Effective Dose Estimate Range (mSv)	Pediatric Effective Dose Estimate Range (mSv)
0	0	0
⊕	<0.1	<0.03
⊕⊕	0.1-1	0.03-0.3
⊕⊕⊕	1-10	0.3-3
⊕⊕⊕⊕	10-30	3-10
⊕⊕⊕⊕⊕	30-100	10-30

Note: Relative radiation level (RRL) assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "varies."

SUMMARY OF LITERATURE REVIEW

Introduction/Background

The clinical syndrome of intracranial hypotension refers to the symptoms caused by cerebrospinal fluid (CSF) hypovolemia and is primarily characterized by postural headaches [1,2]. According to the *International Classification of Headache Disorders, third edition*, the low CSF pressure headache is typically orthostatic in nature, is caused by low CSF pressure (<6 cm H₂O) or CSF leakage, and remits after normalization of CSF pressure or a successful sealing of the CSF leak [3]. The onset of symptoms may be spontaneous or secondary depending on a temporal relation to a presumed cause, such as a recent procedural dural puncture. Headache symptoms may be accompanied by additional symptomatology to include nausea, vomiting, neck pain, tinnitus, changes in hearing, and photophobia [4].

It is estimated that spontaneous intracranial hypotension (SIH) occurs with an incidence of approximately 5 per 100,000 individuals annually [5]. The true incidence of this

condition may be higher, because SIH is thought to be both highly underdiagnosed and a misdiagnosed disorder [4,6-8]. Clinical risk factors for the development of SIH include spinal osteophytes that can perforate the dura, weakened ectatic dura/meningeal cysts as can be seen with collagen vascular disease, and a history of bariatric surgery in which it is postulated that rapid loss of epidural fat may weaken the dura and predispose to CSF leakage [4,9-12]. Secondary intracranial hypotension symptoms related to dural puncture are thought to occur with a frequency of approximately 2% to 8% of cases, with risk factors in part related to needle type and gauge used [13-15].

The pathophysiologic mechanism of headache symptoms and various neurological deficits in patients with intracranial hypotension is not well understood but likely multifactorial and may be attributed to 1) compensatory venodilation, blood volume expansion, and dural sinus stretching as the body attempts to maintain a stable intracranial volume in response to decreased CSF volume; and 2) downward traction on the meninges, nerves, and brain

parenchyma as the brain loses buoyancy and begins to sag in response to decreased CSF volume. The findings of venodilation and brain sagging have well-defined imaging findings and have been shown to resolve along with clinical improvement of headache symptoms [16,17].

The 3 main causes of intracranial hypotension are CSF leakage through a dural defect, leaking meningeal diverticulum, and CSF-venous fistula [18-20]. It is important to note that in the upright position, intracranial hydrostatic pressure is slightly negative relative to atmosphere, whereas hydrostatic pressure in the spine is positive relative to atmosphere [21]. Consequently, the spine has been shown to represent the anatomical source of most symptomatic CSF leaks and venous fistulas, such that the imaging investigation of leak source should be directed primarily toward the spine and not intracranially [22].

Imaging plays a critical role in the diagnostic evaluation of intracranial hypotension. The goals of imaging are 2-fold: 1) to confirm the diagnosis of intracranial hypotension and 2) to localize the source of leak for targeted therapy such as epidural blood patch, percutaneous fibrin glue treatment, endovascular venous fistula embolization, and surgical dural repair or venous fistula ligation [23,24]. Intracranial imaging features suggestive of intracranial hypotension include qualitative signs (engorgement of venous sinuses, pachymeningeal enhancement, midbrain descent, superficial siderosis, subdural hygroma or hematoma, and convex superior surface of the pituitary) and quantitative signs (pituitary height, pontomesencephalic angle, suprasellar cistern, prepontine cistern, midbrain descent, venous-hinge angle, mamillopontine angle, tonsillar descent, and area cavum veli interpositi) [4,16,25-27]. The cumulative presence of these intracranial findings has been shown to correlate with a likelihood of finding a spinal leak source [16]. The spinal imaging findings associated with SIH include direct evidence of CSF leakage via epidural fluid collections and CSF-venous fistula as well as secondary indirect signs of CSF leakage such as dilated epidural venous plexus, subdural hygromas, and dural enhancement [24,28-30]. It should be noted that CSF pressure can be normal in patients with SIH, and the absence of a low CSF pressure should not exclude this condition [31,32]. It also bears mentioning that the diagnosis of SIH is challenging, and in some cases SIH cannot be definitely diagnosed or excluded until a full diagnostic workup with invasive imaging (myelography) has been performed. In cases in which symptoms persist after a negative full imaging workup, the possibility of SIH mimicking pathologies such as positional orthostatic tachycardia syndrome, cervicogenic headaches, migraines, or new daily persistent headache syndromes should be considered [33].

Using the best available evidence, this document provides diagnostic imaging recommendations for intracranial hypotension across various clinical presentations. In cases in which conservative/medical management or a therapeutic procedural intervention may be a more appropriate first step over imaging, the evidence to support such practices is discussed in the variant narrative.

Initial Imaging Definition

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)
- OR
- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).

DISCUSSION OF PROCEDURES BY VARIANT

Variant 1: Adult. Orthostatic headache from suspected intracranial hypotension, without recent spinal intervention that could cause CSF leakage. Initial imaging

This clinical scenario refers to a patient who demonstrates postural orthostatic headaches with or without additional secondary SIH symptoms. The absence of a recent spinal intervention such as a dural puncture is relevant because orthostatic headaches are known, usually self-limiting sequelae of such procedures that do not typically require an imaging workup [4,13]. Orthostatic headaches without a temporal relation to dural puncture usually require 2 initial imaging examinations: brain imaging to help confirm a suspected SIH diagnosis and spine imaging to assist in localizing a potential source of CSF leak [4].

CT Complete Spine With IV Contrast. There is no relevant literature to support the use of CT complete spine with intravenous (IV) contrast in the initial imaging of suspected SIH.

CT Complete Spine Without and With IV Contrast. There is no relevant literature to support the use of CT complete spine without and with IV contrast in the initial imaging of suspected SIH.

CT Complete Spine Without IV Contrast. There is no relevant literature to support the use of CT complete spine without IV contrast in the initial imaging of suspected SIH.

CT Head Cisternography. There is no relevant literature to support the use of CT head cisternography in the initial imaging of suspected SIH. The spine has been shown to represent the anatomical source of most symptomatic CSF leaks and venous fistulas, such that the imaging investigation of leak source should be directed primarily toward the spine and not intracranially [22].

CT Head With IV Contrast. There is no relevant literature to support the use of CT head with IV contrast in the initial imaging of suspected SIH.

CT Head Without and With IV Contrast. There is no relevant literature to support the use of CT head without and with IV contrast in the initial imaging of suspected SIH.

CT Head Without IV Contrast. There is no relevant literature to support the use of CT head without IV contrast in the initial imaging of suspected SIH.

CT Myelography Complete Spine. Although CT myelography complete spine can detect epidural contrast collections suggestive of dural defect or leaking meningeal diverticulum, MRI complete spine optimized with fluid sensitive sequences has been shown to detect epidural collections with equal sensitivity and is a preferred initial imaging option over CT myelography complete spine because it avoids the need for lumbar puncture [34-36].

CT Myelography Dynamic Complete Spine. There is no relevant literature to support the use of dynamic CT myelography complete spine in the initial imaging of suspected SIH. Dynamic CT myelography plays an important role in the subsequent imaging workup of SIH after the initial brain and spine imaging [37,38]. Results from an initial spine MRI or conventional CT myelogram provide useful information on how a subsequent dynamic CT myelogram will be performed, such as prone positioning for suspected ventral dural defect or decubitus positioning for suspected leaking meningeal diverticulum or CSF-venous fistula [24,37-39]. Dynamic CT myelography involves an initial scan followed by delayed phase scans in immediate succession and, when performed in the decubitus position, may require 2 separate contrast injections due to the transient temporal characteristics associated with CSF-venous fistula visualization as well as limitations in contrast dosing [40-44].

DTPA Cisternography. Although diethylenetriamine pentaacetate (DTPA) cisternography can detect epidural collections suggestive of dural defect or leaking meningeal diverticulum, MRI complete spine optimized with fluid sensitive sequences is typically the preferred initial imaging option over DTPA cisternography complete spine because it

avoids the need for lumbar puncture and has superior spatial resolution for lesion localization [45,46].

MR Myelography Complete Spine. There is no relevant literature to support the use of MR myelography complete spine in the initial imaging of suspected SIH. An MR myelogram with intrathecal gadolinium administration has been used in several studies as a subsequent follow-up imaging examination after initial spine imaging to increase sensitivity for the detection of slow leaking dural and meningeal diverticular defects [47-49]. Some limited evidence suggests a potential role for MR myelography in the detection of CSF-venous fistulas [50]. It should be noted that intrathecal use of gadolinium is currently off label. Although studies have suggested that intrathecal gadolinium can be administered safely in small doses, the safety profile of such imaging is not formally approved for such use, and special dosing caution is required to avoid potential of gadolinium induced neurotoxicity [51].

MRI Complete Spine With IV Contrast. There is no relevant literature to support the use of MRI complete spine with IV contrast in the initial imaging of suspected SIH.

MRI Complete Spine Without and With IV Contrast. MRI complete spine without and with IV contrast can be useful in the initial evaluation of suspected SIH. The noncontrast component of this examination optimized with fluid sensitive sequences is most useful, particularly when performed with 3-D T2-weighted fat saturated sequences, which increases sensitivity for detecting fluid collections outside of the thecal sac [52]. It can detect with a high degree of accuracy the presence of epidural fluid collections and meningeal diverticula that can inform positioning and regions of interest for subsequent CSF leak localization imaging examinations, such as dynamic CT myelogram complete spine and digital subtraction myelography complete spine [25,34-36]. The contrast component of this examination may demonstrate dural enhancement and engorged epidural venous plexus, which are also imaging features that support a diagnosis of SIH [28,29].

MRI Complete Spine Without IV Contrast. MRI complete spine without IV contrast optimized with fluid sensitive sequences is most useful in the initial evaluation of suspected SIH, particularly when performed with 3-D T2-weighted fat saturated sequences, which increases sensitivity for detecting fluid collections outside of the thecal sac [52]. This examination can detect with a high degree of accuracy the presence of epidural fluid collections and meningeal diverticula that can inform positioning and regions of interest for subsequent CSF leak localization

imaging examinations, such as dynamic CT myelogram complete spine and digital subtraction myelography complete spine [25,34-36].

MRI Head With IV Contrast. There is no relevant literature to support the use of MRI head with IV contrast in the initial imaging of suspected SIH.

MRI Head Without and With IV Contrast. MRI head without and with IV contrast is most useful in the initial evaluation of suspected SIH. Suggestive imaging features of SIH are best visualized on MRI head without and with IV contrast and include qualitative signs (engorgement of venous sinuses, pachymeningeal enhancement, midbrain descent, superficial siderosis, subdural hygroma or hematoma, and convex superior surface of the pituitary) and quantitative signs (pituitary height, pontomesencephalic angle, suprasellar cistern, prepontine cistern, midbrain descent, venous-hinge angle, mamillopontine angle, tonsillar descent, and area cavum veli interpositi) [16,25,26]. The cumulative presence of these intracranial findings has been shown to correlate with the likelihood of finding a spinal leak source [16].

MRI Head Without IV Contrast. MRI head without IV contrast can be useful in the initial evaluation of suspected SIH. Although imaging features of suspected SIH are best visualized on MRI head without and with IV contrast, some imaging features such as midbrain descent, superficial siderosis, subdural hygroma or hematoma, convex superior surface of the pituitary, pituitary height, pontomesencephalic angle, suprasellar cistern, prepontine cistern, midbrain descent, venous-hinge angle, mamillopontine angle, tonsillar descent, and area cavum veli interpositi may be evaluated on noncontrast MRI sequences [16,25,26]. The cumulative presence of these intracranial findings has been shown to correlate with likelihood of finding a spinal leak source [16].

Radiographic Myelography Digital Subtraction Complete Spine. There is no relevant literature to support the use of dynamic digital subtraction myelography in the initial imaging of suspected SIH. Dynamic digital subtraction myelography plays an important role in the subsequent imaging workup of SIH after initial brain and spine imaging [53]. Results from an initial spine MRI or conventional CT myelogram provide useful information on how a subsequent dynamic digital subtraction myelogram will be performed, such as prone positioning for suspected ventral dural defect or decubitus positioning for suspected leaking meningeal diverticulum or CSF-venous fistula [24,53,54]. Dynamic digital subtraction myelography involves continuous real-time fluoroscopic x-ray imaging of the

entire spine or of a focused region of the spine where there is suspicion for CSF leak. When performed in the decubitus position, 2 separate contrast injections may be required due to the transient temporal characteristics associated with CSF-venous fistula visualization as well as limitations in contrast dosing [40-44].

Variant 2: Adult. Orthostatic headache from suspected intracranial hypotension within 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

Initial imaging

Leakage of CSF following a dural puncture may be of sufficient volume to elicit symptoms of intracranial hypotension. Postdural puncture headaches occur with an estimated frequency of 2% to 8% [13-15]. Risk factors for postdural puncture headaches include the use of a larger gauge needle, multiple attempts at dural puncture, the use of a cutting needle versus pencil point tip needle, needle orientation perpendicular rather than parallel to spine longitudinal axis (when using a cutting needle), and dural puncture in the sitting position as opposed to lateral decubitus positioning [55-58]. Imaging is not typically indicated in this clinical setting because postdural puncture headaches are typically self-limited, with most symptoms fully resolving within 1 week without any treatment [13]. The initial management of postdural puncture headaches is conservative medical management, with consideration of epidural blood patch if symptoms are severe or not beginning to resolve by 2 to 3 days postdural puncture [59-61].

CT Complete Spine With IV Contrast. There is no relevant literature to support the use of CT complete spine with IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

CT Complete Spine Without and With IV Contrast. There is no relevant literature to support the use of CT complete spine without and with IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

CT Complete Spine Without IV Contrast. There is no relevant literature to support the use of CT complete spine without IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

CT Head Cisternography. There is no relevant literature to support the use of CT head cisternography in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

CT Head With IV Contrast. There is no relevant literature to support the use of CT head with IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

CT Head Without and With IV Contrast. There is no relevant literature to support the use of CT head without and with IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

CT Head Without IV Contrast. There is no relevant literature to support the use of CT head without IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

CT Myelography Complete Spine. There is no relevant literature to support the use of CT myelography complete spine in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

CT Myelography Dynamic Complete Spine. There is no relevant literature to support the use of dynamic CT myelography complete spine in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

DTPA Cisternography. There is no relevant literature to support the use of DTPA cisternography in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

MR Myelography Complete Spine. There is no relevant literature to support the use of MR myelography complete spine in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

MRI Complete Spine With IV Contrast. There is no relevant literature to support the use of MRI complete spine with IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

MRI Complete Spine Without and With IV Contrast. There is no relevant literature to support the use of MRI complete spine without and with IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

MRI Complete Spine Without IV Contrast. There is no relevant literature to support the use of MRI complete spine without IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

MRI Head With IV Contrast. There is no relevant literature to support the use of MRI head with IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

MRI Head Without and With IV Contrast. There is no relevant literature to support the use of MRI head without and with IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

MRI Head Without IV Contrast. There is no relevant literature to support the use of MRI head without IV contrast in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

Radiographic Myelography Digital Subtraction Complete Spine. There is no relevant literature to support the use of dynamic digital subtraction myelography complete spine in the initial imaging of suspected intracranial hypotension within 72 hours of dural puncture.

Variant 3: Adult. Orthostatic headache from suspected intracranial hypotension without improvement post 72 hours of dural puncture or other spinal intervention that could cause CSF leakage. Initial imaging

This clinical variant refers to a patient with orthostatic headache in temporal relation to a dural puncture that is not improving following a trial of conservative management. Imaging is not usually warranted in this clinical scenario, because the next management step for such patients typically involves an epidural blood patch procedure directed at the level of dural puncture [59-61].

CT Complete Spine With IV Contrast. There is no relevant literature to support the use of CT complete spine with IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

CT Complete Spine Without and With IV Contrast. There is no relevant literature to support the use of CT complete spine without and with IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

CT Complete Spine Without IV Contrast. There is no relevant literature to support the use of CT complete spine without IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

CT Head Cisternography. There is no relevant literature to support the use of CT head cisternography in the initial imaging of suspected intracranial hypotension without

improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

CT Head With IV Contrast. There is no relevant literature to support the use of CT head with IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

CT Head Without and With IV Contrast. There is no relevant literature to support the use of CT head without and with IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

CT Head Without IV Contrast. There is no relevant literature to support the use of CT head without IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

CT Myelography Complete Spine. There is no relevant literature to support the use of CT myelography complete spine in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

CT Myelography Dynamic Complete Spine. There is no relevant literature to support the use of dynamic CT myelography complete spine in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

DTPA Cisternography. There is no relevant literature to support the use of DTPA cisternography in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

MR Myelography Complete Spine. There is no relevant literature to support the use of MR myelography complete spine in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

MRI Complete Spine With IV Contrast. There is no relevant literature to support the use of MRI complete spine with IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

MRI Complete Spine Without and With IV Contrast. There is no relevant literature to support the use of MRI complete spine without and with IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

MRI Complete Spine Without IV Contrast. There is no relevant literature to support the use of MRI complete spine without IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

MRI Head With IV Contrast. There is no relevant literature to support the use of MRI head with IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

MRI Head Without and With IV Contrast. There is no relevant literature to support the use of MRI head without and with IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

MRI Head Without IV Contrast. There is no relevant literature to support the use of MRI head without IV contrast in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

Radiographic Myelography Digital Subtraction Complete Spine. There is no relevant literature to support the use of dynamic digital subtraction myelography complete spine in the initial imaging of suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage.

Variant 4: Adult. Obtundation with initial brain imaging features of suspected intracranial hypotension. Next imaging study

This clinical scenario represents a severe clinical manifestation of SIH, which may represent sequela of more severe mechanical traction forces from brain sagging in the setting of CSF hypovolemia [62,63]. There are some limited reports of successful acute management of these critically ill patients with intrathecal saline infusions via lumbar drains, which may serve as a temporizing measure to raise CSF pressure and reverse obtundation [64-67]. The subsequent management of such patients is otherwise similar to

patients with SIH without impaired consciousness and focuses on spine imaging to localize a source of leak that may be targeted for definitive treatment [24].

CT Complete Spine With IV Contrast. There is no relevant literature to support CT complete spine with IV contrast as a next imaging study in the clinical setting of obtundation with initial brain imaging features of suspected intracranial hypotension.

CT Complete Spine Without and With IV Contrast. There is no relevant literature to support CT complete spine without and with IV contrast as a next imaging study in the clinical setting of obtundation with initial brain imaging features of suspected intracranial hypotension.

CT Complete Spine Without IV Contrast. There is no relevant literature to support CT complete spine without IV contrast as a next imaging study in the clinical setting of obtundation with initial brain imaging features of suspected intracranial hypotension.

CT Myelography Complete Spine. Although CT myelography complete spine can detect epidural contrast collections suggestive of dural defect or leaking meningeal diverticulum, MRI complete spine optimized with fluid sensitive sequences has been shown to detect epidural collections with equal sensitivity and is a preferred initial imaging option over CT myelography complete spine because it avoids the need for lumbar puncture [34,35].

CT Myelography Dynamic Complete Spine. There is no relevant literature to support the use of dynamic CT myelography complete spine as a next imaging study in the clinical setting of obtundation with initial brain imaging features of suspected intracranial hypotension. Dynamic CT myelography plays an important role in the subsequent imaging workup of SIH after initial brain and spine imaging [37,38]. Results from an initial spine MRI or conventional CT myelogram provide useful information on how a subsequent dynamic CT myelogram will be performed, such as prone positioning for suspected ventral dural defect or decubitus positioning for suspected leaking meningeal diverticulum or CSF-venous fistula [24,37-39]. Dynamic CT myelography involves an initial scan followed by delayed phase scans in immediate succession and, when performed in the decubitus position, may require 2 separate contrast injections due to the transient temporal characteristics associated with CSF-venous fistula visualization as well as limitations in contrast dosing [40-44].

DTPA Cisternography. Although DTPA cisternography can detect epidural collections suggestive of dural defect or

leaking meningeal diverticulum, MRI complete spine optimized with fluid sensitive sequences is typically the preferred initial imaging option over DTPA cisternography complete spine because it avoids the need for lumbar puncture and has superior spatial resolution for lesion localization [45,46].

MR Myelography Complete Spine. There is no relevant literature to support the use of MR myelography complete spine as a next imaging study in the clinical setting of obtundation with initial brain imaging features of suspected intracranial hypotension. An MR myelogram with intrathecal gadolinium administration has been used in several studies as a subsequent follow-up imaging examination after initial spine imaging to increase the sensitivity for detection of slow leaking dural and meningeal diverticular defects [47-49]. Some limited evidence suggests a potential role for MR myelography in the detection of CSF-venous fistulas [50]. It should be noted that intrathecal use of gadolinium is currently off label. Although studies have suggested that intrathecal gadolinium can be administered safely in small doses, the safety profile of such imaging is not formally approved for such use, and special dosing caution is required to avoid potential of gadolinium induced neurotoxicity [51].

MRI Complete Spine With IV Contrast. There is no relevant literature to support the use of MRI complete spine with IV contrast as a next imaging study in the clinical setting of obtundation with initial brain imaging features of suspected intracranial hypotension.

MRI Complete Spine Without and With IV Contrast. MRI complete spine without and with IV contrast can be useful as a next imaging study in the clinical setting of obtundation with initial brain imaging features of suspected intracranial hypotension. The noncontrast component of this examination optimized with fluid sensitive sequences is most useful, particularly when performed with 3-D T2-weighted fat saturated sequences, which increases the sensitivity for detecting fluid collections outside of the thecal sac [52]. It can detect with a high degree of accuracy the presence of epidural fluid collections and meningeal diverticula that can inform positioning and regions of interest for subsequent CSF leak localization imaging examinations, such as dynamic CT myelogram complete spine and digital subtraction myelography complete spine [25,34-36]. The contrast component of this examination may demonstrate dural enhancement and engorged epidural venous plexus, which are also imaging features that support a diagnosis of SIH [28,29].

MRI Complete Spine Without IV Contrast. MRI complete spine without IV contrast optimized with fluid

sensitive sequences is most useful as a next imaging study in the clinical setting of obtundation with initial brain imaging features of suspected intracranial hypotension, particularly when performed with 3-D T2-weighted fat saturated sequences, which increases sensitivity for detecting fluid collections outside of the thecal sac [52]. This examination can detect with a high degree of accuracy the presence of epidural fluid collections and meningeal diverticula that can inform positioning and regions of interest for subsequent CSF leak localization imaging examinations, such as dynamic CT myelogram complete spine and digital subtraction myelography complete spine [25,34-36].

Radiographic Myelography Digital Subtraction Complete Spine. There is no relevant literature to support the use of dynamic digital subtraction myelogram complete spine as a next imaging study in the clinical setting of obtundation with initial brain imaging features of suspected intracranial hypotension. Dynamic digital subtraction myelography plays an important role in the subsequent imaging workup of SIH after initial brain and spine imaging [53]. Results from an initial spine MRI or conventional CT myelogram provide useful information on how a subsequent dynamic digital subtraction myelogram will be performed, such as prone positioning for suspected ventral dural defect or decubitus positioning for suspected leaking meningeal diverticulum or CSF-venous fistula [24,53,54]. Dynamic digital subtraction myelography involves continuous real-time fluoroscopic x-ray imaging of the entire spine or of a focused region of the spine where there is suspicion for CSF leak. When performed in the decubitus position, 2 separate contrast injections may be required due to the transient temporal characteristics associated with CSF-venous fistula visualization as well as limitations in contrast dosing [40-44].

Variant 5: Adult. Chronic daily headache from suspected intracranial hypotension with negative initial brain and spine imaging, but with history and clinical examination suggesting CSF leakage. Next imaging study

Negative initial imaging should not preclude continued diagnostic workup in a patient with clinically suspected SIH [4,53]. Approximately 20% of initial brain MRIs and 46% to 67% of initial spine imaging in patients with clinically suspected SIH may have normal results [4]. Of note, CSF-venous fistulas and slow meningeal diverticular leaks are often subtle imaging findings that may not be readily detectable using conventional imaging techniques with limited temporal resolution and may require follow-up imaging with more advanced imaging procedures to definitely

identify or exclude a more subtle spinal CSF leak source [7,53,68-70].

CT Head Cisternography. There is no relevant literature to support the use of CT head cisternography in the subsequent imaging of suspected SIH. The spine has been shown to represent the anatomical source of most symptomatic CSF leaks and venous fistulas, such that the imaging investigation of leak source should be directed primarily toward the spine and not intracranially [22].

CT Myelography Dynamic Complete Spine. Dynamic CT myelography plays an important role in the subsequent imaging workup of SIH after initial brain and spine imaging [37,38]. Results from an initial spine MRI or conventional CT myelogram provide useful information on how a subsequent dynamic CT myelogram will be performed, such as prone positioning for suspected ventral dural defect or decubitus positioning for suspected leaking meningeal diverticulum or CSF-venous fistula [24,37-39]. Dynamic CT myelography involves an initial scan followed by delayed phase scans in immediate succession and, when performed in the decubitus position, may require 2 separate contrast injections due to the transient temporal characteristics associated with CSF-venous fistula visualization as well as limitations in contrast dosing [40-44].

DTPA Cisternography. DTPA cisternography of the spine can detect CSF leaks with similar accuracy to conventional CT myelography [45]. Due to its limited spatial resolution, a positive DTPA cisternogram may require further investigation with subsequent dynamic CT myelography or dynamic digital subtraction myelography to definitively localize leak for treatment planning [45,46].

MR Myelography Complete Spine. An MR myelogram with intrathecal gadolinium administration has been used in several studies to increase sensitivity for the detection of slow leaking dural and meningeal diverticular defects [47-49]. Some limited evidence suggests a potential role for MR myelography in the detection of CSF-venous fistulas [50]. It should be noted that intrathecal use of gadolinium is currently off label. Although studies have suggested that intrathecal gadolinium can be administered safely in small doses, the safety profile of such imaging is not formally approved for such use, and special dosing caution is required to avoid potential of gadolinium induced neurotoxicity [51].

Radiographic Myelography Digital Subtraction Complete Spine. Dynamic digital subtraction myelography plays an important role in the subsequent imaging workup of SIH after initial brain and spine imaging [53]. Results from an initial spine MRI or conventional CT myelogram provide useful information on how a subsequent dynamic digital

subtraction myelogram will be performed, such as prone positioning for suspected ventral dural defect or decubitus positioning for suspected leaking meningeal diverticulum or CSF-venous fistula [24,53,54]. Dynamic digital subtraction myelography involves continuous real-time fluoroscopic x-ray imaging of the entire spine or of a focused region of the spine where there is suspicion for CSF leak. When performed in the decubitus position, 2 separate contrast injections may be required due to the transient temporal characteristics associated with CSF-venous fistula visualization as well as limitations in contrast dosing [40-44].

Variant 6: Adult. Rebound headache following epidural blood patch or fibrin glue patch treatment for suspected intracranial hypotension. Initial imaging

Rebound headaches are known to occur in about a quarter of patients following treatment of a CSF leak and are characterized by a postprocedural elevation in CSF pressure, usually occurring within the first 1 to 2 postprocedural days [71]. The clinical syndrome of rebound headaches can include a development of a phenotypically new headache with characteristic reversal of a patient's preprocedural orthostatic symptoms, whereas the patient feels relief of headache in the upright position and exacerbation of symptoms in the recumbent position [10]. Headache location may also change, from the characteristic occipital region predominant in SIH headaches to a more anteriorly located frontal, periorbital, or retroorbital location. Additional features of rebound headache include nausea, emesis, and blurry vision. It is important to recognize the clinical features of rebound headache because mistaking these symptoms as refractory SIH may subject the patient to unnecessary imaging or unnecessary repeat blood/fibrin patch procedures that could raise CSF pressure further and exacerbate the condition. Rebound headaches are usually self-limited and minor and can be managed conservatively. Acetazolamide, which lowers CSF production, may be prescribed in the postprocedural period to ameliorate symptoms of rebound headache. CSF drainage via lumbar puncture or lumbar drain can be used in more severe cases that are refractory to medical management [10].

CT Complete Spine With IV Contrast. There is no relevant literature to support the use of CT complete spine with IV contrast in the initial imaging of post-SIH treatment rebound headaches.

CT Complete Spine Without and With IV Contrast. There is no relevant literature to support the use of CT complete spine without and with IV contrast in the initial imaging of post-SIH treatment rebound headaches.

CT Complete Spine Without IV Contrast. There is no relevant literature to support the use of CT complete spine without IV contrast in the initial imaging of post-SIH treatment rebound headaches.

CT Head Cisternography. There is no relevant literature to support the use of CT head cisternography in the initial imaging of post-SIH treatment rebound headaches.

CT Head With IV Contrast. There is no relevant literature to support the use of CT head with IV contrast in the initial imaging of post-SIH treatment rebound headaches.

CT Head Without and With IV Contrast. There is no relevant literature to support the use of CT head without and with IV contrast in the initial imaging of post-SIH treatment rebound headaches.

CT Head Without IV Contrast. There is no relevant literature to support the use of CT head without IV contrast in the initial imaging of post-SIH treatment rebound headaches.

CT Myelography Complete Spine. There is no relevant literature to support the use of CT myelography complete spine in the initial imaging of post-SIH treatment rebound headaches.

CT Myelography Dynamic Complete Spine. There is no relevant literature to support the use of dynamic CT myelography complete spine in the initial imaging of post-SIH treatment rebound headaches.

DTPA Cisternography. There is no relevant literature to support the use of DTPA cisternography in the initial imaging of post-SIH treatment rebound headaches.

MR Myelography Complete Spine. There is no relevant literature to support the use of MR myelography complete spine in the initial imaging of post-SIH treatment rebound headaches.

MRI Complete Spine With IV Contrast. There is no relevant literature to support the use of MRI complete spine with IV contrast in the initial imaging of post-SIH treatment rebound headaches.

MRI Complete Spine Without and With IV Contrast. There is no relevant literature to support the use of MRI complete spine without and with IV contrast in the initial imaging of post-SIH treatment rebound headaches.

MRI Complete Spine Without IV Contrast. There is no relevant literature to support the use of MRI complete spine without IV contrast in the initial imaging of post-SIH treatment rebound headaches.

MRI Head With IV Contrast. There is no relevant literature to support the use of MRI head with IV contrast in the initial imaging of post-SIH treatment rebound headaches.

MRI Head Without and With IV Contrast. There is no relevant literature to support the use of MRI head without and with IV contrast in the initial imaging of post-SIH treatment rebound headaches.

MRI Head Without IV Contrast. There is no relevant literature to support the use of MRI head without IV contrast in the initial imaging of post-SIH treatment rebound headaches.

Radiographic Myelography Digital Subtraction Complete Spine. There is no relevant literature to support the use of dynamic digital subtraction myelography complete spine in the initial imaging of post-SIH treatment rebound headaches.

SUMMARY OF HIGHLIGHTS

- **Variant 1:** In an adult with an orthostatic headache from suspected intracranial hypotension, without recent spinal intervention that could cause CSF leakage, an MRI of the brain and the complete spine, either without and with IV contrast or without IV contrast, are both required to assist in localizing a potential CSF leak.
- **Variant 2:** In an adult with an orthostatic headache from suspected intracranial hypotension within 72 hours of dural puncture or other spinal intervention that could cause CSF leakage, imaging is not typically indicated because postdural puncture headaches are typically self-limited, with most symptoms fully resolving within 1 week without any treatment. The initial management of postdural puncture headaches is conservative medical management, with consideration of an epidural blood patch if symptoms are severe or not beginning to resolve by 2 to 3 days postdural puncture.
- **Variant 3:** In an adult with an orthostatic headache from suspected intracranial hypotension without improvement after 72 hours of dural puncture or other spinal intervention that could cause CSF leakage, imaging is not typically indicated because the subsequent management step for such patients involves an epidural blood patch procedure directed at the level of dural puncture.
- **Variant 4:** In an adult who is obtunded with initial brain imaging features of suspected intracranial

hypotension, an MRI of the complete spine, either without and with IV contrast or without IV contrast, is required to assist in localizing a potential CSF leak. An intrathecal saline infusion procedure may also be considered as a temporizing measure to restore CSF pressures and reverse symptoms. This scenario represents a severe clinical manifestation of SIH, which may represent the sequela of more severe mechanical traction forces from brain sagging in CSF hypovolemia. The subsequent management of such patients is otherwise like that of patients with SIH without impaired consciousness. It focuses on spine imaging to localize a source of leak that may be targeted for definitive treatment.

- **Variant 5:** In an adult with chronic daily headache from suspected intracranial hypotension with negative initial brain and spine imaging but with history and clinical examination suggesting CSF leakage, either dynamic CT or dynamic digital subtraction myelography is indicated in the subsequent imaging workup of SIH because negative initial imaging should not preclude continued diagnostic workup. For instance, CSF-venous fistulas and slow meningeal diverticular leaks are often subtle imaging findings that may not be readily detectable using conventional imaging techniques with limited temporal resolution and may require follow-up imaging with more advanced imaging procedures to identify or exclude a more subtle spinal CSF leak source.
- **Variant 6:** Imaging is not typically indicated in an adult with rebound headache following epidural blood patch or fibrin glue patch treatment for suspected intracranial hypotension. Rebound headaches are usually self-limited and minor and can be managed conservatively.

SUPPORTING DOCUMENTS

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

RELATIVE RADIATION LEVEL INFORMATION

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication

has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table 2). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document [72].

REFERENCES

- Dobrocky T, Nicholson P, Hani L, et al. Spontaneous intracranial hypotension: searching for the CSF leak. *Lancet Neurol* 2022;21:369-80.
- Kranz PG, Gray L, Malinzak MD, Amrhein TJ. Spontaneous intracranial hypotension: pathogenesis, diagnosis, and treatment. *Neuroimaging Clin N Am* 2019;29:581-94.
- Headache Classification Committee of the International Headache Society (IHS). The international classification of headache disorders, 3rd edition. *Cephalalgia* 2018;38:1-211.
- D'Antona L, Jaime Merchan MA, Vassiliou A, et al. Clinical presentation, investigation findings, and treatment outcomes of spontaneous intracranial hypotension syndrome: a systematic review and meta-analysis. *JAMA Neurol* 2021;78:329-37.
- Schievink WI, Maya MM, Moser F, Tourje J, Torbati S. Frequency of spontaneous intracranial hypotension in the emergency department. *J Headache Pain* 2007;8:325-8.
- Kim YJ, Cho HY, Seo DW, et al. Misdiagnosis of spontaneous intracranial hypotension as a risk factor for subdural hematoma. *Headache* 2017;57:1593-600.
- Kranz PG, Gray L, Amrhein TJ. Spontaneous intracranial hypotension: 10 myths and misperceptions. *Headache* 2018;58:948-59.
- Schievink WI. Misdiagnosis of spontaneous intracranial hypotension. *Arch Neurol* 2003;60:1713-8.
- Beck J, Ulrich CT, Fung C, et al. Diskogenic microspurs as a major cause of intractable spontaneous intracranial hypotension. *Neurology* 2016;87:1220-6.
- Kranz PG, Amrhein TJ, Gray L. Rebound intracranial hypertension: a complication of epidural blood patching for intracranial hypotension. *AJNR Am J Neuroradiol* 2014;35:1237-40.
- Liu FC, Fuh JL, Wang YF, Wang SJ. Connective tissue disorders in patients with spontaneous intracranial hypotension. *Cephalalgia* 2011;31:691-5.
- Schievink WI, Gordon OK, Tourje J. Connective tissue disorders with spontaneous spinal cerebrospinal fluid leaks and intracranial hypotension: a prospective study. *Neurosurgery* 2004;54:65-70; discussion 70-1.
- Amorim JA, Gomes de Barros MV, Valenca MM. Post-dural (post-lumbar) puncture headache: risk factors and clinical features. *Cephalalgia* 2012;32:916-23.
- DelPizzo K, Cheng J, Dong N, et al. Post-dural puncture headache is uncommon in young ambulatory surgery patients. *HSS J* 2017;13:146-51.
- Philip JT, Flores MA, Beegle RD, Dodson SC, Messina SA, Murray JV. Rates of epidural blood patch following lumbar puncture comparing atraumatic versus bevel-tip needles stratified for body mass index. *AJNR Am J Neuroradiol* 2022;43:315-8.
- Dobrocky T, Grunder L, Breiding PS, et al. Assessing spinal cerebrospinal fluid leaks in spontaneous intracranial hypotension with a scoring system based on brain magnetic resonance imaging findings. *JAMA Neurol* 2019;76:580-7.
- Mamlouk MD, Shen PY, Sedrak MF, Dillon WP. CT-guided fibrin glue occlusion of cerebrospinal fluid-venous fistulas. *Radiology* 2021;299:409-18.
- Kranz PG, Luetmer PH, Diehn FE, Amrhein TJ, Tanpitukpongse TP, Gray L. Myelographic techniques for the detection of spinal CSF leaks in spontaneous intracranial hypotension. *AJR Am J Roentgenol* 2016;206:8-19.
- Schievink WI, Maya MM, Jean-Pierre S, Nuno M, Prasad RS, Moser FG. A classification system of spontaneous spinal CSF leaks. *Neurology* 2016;87:673-9.
- Schievink WI. Spontaneous intracranial hypotension. *N Engl J Med* 2021;385:2173-8.
- Magnaes B. Body position and cerebrospinal fluid pressure. Part 2: clinical studies on orthostatic pressure and the hydrostatic indifferent point. *J Neurosurg* 1976;44:698-705.
- Schievink WI, Schwartz MS, Maya MM, Moser FG, Rozen TD. Lack of causal association between spontaneous intracranial hypotension and cranial cerebrospinal fluid leaks. *J Neurosurg* 2012;116:749-54.
- Kranz PG, Gray L, Taylor JN. CT-guided epidural blood patching of directly observed or potential leak sites for the targeted treatment of spontaneous intracranial hypotension. *AJNR Am J Neuroradiol* 2011;32:832-8.
- Callen AL, Timpone VM, Schwertner A, et al. Algorithmic multimodality approach to diagnosis and treatment of spinal CSF leak and venous fistula in patients with spontaneous intracranial hypotension. *AJR Am J Roentgenol* 2022;219:292-301.
- Watanabe A, Horikoshi T, Uchida M, Koizumi H, Yagishita T, Kinouchi H. Diagnostic value of spinal MR imaging in spontaneous intracranial hypotension syndrome. *AJNR Am J Neuroradiol* 2009;30:147-51.
- Chen ST, Wu JW, Wang YF, Lirng JF, Hseu SS, Wang SJ. The time sequence of brain MRI findings in spontaneous intracranial hypotension. *Cephalalgia* 2022;42:12-9.
- Schievink WI, Maya M, Moser F, Nuno M. Long-term risks of persistent ventral spinal CSF leaks in SIH: superficial siderosis and birachial amyotrophy. *Neurology* 2021;97:e1964-70.
- Medina JH, Abrams K, Falcone S, Bhatia RG. Spinal imaging findings in spontaneous intracranial hypotension. *AJR Am J Roentgenol* 2010;195:459-64.
- Dillon WP. Spinal manifestations of intracranial hypotension. *AJNR Am J Neuroradiol* 2001;22:1233-4.
- Kranz PG, Amrhein TJ, Gray L. CSF venous fistulas in spontaneous intracranial hypotension: imaging characteristics on dynamic and CT myelography. *AJR Am J Roentgenol* 2017;209:1360-6.
- Kranz PG, Tanpitukpongse TP, Choudhury KR, Amrhein TJ, Gray L. How common is normal cerebrospinal fluid pressure in spontaneous intracranial hypotension? *Cephalalgia* 2016;36:1209-17.
- Callen AL, Pattee J, Thaker AA, et al. Relationship of Bern score, spinal elastance, and opening pressure in patients with spontaneous intracranial hypotension. *Neurology* 2023;100:e2237-46.
- Bond KM, Benson JC, Cutsforth-Gregory JK, Kim DK, Diehn FE, Carr CM. Spontaneous intracranial hypotension: atypical radiologic appearances, imaging mimickers, and clinical look-alikes. *AJNR Am J Neuroradiol* 2020;41:1339-47.
- Wang YF, Lirng JF, Fuh JL, Hseu SS, Wang SJ. Heavily T2-weighted MR myelography vs CT myelography in spontaneous intracranial hypotension. *Neurology* 2009;73:1892-8.
- Kim BR, Lee JW, Lee E, Kang Y, Ahn JM, Kang HS. Utility of heavily T2-weighted MR myelography as the first step in CSF leak detection and the planning of epidural blood patches. *J Clin Neurosci* 2020;77:110-5.
- Starling A, Hernandez F, Hoxworth JM, et al. Sensitivity of MRI of the spine compared with CT myelography in orthostatic headache with CSF leak. *Neurology* 2013;81:1789-92.

37. Caton MT Jr, Laguna B, Soderlund KA, Dillon WP, Shah VN. Spinal compliance curves: preliminary experience with a new tool for evaluating suspected CSF venous fistulas on CT myelography in patients with spontaneous intracranial hypotension. *AJNR Am J Neuroradiol* 2021;42:986-92.
38. Dobrocky T, Mosimann PJ, Zibold F, et al. Cryptogenic cerebrospinal fluid leaks in spontaneous intracranial hypotension: role of dynamic CT myelography. *Radiology* 2018;289:766-72.
39. Madhavan AA, Verdoorn JT, Shlapak DP, et al. Lateral decubitus dynamic CT myelography for fast cerebrospinal fluid leak localization. *Neuroradiology* 2022;64:1897-903.
40. Mamlouk MD, Ochi RP, Jun P, Shen PY. Decubitus CT myelography for CSF-venous fistulas: a procedural approach. *AJNR Am J Neuroradiol* 2021;42:32-6.
41. Kim DK, Brinjikji W, Morris PP, et al. Lateral decubitus digital subtraction myelography: tips, tricks, and pitfalls. *AJNR Am J Neuroradiol* 2020;41:21-8.
42. Schievink WI, Maya MM, Moser FG, et al. Lateral decubitus digital subtraction myelography to identify spinal CSF-venous fistulas in spontaneous intracranial hypotension. *J Neurosurg Spine* 2019:1-4.
43. Shlapak DP, Mark IT, Kim DK, et al. Incremental diagnostic yield and clinical outcomes of lateral decubitus CT myelogram immediately following negative lateral decubitus digital subtraction myelogram. *Neuroradiol J* 2023;19714009231173110.
44. Carlton Jones L, Goadsby PJ. Same-day bilateral decubitus CT myelography for detecting CSF-venous fistulas in spontaneous intracranial hypotension. *AJNR Am J Neuroradiol* 2022;43:645-8.
45. Monteith TS, Kralik SF, Dillon WP, Hawkins RA, Goadsby PJ. The utility of radioisotope cisternography in low CSF/volume syndromes compared to myelography. *Cephalalgia* 2016;36:1291-5.
46. Sakurai K, Nishio M, Yamada K, et al. Comparison of the radioisotope cisternography findings of spontaneous intracranial hypotension and iatrogenic cerebrospinal fluid leakage focusing on chronological changes. *Cephalalgia* 2012;32:1131-9.
47. Madhavan AA, Carr CM, Benson JC, et al. Diagnostic yield of intrathecal gadolinium MR myelography for CSF leak localization. *Clin Neuroradiol* 2022;32:537-45.
48. Akbar JJ, Luetmer PH, Schwartz KM, Hunt CH, Diehn FE, Eckel LJ. The role of MR myelography with intrathecal gadolinium in localization of spinal CSF leaks in patients with spontaneous intracranial hypotension. *AJNR Am J Neuroradiol* 2012;33:535-40.
49. Chazen JL, Talbott JF, Lantos JE, Dillon WP. MR myelography for identification of spinal CSF leak in spontaneous intracranial hypotension. *AJNR Am J Neuroradiol* 2014;35:2007-12.
50. Chazen JL, Robbins MS, Strauss SB, Schweitzer AD, Greenfield JP. MR myelography for the detection of CSF-venous fistulas. *AJNR Am J Neuroradiol* 2020;41:938-40.
51. Patel M, Atyani A, Salameh JP, McInnes M, Chakraborty S. Safety of intrathecal administration of gadolinium-based contrast agents: a systematic review and meta-analysis. *Radiology* 2020;297:75-83.
52. Dobrocky T, Winklehner A, Breiding PS, et al. Spine MRI in spontaneous intracranial hypotension for CSF leak detection: non-superiority of intrathecal gadolinium to heavily T2-weighted fat-saturated sequences. *AJNR Am J Neuroradiol* 2020;41:1309-15.
53. Schievink WI, Maya M, Prasad RS, et al. Spontaneous spinal cerebrospinal fluid-venous fistulas in patients with orthostatic headaches and normal conventional brain and spine imaging. *Headache* 2021;61:387-91.
54. Schievink WI, Moser FG, Maya MM, Prasad RS. Digital subtraction myelography for the identification of spontaneous spinal CSF-venous fistulas. *J Neurosurg Spine* 2016;24:960-4.
55. Flaatten H, Thorsen T, Askeland B, et al. Puncture technique and postural postdural puncture headache. A randomised, double-blind study comparing transverse and parallel puncture. *Acta Anaesthesiol Scand* 1998;42:1209-14.
56. Zorrilla-Vaca A, Makkar JK. Effectiveness of lateral decubitus position for preventing post-dural puncture headache: a meta-analysis. *Pain Physician* 2017;20:E521-9.
57. Seeberger MD, Kaufmann M, Staender S, Schneider M, Scheidegger D. Repeated dural punctures increase the incidence of postdural puncture headache. *Anesth Analg* 1996;82:302-5.
58. Zorrilla-Vaca A, Mathur V, Wu CL, Grant MC. The impact of spinal needle selection on postdural puncture headache: a meta-analysis and meta-regression of randomized studies. *Reg Anesth Pain Med* 2018;43:502-8.
59. Booth JL, Pan PH, Thomas JA, Harris LC, D'Angelo R. A retrospective review of an epidural blood patch database: the incidence of epidural blood patch associated with obstetric neuraxial anesthetic techniques and the effect of blood volume on efficacy. *Int J Obstet Anesth* 2017;29:10-7.
60. Safa-Tisseront V, Thormann F, Malassine P, et al. Effectiveness of epidural blood patch in the management of post-dural puncture headache. *Anesthesiology* 2001;95:334-9.
61. American Society of Anesthesiologists. Statement on post-dural puncture headache management. Available at: <https://www.asahq.org/standards-and-practice-parameters/statement-on-post-dural-puncture-headache-management>. Accessed March 29, 2024.
62. Idrissi AL, Lacour JC, Klein O, Schmitt E, Ducrocq X, Richard S. Spontaneous intracranial hypotension: characteristics of the serious form in a series of 24 patients. *World Neurosurg* 2015;84:1613-20.
63. Schievink WI, Maya MM, Moser FG, Jean-Pierre S, Nuno M. Coma: a serious complication of spontaneous intracranial hypotension. *Neurology* 2018;90:e1638-45.
64. Muram S, Yavin D, DuPlessis S. Intrathecal saline infusion as an effective temporizing measure in the management of spontaneous intracranial hypotension. *World Neurosurg* 2019;125:37-41.
65. Stephen CD, Rojas R, Lioutas VA, Papavassiliou E, Simon DK. Complicated spontaneous intracranial hypotension treated with intrathecal saline infusion. *Pract Neurol* 2016;16:146-9.
66. Sass C, Kosinski C, Schmidt P, Mull M, Schulz J, Schiefer J. Intrathecal saline infusion: an emergency procedure in a patient with spontaneous intracranial hypotension. *Neurocrit Care* 2013;19:116-8.
67. Binder DK, Dillon WP, Fishman RA, Schmidt MH. Intrathecal saline infusion in the treatment of obtundation associated with spontaneous intracranial hypotension: technical case report. *Neurosurgery* 2002;51:830-6; discussion 36-7.
68. Farb RI, Nicholson PJ, Peng PW, et al. Spontaneous intracranial hypotension: a systematic imaging approach for CSF leak localization and management based on MRI and digital subtraction myelography. *AJNR Am J Neuroradiol* 2019;40:745-53.
69. Kranz PG, Gray L, Malinzak MD, Houk JL, Kim DK, Amrhein TJ. CSF-venous fistulas: anatomy and diagnostic imaging. *AJR Am J Roentgenol* 2021;217:1418-29.
70. Amrhein TJ, Gray L, Malinzak MD, Kranz PG. Respiratory phase affects the conspicuity of CSF-venous fistulas in spontaneous intracranial hypotension. *AJNR Am J Neuroradiol* 2020;41:1754-6.
71. Schievink WI, Maya MM, Jean-Pierre S, Moser FG, Nuno M, Pressman BD. Rebound high-pressure headache after treatment of spontaneous intracranial hypotension: MRV study. *Neurol Clin Pract* 2019;9:93-100.
72. American College of Radiology. ACR Appropriateness Criteria® Radiation dose assessment introduction. Available at: <https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf>. Accessed March 29, 2024.