ACR–ASNR–ASSR–SIR–SNIS PRACTICE PARAMETER FOR THE PERFORMANCE OF IMAGE-GUIDED EPIDURAL STEROID INJECTION

Adopted 2019 (Resolution 14)

The American College of Radiology, with more than 30,000 members, is the principal organization of radiologists, radiation oncologists, and clinical medical physicists in the United States. The College is a nonprofit professional society whose primary purposes are to advance the science of radiology, improve radiologic services to the patient, study the socioeconomic aspects of the practice of radiology, and encourage continuing education for radiologists, radiation oncologists, medical physicists, and persons practicing in allied professional fields.

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.

---

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 developed collaboratively by the American College of Radiology (ACR), the American Society of Neuroradiology (ASNR), the American Society of Spine Radiology (ASSR), the Society of Interventional Radiology (SIR), and the Society of NeuroInterventional Surgery (SNIS).

Interventional spine procedures comprise a broad spectrum of treatment techniques (eg, facet joint and sacroiliac joint injections, vertebral augmentation) that are beyond the scope of this manuscript. This document focuses on epidural steroid injections (ESIs), which are commonly performed for the nonsurgical treatment of neck and low back pain (LBP) after other conservative and noninvasive treatments, such as physical therapy and oral medications, have failed [1]. It is critical to determine appropriate utilization of ESI and to identify optimal techniques. An added challenge in evaluating spinal interventional techniques is that the practices of different specialties are highly variable even for the commonly performed procedures and treatable conditions.

Although numerous studies pertaining to all aspects of interventional pain management have been published, there is still some controversy concerning the effectiveness of ESIs because of the variability of the methods in various studies [2] (FDA Drug Safety Communication: FDA requires label changes to warn of rare but serious neurologic problems after epidural corticosteroid injections for pain. Available at: http://www.fda.gov/downloads/Drugs/DrugSafety/UCM394286.pdf). Additionally, there have been technical advances in procedures that enable precise needle placement to a 1- to 2-mm target zone in 3-D space with confirmation of placement with the flow of contrast prior to the administration of the medication distribution by real-time observation of contrast flow [3].

Injections are often done for diagnostic and therapeutic benefit. Local anesthetic injection provides information regarding whether the pain generator is coming from the targeted location (ESI, intra-articular facet, nerve root, etc). The main controversy surrounding these injections is the therapeutic benefit derived from the steroid component of the injectate.

After the U.S. Food and Drug Administration (FDA) issued a warning in April 23, 2014, that "injection of corticosteroids into the epidural space of the spine may result in rare but serious adverse events, including loss of vision, stroke, paralysis, and death" (https://www.fda.gov/Drugs/DrugSafety/), and a *Warning* was added to the drug labels of injectable corticosteroids to describe these risks. In response to this, an expert working group with facilitation from the FDA Safe Use Initiative and representatives from leading specialty societies reviewed the existing scientific evidence and assembled consensus clinical considerations aimed at reducing the risk of severe neurologic complications [4]. A review article by Manchikanti et al emphasized alternate techniques to traditional teachings, including avoidance of particulate steroids and utilization of a blunt needle, and understanding of the risk factors of approach, particularly transforaminal ESIs, to improve safety [5]. With ESIs, as with any invasive procedure, the optimal outcome for the patient is when the appropriate procedure is performed by qualified physicians with consideration of all risks and benefits.

A review of the literature was performed. When published data were felt to be inadequate, data from the expert panel members' own quality assurance programs were used to supplement. Thresholds for quality assurance have been updated in accordance with available data in the literature.

These practice parameters are intended to be used in quality improvement programs to assess ESI procedures. The most important processes of care are (1) patient selection, (2) performing the procedure, (3) monitoring the patient, and (4) appropriate patient follow-up. The outcome measures or indicators for these processes are indications, success rates, and complication rates.

II. DEFINITIONS

The epidural space is essentially continuous from the craniocervical junction to the second sacral segment [6], with some anatomic compartmentalization by dorsal median connective tissue [7]. It is filled with compressible fat and venous structures [8]. The epidural space can be accessed using different approaches (eg, caudal, interlaminar, and transforaminal). Once the needle is in the epidural space, the medication is injected and

epidurography with contrast media is usually performed to verify the proper needle position, and subsequently navigates cranially and caudally within the epidural space. ESIs are performed in the cervical and lumbar spine and less often in the thoracic spine.

Interlaminar ESI:

The epidural needle can be advanced in the midline between adjacent spinous processes or paramidline between the target laminae to traverse the ligamentum flavum and enter the dorsal epidural space. Although usually possible in all cases, in those patients with ossification of the supraspinous ligament or Baastrup disease, the paramidline approach may be preferred. Blunt-tip needles have been advocated for overall safety (eg, decrease risk of dural puncture [9]). Bevel tip orientation may result in inadvertent nonepidural needle penetration during fluoroscopically guided lumbar interlaminar ESI (ILESI), particularly if the needle is directed toward the superior lamina approach and the bevel tip is caudally orientated [10].

During an ILESI, inadvertent intrafacet injection [11] can occur because of needle entry into the retrodural space of Okada, an anatomic space located dorsal to the ligamentum flavum that allows communication between bilateral facet joints and the interspinous bursa at a single spinal level [12,13]. Needle entry into this space can mimic the loss of resistance normally felt during entrance into the epidural space. However, this nontarget delivery of medication results in decreased effectiveness of the procedure as the medication is not treating the intended pathology. The incidence of inadvertent intrafacet injection during attempted ILESI by using fluoroscopic guidance is reportedly 0.75% to 1.2% [14,15], which may be an underestimation, whereas that of ILESI performed under CT guidance is 7.5% [15]. Recognizing this false-positive position is important for redirection and appropriate needle tip placement. As such, CT-guidance can be of benefit in situations where conventional fluoroscopic guidance may be challenging or has proven unsuccessful.

The multispecialty FDA Safe Use Initiative Expert Working Group proposed that cervical ILESI be performed at C7-T1, which is based on reports that at other segmental levels the cervical epidural space is often narrow, making the dural sac and spinal cord more susceptible to penetration and injury [16-19].

Transforaminal ESI:

Although ESIs are effective in managing lumbar disc herniation regardless of the approach used (interlaminar, caudal, or transforaminal), the basic principle is to select the approach that will allow injection closest to the source of the pain. Corticosteroids delivered as close as technically feasible to the site of the lesion will generally obtain optimal results (and allows for lowest dose of medication for clinical effectiveness). The transforaminal approach for ESIs is a target-specific approach allowing maximal delivery of medication to the relevant nerve root. With this approach, the injectate flow is directed toward the anterior and lateral epidural space (ie, the inflammatory site between the herniated disc and the anterior nerve root dural sleeve), and may extend over 1 to 2 spinal levels [20,21]. For a lateralized lumbar disc herniation, a preganglionic transforaminal ESI (TFESI) (at the supra-adjacent intervertebral disc level or one level superior) is preferred by some over a paramidline interlaminar injection [22,23]. If there is migration of the disc, ganglionic TFESI (at the exiting nerve root level) may be useful [24].

In a lumbar TFESI, the needle may be placed in an intervertebral foramen via a subpedicular/supraneural or infraneural/retrodiscal approach. With the subpedicular approach, the needle is advanced inferior to the pedicle and superolateral to the spinal nerve of interest, toward the "safe triangle" [25]. The supraneural approach decreases risk of damage to the nerve, dorsal root ganglion, and dural sleeve [26,27]. The disadvantages of this approach include intraneural injection, neural trauma, technical difficulty in the presence of fusion and/or hardware, intravascular injection, intradiscal injection, and spinal cord trauma [28-35].

The infraneural/retrodiscal approach is an alternative TFESI trajectory using Kambin's triangle, which is defined as a right triangle over the dorsolateral disc [36]. In addition to avoiding epidural bleeding and scarring, the advantage of this approach is the decreased risk of intravascular penetration. Murthy et al. reported that the artery of Adamkiewicz (or artery) runs through the "safe triangle," and this may result in injection of medications within the artery or directly damage a feeding vessel [37]. By spinal angiography, the radiculomedullary artery is

located in the superior half of the intervertebral foramen in 97% of cases and is never seen in the inferior one-fifth of the intervertebral foramen [37]. The authors concluded that the safest needle placement for a TFESI, particularly at L3 and above, may be in an inferior and slightly posterior position within the foramen and relative to the nerve. Although there is decreased risk of injuring a radiculomedullary artery, this approach still carries 6.6% risk of vascular injections [38]. Although some authors have found the risk of inadvertent vascular injection during lumbosacral transforaminal injections comparable between blunt-tip and pencil-point needles [39], others have found that blunt needles had decreased incidence of vascular penetration and paresthesias [40]. Other risks of infraneural/retrodiscal TFESI include inadvertent intradiscal penetration (4.7%) [38,41] and subarachnoid or subdural extra-arachnoid injection (3.1%) [38].

In the cervical spine, a TFESI is performed by inserting the needle posteriorly along the neural foraminal axis, which avoids the anteriorly positioned vertebral artery and the intraforaminal spinal nerve. The interventionalist must be aware of spinal segmental arteries arising from the deep or ascending cervical artery, which enter at variable locations and often course through the foramen, penetrate the dura, and join the anterior and posterior spinal arteries. In addition to the risk of exiting nerve or vessel injury, injection of the particulate steroid directly into one of these vessels can lead to catastrophic spinal cord injury [4].

Given the potential of catastrophic neurologic complications after cervical TFESI, some authors have questioned the continued use of TFESI in this setting [42] and advocate interlaminar midline or paramidline approaches in the cervical spine regardless of disease categories or laterality of symptoms because of the overall safety of an interlaminar approach and possible greater patient comfort [24]. Choi et al found no statistically significant difference in symptom improvement between interlaminar and transforaminal approaches [43] and lower inadvertent vascular uptake and patient discomfort with the latter. Others advocate technical strategies to improve the safety of the procedure [44,45] or alternative approaches, which potentially carry fewer risks [42,46]. One such alternative is intra-articular facet steroid injections [46,47]. Anatomically, the facet joint ventral recess is in close proximity to the exiting spinal nerve root, and leakage of contrast into the foramen can be seen during a facet injection. Therefore, using a facet joint injection approach to deliver corticosteroids in the vicinity of the target spinal nerve root may be a viable alternative to the riskier transforaminal approach [46,48].

Selective nerve root block:

A selective nerve root block has a similar approach as a TFESI; however, the needle tip is not advanced as medially into the neural foramen. Rather, the goal of this approach is to cover the target nerve, particularly when isolated spinal nerve root irritation is suspected. Selective nerve blocks are often requested to provide more specific diagnostic information via delivery in a selective fashion [49].

Caudal ESI:

The epidural space is accessed via the sacral canal through the sacral hiatus coccygeal ligament using fluoroscopic guidance [50]. With the caudal/interlaminar route, the flow of injectate is predominantly into the posterior epidural space [20]. This is an alternative approach when transforaminal or interlaminar approaches are technically challening or contraindicated.

III. OVERVIEW

In the appropriate patient population, ESIs can improve mobility and function.

Multifactorial degenerative changes, such as herniated intervertebral disc material, thickening of the ligamentum flavum, and productive osteophyte formation along endplates and facet joints, are the leading cause of neck pain and LBP. A disc herniation may cause spinal nerve compression and inflammation, resulting in radicular pain [51]. The mechanical compression may result in nerve root microcirculatory changes, leading to ischemia, venous congestion, and inflammatory changes around nerve roots [52,53]. The ensuing intraneural edema and demyelination have been shown to be critical factors for the production of pain in association with nerve root compression [53]. There may also be a chemical radiculitis [54]. Because an inflammatory reaction is recognized as at least partly responsible for the irritation of the spinal nerve, corticosteroids are logically part of the treatment

armamentarium. The injected corticosteroids contribute to pain reduction by interrupting the synthesis of prostaglandins, blocking conduction of nociceptive C fibers, and controlling edema around the nerve root [55-59].

For radiculopathy, the AHRQ report found that the evidence slightly favored ESIs over placebo interventions in mean improvement of pain and in function at immediate-term (=2 weeks) follow-up and risk of surgery at short-term (>2 weeks to =3 months) follow-up [60]. However, there were no differences between ESIs and placebo interventions in likelihood of experiencing a successful pain, function, or composite outcome or likelihood of undergoing surgery in the long term [60]. There were no clear differential effects of the epidural approach used, different corticosteroids, different doses, use of imaging correlation, restriction to patients with herniated disc, duration of symptoms, or exclusion of patients with prior surgery. For spinal stenosis or nonradicular back pain treated with ESIs versus placebo interventions, the limited evidence showed no differences in outcomes related to pain or function [60]. Of note, the trials assessed used placebo interventions—such as epidural local anesthetic injection, epidural saline injection, soft-tissue injections, and no injection—and it is possible that these interventions may have had some therapeutic effects [61]. In addition, using different data points in different papers makes the literature less generalizable to the wider patient population. Other studies report that TFESIs and ILESIs are clinically effective for short-term and long-term relief of radicular pain and radiculopathy [51,62-64], although the paucity of high-quality randomized trials literature continues to confound the evidence.

The efficacy of ESIs is thought to be primarily due to the anti-inflammatory effect of the steroids by inhibiting phospholipase A1 and decreasing cell-mediated inflammation. Steroids may have additional effects: reversible local anesthesia [57,65-69], decreased transmission in unmyelinated C-fibers [70], diminished excess neurotransmitter release, dilution/dispersion of inflammatory compounds, alteration of the osmolality benefiting nerve function, suppression of the ectopic discharges from injured nerves, reduction of collagen formation/scarring, improvement of perfusion, and decreased capillary permeability/edema induced by herniated nucleus pulposus [65].

However, some studies have shown that epidural injections with or without steroids are efficacious in various spinal degenerative pathologies [5,71], suggesting that the mechanism of action of ESIs may not be the anti-inflammatory effect of the steroid as it is traditionally thought. Many corticosteroids activate not only the target glucocorticoid receptor (GR) but also the mineralocorticoid receptor, which may have proinflammatory effects countering the effects of GR activation [72]. A recent multicenter randomized controlled trial on ESI (interlaminar or transforaminal) for spinal stenosis, the largest trial (n = 386) to date in this population, found that epidural injection of glucocorticoids plus lidocaine offered minimal or no short-term benefit as compared with epidural injection of lidocaine alone [73]. Similarly, a long-term randomized, double-blind, active-control trial of 120 patients comparing lumbar interlaminar epidural injections of local anesthetic with a mixture of local anesthetic and steroids found that lumbar interlaminar epidural injections of local anesthetic with or without steroids provide relief in a significant proportion of patients with lumbar-central spinal stenosis at 2 years follow-up [74].

Preservative-free local anesthetic, often added to the steroid injectate, inhibits nerve excitation/conduction by blocking sodium channels, suppresses nociceptive transduction, and decreases release of proinflammatory cytokines. The anti-inflammatory effects also contribute to long-term pain relief [75]. Caution should be used with anesthetic in cervical TFESI as inadvertent intravascular injection of bupivacaine can lead to arteriole vasospasms and increases the risk of central nervous system infarction [75]. Local anesthetics and steroids may affect other pathophysiologic mechanisms of chronic pain, including noxious peripheral stimulation, excess nociception, resulting in the sensitization of the pain pathways at several neuronal levels, phenotype changes as part of neural plasticity, and excess release of neurotransmitters causing complex central responses, including hyperalgesia [74,76-83].

The neuromodulating effects of local anesthetics have been understudied and underappreciated. The mechanisms of pathological pain have been well demonstrated in the literature. The pathological and neurochemical milieu is different in acute nucleus pulposus rupture as compared to that in chronic spinal stenosis [84]. Cytokines and interferon-γ, among other proinflammatory agents, are not nearly as active in the nonacute setting. Anesthetics can mitigate neurotransmitter release at the sites of injury and inhibit the physiological cause of pain. Short-acting anesthetics are known to have a neuromodulating effect, possibly delaying or preventing the transition of acute pain into the chronic pain syndromes. The individual biology and psychological effects of pain clearly adds to the

different patient outcomes [85]. The role of local anesthetic in the postoperative patient has been studied as well and supports the concept of preventing acute migration into a chronic pain syndrome [86]. Rehabilitation after injections can also play an additive positive role. Such is the reason that multidisciplinary teams are necessary for the best outcomes, and most of the literature supports this integrative medicine.

The injected volume itself have analgesic effects, and higher volumes are associated with better outcomes [87,88]. The proposed mechanism may be that the injected fluid leads to the lysis of neural adhesions by means of stretching along the dura and nerve roots [89].

IV. INDICATIONS AND CONTRAINDICATIONS

Indications include, but are not limited to, the following:

1. Radiculopathy: complex of symptoms that can arise from nerve root pathology, including paresthesia, hypoesthesia, anesthesia, motor loss, and pain [90]; specific observable physical examination and electrophysiologic findings. Radiculopathy may be confined to a single nerve root distribution (mono-), or more than one (poly-).
2. Radicular pain: single symptom of pain that can arise from one or more cervical, thoracic, or lumbar spinal nerve roots [90], which are inflamed and irritated [91]; diagnosed by a combination of physical examinations (eg, straight leg test) and controlled selective nerve blocks. Radicular pain and radiculopathy that are due to nerve root compression from local malignancy may also be amendable by palliative treatment with ESIs.
3. Spinal stenosis: mechanical pressure on the spinal cord, dura, or nerve roots that is due to a multitude of degenerative causes; pain, numbness, or upper- or lower-extremity weakness have a gradual onset and improve with forward flexion, "shopping cart sign" [92]
4. Axial pain: symptoms exacerbated by forward flexion [92]; sources of axial LBP include the facet joint, sacroiliac joint, intervertebral disc, vertebral end plates, paraspinal muscles, and fascia. These various targets are beyond the scope of this document.
5. Postsurgery syndrome or failed back surgery syndrome (FBSS): residual or recurrent back pain and disability after surgical intervention, which reportedly accounts for up to 40% of patients with chronic LBP. It may be possible to manage some etiologies with interventional techniques, including epidural fibrosis, sacroiliac joint pain, disc herniation, discogenic pain, spinal stenosis, recurrent synovial cysts, seromas, other collections, and facet joint pain [93-100]. Caudal ESIs have been reported to be effective in managing FBSS [101,102], with long-term pain relief achieved by adding hyaluronidase [102].
6. Persistent/incomplete pain relief following vertebral augmentation (kyphoplasty, vertebroplasty).

Contraindications [103,104]: Prior to performing an interventional spine procedure, pre-existing conditions must be evaluated to avoid complications.

Absolute contraindications:

1. Coagulopathy not correctible
2. Concurrent systemic infection
3. Infectious spondylitis
4. Acute spinal cord compression
5. Myelopathy or cauda equina syndrome
6. Inability to obtain informed consent
7. Infection at the skin puncture site

Relative contraindications:

1. Uncorrected antiocoagulation therapy – ILESIs and TFESIs are considered intermediate-risk procedures with moderate risk of bleeding [105]
2. Hypersensitivity to administered agents – allergy to contrast may be treated with premedication with antihistamine agents or an alternative approach (such as using CT guidance with air as the contrast medium

may be considered.

3. Pregnancy – Although such interventions may be performed without image guidance in pregnant patients, there is a 30% rate of incorrect placement [106]. Other options include MRI-guided injections and ultrasound-guided injections as image-guided procedures have a significantly greater margin of safety and should be utilized when feasible [107].
4. Hepatitis – When performing neuraxial blockade in hepatitis C patients, thrombocytopenia must be excluded in order to avoid hematoma formation and its associated neurologic complications [108].
5. Uncontrolled diabetes mellitus- Insulin-dependent diabetics are at risk of elevated blood sugars after steroid injections.
6. Congestive heart failure – The steroid may lead to fluid retention
7. Immunosuppressed state- Preprocedural antibiotics may be considered
8. Patient improving on medical and physical therapy
9. Severe spinal canal stenosis
10. No response to previous well-performed ESI
11. Complication to steroid therapy (Cushings, etc)

Factors have been reported that negatively affect outcomes of ESIs: smoking, chronic pain syndrome, axial-only pain or diffuse pain, opioid dependence, and patients undergoing personal injury legal and disability claims [109].

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A. Physician

In general, the requirements for physicians performing image-guided ESI may be met by adhering to the recommendations listed below:

1. Certification in Radiology, Diagnostic Radiology, or Interventional Radiology/Diagnostic Radiology (IR/DR) by the American Board of Radiology, the American Osteopathic Board of Radiology, the Royal College of Physicians and Surgeons of Canada or the Collège des Médecins du Québec and has performed (with supervision) a sufficient number of ESI procedures to demonstrate competency as attested by the supervising physician(s).

   or

2. Completion of an approved residency or fellowship program 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 an American Osteopathic Association (AOA)–approved residency program and has performed (with supervision) a sufficient number of ESI procedures to demonstrate competency as attested by the supervising physician(s).

   or

3. A physician who did not successfully complete an ACGME-approved radiology residency or fellowship program that included the above may still be considered qualified to perform ESI provided the following can be demonstrated: the physician must have at least 1 year of experience in performing percutaneous image-guided spine procedures, during which the physician was supervised by a physician with active privileges in these spine procedures. During this year, he or she must have performed (with supervision) a sufficient number of image-guided spine interventional procedures, particularly ESIs as primary operator with outcomes within the quality improvement thresholds of this practice parameter.

   and

4. Physicians meeting any of the qualifications in 1, 2, or 3 above must have written substantiation that they are familiar with all of the following:

   a. Indications and contraindications for ESIs.

b. Periprocedural and intraprocedural assessment, monitoring, and management of the patient, and particularly the recognition and initial management of procedural complications.
c. Appropriate use and operation of fluoroscopic and radiographic equipment, digital subtraction systems, and other electronic imaging systems.
d. Principles of radiation protection, hazards of radiation, and radiation monitoring requirements, as well as principles of ALARA, as they apply to both patients and personnel.
e. Anatomy, physiology, and pathophysiology of the spine, spinal cord, and nerve roots.
f. Pharmacology of contrast agents and implanted materials and recognition and treatment of potential adverse reactions to these substances.
g. Technical aspects of performing this procedure. These include proper sterile techniques.

The written substantiation should come from the chief of interventional radiology, the chief of neuroradiology, the chief of musculoskeletal radiology, the chief of interventional neuroradiology, or the chair of the department of the institution in which the physician will be providing these services[1]. Substantiation could also come from a prior institution in which the physician provided the services, but only at the discretion of the current interventional, neurointerventional, or neuroradiology chief, or the chair who solicits the additional input.

and

5. Physicians must possess certain fundamental knowledge and skills that are required for the appropriate application and safe performance of ESIs:
    a. In addition to a basic understanding of spinal anatomy, physiology, and pathophysiology, the physician must have sufficient knowledge of the clinical and imaging evaluation of patients with spinal disorders to determine those for whom ESIs are indicated.
    b. The physician must fully appreciate the benefits and risks of epidural steroids and the alternatives to the procedure.
    c. The physician is required to be competent in the use of fluoroscopy, CT, and MRI or interpretation of images in the modalities used to evaluate potential patients and guide the epidural steroid procedure.
    d. The physician should be able to recognize, interpret, and act immediately on image findings.
    e. The physician must have the ability, skills, and knowledge to evaluate the patient's clinical status and to identify those patients who might be at increased risk, who may require additional perioperative care, or who have relative contraindications to the procedure.
    f. The physician must be capable of providing the initial clinical management of complications of ESIs, including administration of basic life support, initiation of treatment for cerebral/spinal cord ischemic injury, intrathecal anesthetic or steroid inadvertent injection, spinal fluid leaks, and recognition of spinal cord compression.
    g. Training in radiation physics and safety is an important component of these requirements. Such training is important to maximize both patient and physician safety. It is highly recommended that the physician has adequate training in and be familiar with the principles of radiation exposure, the hazards of radiation exposure to both patients and radiologic personnel, and the radiation monitoring requirements for the imaging methods listed above.

Maintenance of Competence

Physicians should perform a sufficient number of ESI procedures to maintain their skills, with acceptable success and complication rates as laid out in this practice parameter. Continued competence depends on participation in a quality improvement program that monitors these rates. Regular attendance at postgraduate courses that provide continuing education on diagnostic and technical advances in ESIs is necessary.

Continuing Medical Education

The physician's continuing education should be in accordance with the ACR Practice Parameter for Continuing Medical Education (CME) [110].

[1]At institutions in which there is joint (dual) credentialing across departments doing like procedures, this substantiation of experience should be done by the chairs of both departments to ensure equity of experience among practitioners when their training backgrounds differ.

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

B. Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently one or more of the subfields in medical physics. The American College of Radiology (ACR) considers certification, continuing education, and experience in the appropriate subfield(s) to demonstrate that an individual is competent to practice one or more of the subfields in medical physics and to be a Qualified Medical Physicist. The ACR strongly recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR), the Canadian College of Physics in Medicine, the American Board of Science in Nuclear Medicine (ABSNM), or the American Board of Medical Physics (ABMP).

A Qualified Medical Physicist should meet the ACR Practice Parameter for Continuing Medical Education (CME). [110]

The appropriate subfield in medical physics for this practice parameter is Diagnostic Medical Physics (previous medical physics certification categories including Radiological Physics, Diagnostic Radiological Physics, and Diagnostic Imaging Physics are also acceptable). (ACR Resolution 17, adopted in 1996 – revised in 2008, 2012, 2022, Resolution 41f)

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

C. 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).

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

D. Radiologic Technologist

The technologist, together with the physician and the nursing personnel, should be responsible for patient comfort. The technologist should be able to prepare and position the patient for the ESI procedure. The technologist should obtain the imaging data in a manner prescribed by the supervising physician. The technologist should also perform regular quality control testing of the equipment under the supervision of the Qualified Medical Physicist.

The technologist should have appropriate training and experience in the ESI procedure and be certified by the American Registry of Radiologic Technologists (ARRT) and/or have an unrestricted state license.

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

E. Nursing Services

Nursing services are an integral part of the team for perioperative patient management and education and assist the physician in monitoring the patient during the ESI procedure, particularly if conscious sedation is given.

VI. SPECIFICATIONS OF THE PROCEDURE

Technical Requirements

VI. SPECIFICATIONS OF THE PROCEDURE

A. Guidance

1. No image guidance: Historically, ESIs were performed without any imaging guidance, resulting in erroneous placement in up to 30% of injections [106]. Because of this and the potential for intrathecal and intravascular injections, image guidance is strongly recommended for spine interventions.

2. Fluoroscopic guidance: According to the multi-specialty FDA Safe Use Initiative Expert Working Group, image guidance for all cervical and lumbar interlaminar injections is recommended to avoid inadvertent spinal cord penetration, intra-vascular, or intrathecal placement. Lateral or oblique views are recommended to gauge depth of needle insertion [4]. Fluoroscopic guidance allows accurate needle placement when combined with contrast medium injection [106,111,112]. Both C-arm and bi-plane fluoroscopy provide multiplanar imaging of the target anatomy, which can help reduce procedural time [113] and are important to perform the procedure safely.

3. CT/CT fluoroscopic guidance (CTF): CT guidance and CT-fluoroscopic guidance is being increasingly used for various procedures, including biopsies, drainages, ESIs and TFESIs, as this allows for highly accurate needle guidance. CT guidance delineates the soft tissue (eg, nerve, vessels, dura, fat, and muscle) and osseous structures unlike fluoroscopic guidance which only provides visualization of bony landmarks. Radiation dose to the patient and interventionalist can be minimized with the use of intermittent fluoroscopy and a low mA [114-116]. Additionally, modification of planning CT can reduce the radiation exposure in CTF lumbar spine injections [117]. CTF guidance enables real-time cross-sectional visualization of needle placement into the epidural space to avoid neural and vascular structures as well as osseous structures, particularly when there is spinal stenosis or interlaminar narrowing [118]. In addition, CT and CTF enable the evaluation of spinal canal and paraspinal regions before insertion of the needle, to permit diagnosis of synovial cysts or cysts of the ligamentum flavum, severe spinal stenosis, epidural scarring and postoperative thecal sac deformity in patients, which may be potential causes of inaccurate needle placement or procedure failure. CTF is the recommended approach for cervical ESI.

   The overall radiation dose from CTF is small compared with a diagnostic CT scan. Tube current selection for CTF procedures ideally balances the need for adequate anatomic visualization against the desire for individual patient dose reduction. Patient body habitus affects the radiation dose from such procedures; decreasing body size results in increases in organ dose during CTF-guided interventions. Therefore, small patients should have tube current reduced compared to average patients to avoid relatively increased organ dose. Tube current of 30 to 40 mA is adequate for lumbar interventions in most average sized patients. Modified tube current settings of 10 to 20 mA and 50 to 70 mA would be appropriate for small and oversized patients, respectively [119]. However, dose considerations must not supersede the need for adequate anatomic visualization sufficient to allow for technical success and to minimize procedural complications.

4. Ultrasound (US): Ultrasonography is highly effective in accurately guiding the epidural needle placement and produces comparative treatment outcome as fluoroscopy [50]. US-guidance offers the advantages of delineating vessels in the needle trajectory [120] and no radiation exposure. However, US has significant limitations based on body habitus and pathology, and operator dependent skills, and is typically not used for performing these procedures.

VI. SPECIFICATIONS OF THE PROCEDURE

B. Technique

With conventional fluoroscopy, the loss of resistance technique is used to determine if the needle is in the epidural space after traversing the ligamentum flavum in ILESI. However, this technique can be unreliable, compared with use of injections of contrast material [121-124]. To confirm needle placement in the epidural space, a dose of contrast agent is injected (1 to 5 mL). Myelographically safe contrast is used in case there is inadvertent intrathecal injection. Contrast is advocated in TFESIs, in particular, because of the increased risk of intravascular injections [31]. Intravascular uptake is reported at a rate of 8% for all lumbar injections, 2% for ILESI, 11% for TFESI, and 21% for TFESI at the S1 level [125]. Negative aspiration will fail to detect intravascular penetration ~50% of the time [31]. Some authors have cautioned that the lack of vessel opacification after contrast administration during a spine intervention with CT/CTF guidance may give a false sense of security [126] because it may be that intravascularly injected contrast is washed away by the time CT is performed and/or that the given vessel enters the cord at a different level and is therefore not imaged [127]. This may be a theoretical disadvantage of CT/CTF. To reliably exclude inadvertent direct vessel puncture, some have advocated real-time imaging with digital subtraction angiography when performed with fluoroscopy [128-130].

In patients that have had a severe or anaphylactic reaction to contrast media, CO_2 air can be used in the same way as iodinated contrast. Air can be injected to verify that the needle is within the epidural space and not intrathecal. Although air can be used with conventional fluoroscopy, CT-guidance provides exquisite discrimination between air and soft-tissue [131].

The choice of image guidance is a matter of operator preference and patient characteristics. In either case, there are several technical requirements to ensure safe and successful ESIs. These include adequate institutional facilities, imaging and monitoring equipment, and support personnel. The following are minimum requirements for any institution in which interventional spine pain management procedures are to be performed:

a. A procedural suite large enough to allow safe and straightforward transfer of the patient from bed to procedural table with sufficient space for appropriate positioning of patient monitoring equipment, anesthesia equipment, respirators, etc. There should be adequate space for the operating team to work unencumbered on either side of the patient and for the circulation of other staff within the room without contaminating the sterile conditions.
b. The majority of these procedures are performed under fluoroscopic guidance. A high-resolution image intensifier or flat-panel detector and video system with adequate shielding, capable of rapid imaging in orthogonal planes and with capabilities for permanent image recording is strongly recommended. The fluoroscope should be compliant with IEC 601-2-43 [132]. Imaging findings are acquired and stored either on conventional film or digitally on computerized storage media. Imaging and image recording must be consistent with the "as low as reasonably achievable" (ALARA) radiation safety guidelines.
c. The facility must provide adequate resources for observing patients during and after spine pain interventional procedure. Physiologic monitoring devices appropriate to the patient's needs—including blood pressure monitoring, pulse oximetry, and electrocardiography—and equipment for cardiopulmonary resuscitation must be available in the procedural suite.

VI. SPECIFICATIONS OF THE PROCEDURE

C. Medications

1. Steroids

The steroids used in ESIs may be particulate versus nonparticulate preparations, which is based on the solubility of the synthetic corticosteroids within water and on their aggregation characteristics. Particulate corticosteroids, such as triamcinolone acetonide, triamcinolone hexacetonide, methylprednisolone acetate, and prednisolone acetate, are esters and can precipitate out of solution and crystallize within a hydrophilic environment. Most of the particles range in size between 0.5 and 100 μm [133]. Particulate steroids have a delayed but sustained anti-inflammatory effect [134]. In contrast, nonparticulate steroids dissolve immediately and are taken up rapidly by cells [134]. Dexamethasone sodium phosphate, a non-particulate steroid with a typical particle size of 0.5 μm [56,75,133], is freely water soluble. Betamethasone preparations are commonly a mixture of betamethasone acetate (insoluble needing esterase activation) and betamethasone sodium phosphate (in solution) and have

characteristics of both particulate and nonparticulate steroids [56,75,133].

The propensity of different corticosteroid particles to aggregate into larger particles depends on the chemical ingredient (esters have larger particulate size), on the varying concentrations, on the drug vehicle, or on the drug mixtures with local anesthetics and/or contrast media prepared in situ for pain treatment [75]. These aggregates, particularly the larger particle sizes, have the potential to embolize with risk for occlusion of small vessels and subsequent neural ischemic injury [135]. Of the different steroids used for ESIs, dexamethasone sodium phosphate is considered safer because its particles have been shown to be the smallest size, approximately one-tenth the size of a red blood cell, and the particles do not aggregate, even in mixtures [56,135]. Given this pharmacokinetic profile, the multispecialty FDA Safe Use Initiative Expert Working Group has recommended dexamethasone as the first-line agent for lumbar transforaminal injections rather than particulate steroids [4], which have been implicated in all cases of severe neurologic complications. However, there has been a case of conus medullaris infarction after TFESI using dexamethasone [136].

Although it may be speculated that patients obtain longer lasting relief of symptoms after epidural injection of particulate steroids compared with nonparticulate steroids, the literature is not strongly supportive of this at this time. The particulate nature and the added preservatives in the particulate mixtures pose the additional risk of intravascular emboli. Therefore, especially in the cervical spine, nonparticulate steroids are considered the safest. Recently, nonparticulate steroids (dexamethasone) have also been shown to have fewer systemic effects compared with particulate steroids in which suppression of the pituitary axis can occur for up to 3 weeks [137].

The differences in steroid doses and the effectiveness of various types have been evaluated in multiple observational studies. Methylprednisolone acetate, available in 40- and 80-mg/mL doses, and triamcinolone are equivalent [138] with relative strength approximately 5 times that of hydrocortisone. Bethamethasone combines a short- and long-acting form and has approximately 30 times the strength of hydrocortisone. A minimal effective dose of corticosteroid is recommended to expose the patient to the least adverse effects. For example, a study comparing 40 and 80 mg of methylprednisolone found comparable results, with a less adverse profile with the 40-mg dosage [139]. Similarly, there was equivalency of 10, 20, and 40 mg of triamcinolone in TFESI for lumbar radicular pain that was due to a herniated disc, such that the 10-mg dose was recommended by the authors [140].

There are numerous studies suggesting timing and frequency for ESI. A systematic review of literature by Manchikanti et al provides guidelines for frequency of interventions, regardless of approach [80]. The evidence is scanty for repeated injections at regular intervals if there is partial response to the initial ESI. Resolution of pain does not warrant a second injection.

Preservative-free local anesthetics inhibit nerve excitation and conduction. Local anesthetics act mainly through inhibition of sodium-specific ion channels on neuronal cell membranes, preventing the development of an action potential in the neuron, thus inhibiting signal conduction. They are administered to induce cutaneous analgesia at the time of a procedure and are also given for local relief at sites of spinal and musculoskeletal pain. Local anesthetics are often administered in conjunction with corticosteroids both as a diagnostic tool but also to provide the patient with immediate relief of symptoms.

There are two groups of local anesthetics: esters (eg, cocaine and procaine) and amides (lidocaine, bupivacaine, ropivacaine). The ester preparations are associated with a risk of severe allergic reactions secondary to the breakdown product paraaminobenzoic acid, whereas true allergic reactions are much less common with amide preparations. Increasing the dose of administered local anesthetic increases the degree of anesthesia and duration of action but does not change the time of onset of anesthesia. Nearly all these preparations can be formulated with epinephrine to prolong their duration of action by approximately 50% [141].

A review of corticosteroids and local anesthetics by MacMahon et al. [75] provides an overview on the potencies of local anesthetics used in spine interventions. Lidocaine is approximately half as potent as bupivacaine. Although lidocaine has a quicker onset, it has a shorter duration of action than does bupivacaine. Ropivacaine is similar in potency to bupivacaine. The most commonly administered local anesthetic in spine procedures is bupivacaine because of its greater potency and longer duration of action as compared with lidocaine. Typical doses of bupivacaine range from 0.5 to 2.0 mL in concentrations of 0.25% or 0.50%. Recommendations for maximum

doses, although not evidence based, are meant to prevent toxicity. The maximum dose of lidocaine is 300 mg, and if there is added epinephrine, then the maximum dose increases to 500 mg. For bupivacaine, the maximum safe dose is approximately 150 mg (2 mg/kg) and that for ropivacaine is 375 mg. It is important to note that the plasma concentration of the anesthetic is affected by the site of injection, which is not taken into account by these doses.

SPECIFICATIONS OF THE PROCEDURE

Surgical and Emergency Support

Although serious complications of ESIs are infrequent, there should be prompt access to advanced imaging for diagnosis, surgical, interventional, and medical management of complications.

VI. SPECIFICATIONS OF THE PROCEDURE

A. Patient Care

1. Preprocedural care
    a. The clinical history and findings, including the indications for the procedure, must be reviewed and recorded in the patient's medical record by the physician performing the procedure. Specific inquiry should be made with respect to relevant medications, prior allergic reactions, and bleeding/clotting status. Refer to multisociety guidelines for interventional spine procedures in patients on antiplatelet and anticoagulant medications [147].
    b. The vital signs and the results of physical and neurological examinations may be obtained and recorded.
    c. The indication(s) for the procedure, including (if applicable) documentation of 6 weeks of physical therapy and failed medical therapy, must be recorded.
    d. Preprocedure imaging should be reviewed.
    e. Informed consent obtained prior to any sedation
    f. A formal "time out" and verification of the correct patient, along with a checklist introducing each member of the team, correct patient, correct consent, marking of site, anticipated blood loss, fire risk, medications, imaging, etc, is mandated to ensure proper patient site and location

Preprocedure imaging assessment of the posterior epidural space is important to determine that there is sufficient epidural space at the target segmental level to allow safe needle placement. Contents of the epidural space include the epidural fat, spinal nerves, extensive venous plexuses, lymphatics, and connective tissue (eg, plica mediana dorsalis and scar tissue after previous surgical intervention). The amount of posterior epidural fat increases with caudal progression, measuring approximately 0.4 mm at C7 to T1, 7.5 mm in the upper thoracic spine, 4.1 mm at the T11 to T12, and 4 to 7 mm in the lumbar regions [148,149]. Age and body weight affect the amount of posterior epidural fat [150,151], which decreases with age. Epidural lipomatosis (ie, excessive hypertrophy and abnormal accumulation of epidural fat) may also be seen with long-term exogenous steroid use, obesity, and ESIs.

There are important indications for reviewing imaging prior to performing an ESI. Although the randomized controlled trial by Cohen et al found that MRI does not improve outcomes in patients who are clinical candidates for ESI and has only a minor effect on decision making [152], cross-sectional imaging, particularly MRI, is helpful to exclude "red flags," such as fracture, tumor, and instability, which would be unsafe conditions for injections. Secondly, MRI may help decide whether a patient will benefit from an ESI and improve outcomes by delineating the site of pathology for appropriate targeting [153]. A retrospective observational study examining the associations between imaging characteristics of compressive lesions and patient outcomes after lumbar TFESI found more favorable outcomes for disc herniations over fixed lesions and single lesions more than tandem lesions [154]. In a small prospective study of 34 patients with degenerative lumbar stenosis confirmed by MRI who received fluoroscopically guided lumbar TFESI at the presumed symptomatic nerve root, 75% had > 50% reduction in pain scores between pre- and postinjection at 1-year follow-up [26]. In patients with radiculopathy that is due to multilevel stenosis, MRI may steer one toward surgery or other treatment options rather than ESI. Lastly, MRI reveals features, such as central and foraminal stenosis, disc herniations that compromise canal diameter,

ligamentum flavum hypertrophy, epidural fibrosis, and previous surgical scaring that can alter the level of procedural difficulty [155]. Previous surgical and epidural interventions (eg, epidural blood patch) at the targeted level may also alter the epidural space and surrounding tissue. The resulting inflammatory changes can cause connective tissue proliferation and adhesions between the dura mater and the ligamentum flavum and granulation changes in the ligamentum flavum [156].

2. Procedural Care
    a. Prior to the initiation of the procedure, a time-out verifying the correct patient, correct procedure and correct site must be performed. The organization should have processes and systems in place for reconciling differences in staff responses during the time-out.
    b. The multispecialty FDA Safe Use Initiative Expert Working Group recommends extension tubing after needle placement in a safe location to avoid dislodging it when syringes are connected [4]. As per guidelines of aseptic technique, face masks and sterile gloves should be worn [157].
    c. Vital signs may be obtained at regular intervals during the course of the procedure depending on the preference of the interventionalist, and a record of these measurements should be maintained.
    d. Some interventionalists may prefer that patients have intravenous access in place for the administration of fluids and medications as needed.
    e. Monitoring of vital signs and pulse oximetry is recommended whether or not sedation is being given for the ESI procedure. Administration of sedation for ESI should be in accordance with the ACR–SIR Practice Parameter for Sedation/Analgesia [158]. A registered nurse or other appropriately trained personnel should be present and have primary responsibility for monitoring the patient. A record of medication doses and times of administration should be maintained. For cervical procedures, heavy sedation or unresponsiveness at the time of injection is not recommended [4]. Analysis of closed claims has revealed that cervical procedures under heavy sedation are significantly associated with an increased risk of spinal cord injury [159]. There is agreement by all societies that sedation should be light enough to allow the patient to communicate pain or other adverse sensations or events during the procedure, especially when performed in the cervical region [4].

3. Postprocedural Care
    a. A procedural note should be written in the patient's medical record summarizing the course of the procedure and what was accomplished, any immediate complications, and the patient's status at the conclusion of the procedure (see complications section below). This information should be communicated to the referring physician in a timely manner.
    b. All patients should be monitored after the procedure by skilled nurses or other appropriately trained personnel. The length of this period will depend on the patient's medical condition and is at the discretion of the performing physician.
    c. Initial ambulation of the patient must be carefully supervised.
    d. The operating physician or a qualified designee (another physician or a nurse) should evaluate the patient after the initial postprocedural period, and these findings should be summarized in a progress note on the patient's medical record. The physician or designee must be available for continuing postprocedural care at the facility and after discharge. Follow-up visits should be arranged prior to the patient leaving the facility.

VII. EQUIPMENT QUALITY CONTROL

Each facility should have documented policies and procedures for monitoring and evaluating the effective management, safety, and proper performance of imaging and interventional equipment. The quality control program should be designed to maximize the quality of the diagnostic information. This may be accomplished as part of a routine preventive maintenance program.

VIII. QUALITY IMPROVEMENT AND DOCUMENTATION

A. Documentation

Results of ESI procedures should be monitored on a continuous basis. Records should be kept of both immediate results and complications by the physician performing the procedure. If the patient is seen in follow-up, long-term results should be recorded. The number and type of complications should be documented. A permanent record of ESI procedures should be maintained in a retrievable image storage format.

1. Imaging labeling should include permanent identification containing:
    a. Facility name and location
    b. Examination date
    c. Patient's first and last names
    d. Patient's identification number and/or date of birth.

2. Separate preprocedure and postprocedure notes should include:
    a. Procedure undertaken and its purpose
    b. Type of anesthesia used (local or moderate)
    c. Listing of level(s) treated and amount of medication (contrast, steroid, and local anesthetic) injected at each level
    d. Evaluation of injection site and focused neurologic examination
    e. Immediate complications, if any, including treatment and outcome
    f. Radiation dose estimate (or fluoroscopy time and the number of images obtained on equipment that does not provide direct dosimetry information) [160-162]

3. Follow-up documentation:
    a. Postprocedure evaluation to assess patient response (pain relief, mobility improvement). Standardized assessment tools, such as the Visual Analog Scale, Short Form (36) Health Survey, and the Roland-Morris disability scale, may be useful for both preoperative and postoperative patient evaluation
    b. Evaluation of injection site and focused neurologic examination
    c. Delayed complications, if any, including treatment and outcome
    d. Record of communications with patient and referring physician
    e. Patient disposition

Reporting should be in accordance with the ACR–SIR–SPR Practice Parameter for the Reporting and Archiving of Interventional Radiology Procedures [163].

VIII. QUALITY IMPROVEMENT AND DOCUMENTATION

B. Informed Consent and Procedural Risk

Informed consent or emergency administrative consent must be obtained and must comply with the ACR–SIR–SPR Practice Parameter on Informed Consent for Image-Guided Procedures [164].

Risks cited may include, but are not limited to, infection, bleeding (including epidural hematoma), allergic reaction, vessel injury, worsening pain or paralysis, spinal cord or nerve injury, arachnoiditis, or death. The potential need for immediate surgical intervention should be discussed. The possibility that the patient may or may not experience significant pain relief should also be discussed.

VIII. QUALITY IMPROVEMENT AND DOCUMENTATION

C. Success and Complication Thresholds

Procedure thresholds or overall thresholds, for example, major complications, may be used as part of ongoing quality assurance programs. When measures such as indications or success rates fall below a minimum threshold or when complication rates exceed a maximum threshold, a review should be performed to determine causes and to implement changes if necessary. For example, if the incidence of infection is one measure of the quality of ESI, values in excess of the defined threshold (1% to 2%) [125] should trigger a review of policies and procedures

within the department to determine the causes and to implement changes to lower the incidence of the complication. Patient referral patterns and selection factors may dictate a different threshold value for a particular indicator at a particular institution. Therefore, setting universal thresholds is very difficult, and each department is urged to alter the thresholds as needed to higher or lower values to meet its own quality assurance program needs.

Complications can be stratified on the basis of outcome. Major complications result in admission to a hospital for therapy (for outpatient procedures), an unplanned increase in the level of care, prolonged hospitalization, permanent adverse sequelae, or death. Minor complications result in no sequelae but may require nominal therapy or a short hospital stay for observation (generally overnight); for further information, see the Proposal of a New Adverse Event Classification by the Society of Interventional Radiology Standards of Practice Committee) [165]. Routine tracking and periodic review of all cases having less than perfect outcomes is strongly encouraged. Although serious complications of ESIs are infrequent, a review for all instances of infection, significant bleeding, symptomatic nerve injury, or death, is recommended.

Success

When an ESI is performed, success is defined as achievement of significant pain relief, reduced disability, and/or improved quality of life. These should be measured by at least one of the relevant and validated measurement tools, such as the ten-point numerical pain rating scale score or a visual analogue scale score (Roland-Morris Back Pain score, Oswestry Disability Index, The Short Form (36) Health Survey, or similar outcome tool to measure pain, disability, and/or quality of life). It is generally accepted that a minimum of 20% change in pain scores is clinically meaningful, based upon previous trials and FDA requirements [166,167]. However, interventional pain management trials have adopted robust outcome measures defined as significant improvement with at least 50% improvement in pain and functional status rather than 10% or 20% improvement [101,168-186].

Complications

Despite its acceptance as a relatively safe procedure, an ESI is not without risk [187,188]. ESIs can be associated with a number of minor, temporary complications and side effects, such as exacerbation of pain, vasovagal reaction, headache, and unintentional dural puncture, [29,189-193]. Vasovagal syncope occurs in 1% to 2% of lumbar ESI and 8% with cervical ESI [194]. Flushing can occur in 2.6% to 11% of patients undergoing ESIs [195-198]. Transient weakness and numbness may be related to the local anesthetic (eg, lidocaine).

Arachnoiditis

Although arachnoiditis has frequently been cited as a potential complication of ESI, there is actually no direct evidence to support this premise. The arachnoid villi allow microscopic communication between the subarachnoid and epidural spaces. In addition, macroscopic communications may pre-exist or be created by prior surgery. Inadvertent subarachnoid drug injection may occur via these routes or by improper needle placement. Thus, it has been postulated that subarachnoid injection of glucocorticoids may occur during ESI and thereby lead to the development of arachnoiditis. Published references to the potential development of arachnoiditis after ESI are based upon historic reports of patients developing arachnoiditis after receiving intrathecal methylprednisolone injections for the treatment of multiple sclerosis [199,200]. Arachnoiditis was not, however, reported in a large and more recent series of patients treated for herpetic neuralgia by intrathecal methylprednisolone injection [201]. Multiple large series of patients treated with ESI have not reported arachnoiditis as a complication [55,202]. Preservatives in the glucocorticoid solution, such as polyethylene glycol and benzyl alcohol [134,203,204], have also been questioned as potential cause of arachnoiditis, but direct causation has never been proven.

In contrast to intrathecal glucocorticoids, spinal surgery and subarachnoid hemorrhage are well documented as potential causes of arachnoiditis [205,206]. Arachnoiditis developing after a single lumbar puncture without any other known cause has also been reported [207]. Some of the patients treated for multiple sclerosis with intrathecal methylprednisolone received in excess of fifty such injections, and these injections were performed long before image guidance became widely used. It seems reasonable to conclude that iatrogenic subarachnoid hemorrhage occurred in at least some of these patients and that such hemorrhage might have caused

arachnoiditis [199,200]. Notable by its absence is "arachnoiditis" among the multiple specific warnings for ESI mandated by the FDA [208]. The FDA does acknowledge 41 submitted reports of arachnoiditis allegedly occurring after ESI [209] but concluded that these reports "did not provide sufficient clinical detail to make a reasonable assessment regarding causality." We were unable to identify any published report of arachnoiditis occurring after ESI in the absence of contemporaneous spinal surgery or subarachnoid hemorrhage.

Bleeding

Spinal hematoma is a rare but serious complication following epidural puncture (incidence less than 1:150,000) [210,211]. The pressure effects of epidural hematoma can lead to compression and/or ischemia of the spinal cord and/or nerve roots [212]. Particular care is needed in individuals with coagulopathy either from intrinsic medical problems or due to medication. There is a risk of 0.0% to 0.4% for hemorrhagic complications when continuing anticoagulants and 0.0% to 0.6% when continuing antiplatelet medications [213,214]. The risk of hemorrhagic complications in anticoagulated patients undergoing ILESIs [215-221] may not be the same for lumbar TFESI. As there may actually be more risk in discontinuing anticoagulants, thus increasing the risk for vascular or cerebrovascular events, the benefits and risks of an ESI should be considered on an individual patient basis and after discussion with the clinician prescribing the anticoagulant [188,222].

Infection

Even with the use of proper sterile technique, infection can occur with spine interventions. Goodman et al noted an infection rate of 1% to 2%, with severe infections noted in 0.01% of all spinal injections, varying among meningitis, epidural abscess, osteomyelitis, and discitis [125].

Vascular Injury

The penetrating needle may cause vascular dissection. Embolic occlusion of a vessel with steroid aggregates, the majority of which are the particulate type, may occur. A rare, devastating complication of cervical and lumbar ESIs is spinal cord infarction, which is hypothesized to be due to embolization of particulate steroids, needle-induced vasospasm, compression from an epidural hematoma or abscess, and mechanical disruption of radiculomedullary arteries [56,223-225]. Preservatives, such as benzyl alcohol, in commercial preparations may be neurotoxic with reports of paraplegia, neural degeneration, and demyelination [226-229].

Nerve Injury

A theoretical risk of ESIs is nerve injury by the procedural needle. Intraneural hematoma may occur from puncture of the nerve root with the needle. Intraneural injection of the medication can be neurotoxic. An awake patient will be able to notify the interventionalist if the needle tip is too close to the nerve.

Dural Puncture

Dural puncture may occur, particularly with ILESI. The incidence of dural puncture in a prospective, observational study of 10,000 procedures was 0.5%, with 1% in the cervical region [202]. Intrathecal injection of local anesthetic may result in variable levels of spinal block. Intrathecal injection in the cervical region may lead to respiratory depression; therefore, appropriate equipment should be readily available to treat the patient. As stated previously, the effects of intrathecal injection of corticosteroid remain of uncertain significance.

Systemic Effects

Corticosteroid therapy can have systemic effects, such as bone loss and osteoporosis [230]. This steroid effect on bone health is particularly concerning in patients with predisposition to osteoporosis, such as postmenopausal women, receiving ESIs. Retrospective evaluation of postmenopausal women with LBP who were treated with or without ESI showed decreased bone mineral density (BMD) in patients treated with ESI. However, there was no significant difference between or within the groups in terms of mean percentage change from baseline BMD [231]. These authors concluded that a maximum cumulative triamcinolone dose of 200 mg in one year would be a safe treatment method with no significant impact on BMD. Kim and Hwang showed that multiple ESIs with a

cumulative triamcinolone dose of approximately 400 mg can reduce BMD in postmenopausal women treated for LBP [232]. Underlying patient characteristics may be an important factor in developing osteoporotic fracture or lower BMD post-ESI. Yi et al found that older age and lower BMD were associated with osteoporotic fracture in postmenopausal women treated for LBP with ESI [233].

The effect of steroids used in spine procedures remains controversial, with some studies showing that patients treated with high-dose glucocorticoid therapy are at risk for lower BMD [230,234,235], whereas others find no change with low-dose administration of neuraxial steroids [33]. A retrospective cohort study comparing patients receiving lumbar ESIs with a control group showed that an increasing number of injections was associated with an increasing likelihood of fractures. Each successive injection increased the risk of fracture by 21% [236]. A recent analysis of the Medicare data revealed that although acute exposure to exogenous steroids via the interlaminar or transforaminal epidural space does not seem to increase the risk of an osteoporotic fracture (spine, hip, or wrist), the prolonged steroid exposure was found to increase the risk of spine fracture for ESI patients [237].

The steroids in ESIs can have endocrinological effects. They can increase blood glucose levels in diabetic patients for 2 to 3 days after an ESI [238-240]. Similarly, ESIs can suppress the hypothalamic-pituitary-adrenal (HPA) axis for up to 3 weeks [241,242]. Maillefert et al found decreased serum cortisol, Adrenocorticotropic hormone (ACTH), and urinary cortisol after the single epidural injection of 15 mg of dexamethasone acetate [243]. The levels returned to normal at day 21. This effect may be dose dependent. Hsu et al found that a single epidural injection of 40 mg of triamcinolone markedly decreased plasma cortisol for only 24 hours, whereas 80 mg resulted in a decrease for up to 14 days posttreatment; HPA axis function returned to normal within 35 days in both groups [244]. A recent article demonstrated fewer systemic effects (ie, suppression of the pituritary axis for up to 3 weeks) with dexamethasone compared with particulate steroids [137].

Less common side effects have included elevated temperature, euphoria, depression, mood swings, transient changes in sleep pattern, local fat atrophy, depigmentation of the skin, and pain flare [187]. Several authors have reported cases of symptomatic epidural lipomatosis following epidural injections of corticosteroids [245-250]. Insomnia (39%), facial erythema (20%), nausea (20%), and rash and pruritus (8%) have been observed following betamethasone injection [187]. Finally, ESIs does not induce weight gain [251].

IX. 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).

X. 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/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

XI. ACKNOWLEDGEMENTS

This practice parameter was developed according to the process described under the heading The Process for Developing ACR Practice Parameters and Technical Standards on the ACR website (https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards) by the Committee on Practice Parameters – Neuroradiology of the ACR Commission on Neuroradiology, in collaboration with the ASNR, the ASSR, the SIR, and the SNIS.

Writing Committee – members represent their societies in the initial and final revision of this practice parameter

ACR

Lubdha M. Shah, MD, Chair

Wende N. Gibbs, MD

John E. Jordan, MD, MPP, FACR

ASNR

Bassem A. Georgy, MD

A. Orlando Ortiz, MD, MBA, FACR

Kent B. Remley, MD

ASSR

John D. Barr, MD, FACR

Daniel T.D. Nguyen, MD

Jeffrey A. Stone, MD, FACR

SNIS

Kristine A. Blackham, MD

Allan L. Brook, MD, FACR

Joshua A. Hirsch, MD, FACR

Committee on Practice Parameters – Neuroradiology

(ACR Committee responsible for sponsoring the draft through the process)

Raymond K. Tu, MD, FACR, Chair

Kristine A. Blackham, MD

Brian A. Conley, MD

Kavita K. Erickson, MD

Adam E. Flanders, MD

H. Simms Hardin, IV, MD

Steven W. Hetts, MD

John E. Jordan, MD, MPP, FACR

Jacqueline C. Junn, MD

Robert J. McDonald, MD

Alexander M. McKinney, IV, MD

David M. Mirsky, MD

Robin J. Mitnick, MD, FACR

Lubdha M. Shah, MD

Max Wintermark, MD

Alexander M. Norbash, MD, FACR, Chair, Commission on Neuroradiology

Jacqueline Anne Bello, MD, FACR, Chair, Commission on Quality and Safety

Matthew S Pollack, MD, FACR, Chair, Committee on Practice Parameters and Technical Standards

Mary S. Newell, MD, FACR, Vice Chair, Committee on Practice Parameters and Technical Standards

Comments Reconciliation Committee

Catherine J. Everett, MD, MBA, FACR, Chair

Daniel Ortiz, MD, Co-Chair

John D. Barr, MD, FACR

Jacqueline A. Bello, MD, FACR

John E. Jordan, MD, MPP, FACR

Paul A. Larson, MD, FACR

Mary S. Newell, MD, FACR

Alexander M. Norbash, MD, FACR

Comments Reconciliation Committee

Kristine A. Blackham, MD

Allan L. Brook, MD, FACR

Harry R. Cramer, Jr., MD

Richard Duszak, Jr., MD, FACR

Joseph J. Gemmete, MD, FACR

Wende N. Gibbs, MD

Bassem A. Georgy, MD

Manraj K.S. Heran, MD

Steven W. Hetts, MD

Joshua A. Hirsch, MD, FACR

Daniel T.D. Nguyen, MD

A. Orlando Ortiz, MD, MBA, FACR

Matthew S. Pollack, MD, FACR

Martin G. Radvany, MD

Kent B. Remley, MD

Lubdha M. Shah, MD

John D. Statler, MD

Jeffrey A. Stone, MD, FACR

Timothy L. Swan, MD, FACR

Venu Vadlamudi, MD

XII. REFERENCES

1. Bicket MC, Chakravarthy K, Chang D, Cohen SP. Epidural steroid injections: an updated review on recent trends in safety and complications. *Pain management.* 2015;5(2):129-146.
2. Peterson C, Hodler J. Evidence-based radiology (part 1): Is there sufficient research to support the use of therapeutic injections for the spine and sacroiliac joints? *Skeletal radiology.* 2010;39:5-9.
3. Bogduk N. *Practice guidelines for spinal diagnostic and treatment procedures*. 2nd ed: International Spine Intervention Society; 2013.
4. Rathmell JP, Benzon HT, Dreyfuss P, et al. Safeguards to prevent neurologic complications after epidural steroid injections: consensus opinions from a multidisciplinary working group and national organizations. *Anesthesiology.* 2015;122(5):974-984.
5. Manchikanti L, Candido KD, Singh V, et al. Epidural steroid warning controversy still dogging FDA. *Pain physician.* 2014;17(4):E451-474.
6. Parkin IG, Harrison GR. The topographical anatomy of the lumbar epidural space. *J Anat.* 1985;141:211-217.
7. Kimmell KT, Dayoub H, Shakir H, Sincoff EH. Spinal dural attachments to the vertebral column: An anatomic report and review of the literature. *Surgical neurology international.* 2011;2:97.
8. Morisot P. [Is posterior lumbar epidural space partitioned?]. *Annales francaises d'anesthesie et de reanimation.* 1992;11(1):72-81.
9. Manchikanti L, Falco FJ, Benyamin RM, Gharibo CG, Candido KD, Hirsch JA. Epidural steroid injections safety recommendations by the Multi-Society Pain Workgroup (MPW): more regulations without evidence or clarification. *Pain physician.* 2014;17(5):E575-588.
10. Koontz NA, Wiggins RH, 3rd, Stoddard GJ, Shah LM. Do Superior or Inferior Interlaminar Approach or Bevel Orientation Predispose to Nonepidural Needle Penetration? *AJR. American journal of roentgenology.*

2017;209(4):895-903.
11. Huang AJ, Rosenthal DI, Palmer WE. Inadvertent intra-articular lumbar facet joint injection during fluoroscopically guided interlaminar epidural steroid injection. *Skeletal radiology.* 2011;40(1):33-45.
12. Lehman VT, Murthy NS, Diehn FE, Verdoorn JT, Maus TP. The posterior ligamentous complex inflammatory syndrome: spread of fluid and inflammation in the retrodural space of Okada. *Clinical radiology.* 2015;70(5):528-535.
13. Murthy NS, Maus TP, Aprill C. The retrodural space of Okada. *AJR. American journal of roentgenology.* 2011;196(6):W784-789.
14. Huang AJ, Palmer WE. Incidence of inadvertent intra-articular lumbar facet joint injection during fluoroscopically guided interlaminar epidural steroid injection. *Skeletal radiology.* 2012;41(2):157-162.
15. Kranz PG, Joshi AB, Roy LA, Choudhury KR, Amrhein TJ. Inadvertent Intrafacet Injection during Lumbar Interlaminar Epidural Steroid Injection: A Comparison of CT Fluoroscopic and Conventional Fluoroscopic Guidance. *AJNR. American journal of neuroradiology.* 2017;38(2):398-402.
16. Aldrete JA, Mushin AU, Zapata JC, Ghaly R. Skin to cervical epidural space distances as read from magnetic resonance imaging films: consideration of the "hump pad.". *Journal of clinical anesthesia.* 1998;10(4):309-313.
17. Goel A, Pollan JJ. Contrast flow characteristics in the cervical epidural space: an analysis of cervical epidurograms. *Spine.* 2006;31(14):1576-1579.
18. Hodges SD, Castleberg RL, Miller T, Ward R, Thornburg C. Cervical epidural steroid injection with intrinsic spinal cord damage. Two case reports. *Spine.* 1998;23(19):2137-2142; discussion 2141-2132.
19. Hogan QH. Epidural anatomy examined by cryomicrotome section. Influence of age, vertebral level, and disease. *Regional anesthesia.* 1996;21(5):395-406.
20. Manchikanti L, Rajgopal R, Pampati V. Comparison of three routes of epidural steroid injections in low back pain. *Pain Digest.* 1999;9:277-285.
21. Furman MB, Cuneo AA. Image and Contrast Flow Pattern Interpretation for Attempted Epidural Steroid Injections. *Physical medicine and rehabilitation clinics of North America.* 2018;29(1):19-33.
22. Jeong HS, Lee JW, Kim SH, Myung JS, Kim JH, Kang HS. Effectiveness of transforaminal epidural steroid injection by using a preganglionic approach: a prospective randomized controlled study. *Radiology.* 2007;245(2):584-590.
23. Kamble PC, Sharma A, Singh V, Natraj B, Devani D, Khapane V. Outcome of single level disc prolapse treated with transforaminal steroid versus epidural steroid versus caudal steroids. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society.* 2016;25(1):217-221.
24. Shim E, Lee JW, Lee E, Ahn JM, Kang Y, Kang HS. Fluoroscopically Guided Epidural Injections of the Cervical and Lumbar Spine. *Radiographics : a review publication of the Radiological Society of North America, Inc.* 2017;37(2):537-561.
25. Manchikanti L, Cash KA, Pampati V, Damron KS, McManus CD. Evaluation of lumbar transforaminal epidural injections with needle placement and contrast flow patterns: a prospective, descriptive report. *Pain physician.* 2004;7(2):217-223.
26. Botwin KP, Gruber RD, Bouchlas CG, et al. Fluoroscopically guided lumbar transformational epidural steroid injections in degenerative lumbar stenosis: an outcome study. *American journal of physical medicine & rehabilitation.* 2002;81(12):898-905.
27. Slipman CW, Chow DW. Therapeutic spinal corticosteroid injections for the management of radiculopathies. *Physical medicine and rehabilitation clinics of North America.* 2002;13(3):697-711.
28. Boswell MV, Hansen HC, Trescot AM, Hirsch JA. Epidural steroids in the management of chronic spinal pain and radiculopathy. *Pain physician.* 2003;6(3):319-334.
29. Botwin KP, Gruber RD, Bouchlas CG, Torres-Ramos FM, Freeman TL, Slaten WK. Complications of fluoroscopically guided transforaminal lumbar epidural injections. *Archives of physical medicine and rehabilitation.* 2000;81(8):1045-1050.
30. Elias M. A rare cause of radiculopathy following transformainal epidual steroid injection. *Pain Clinic.* 1998;11:159-160.
31. Furman MB, O'Brien EM, Zgleszewski TM. Incidence of intravascular penetration in transforaminal lumbosacral epidural steroid injections. *Spine.* 2000;25(20):2628-2632.
32. Houten JK, Errico TJ. Paraplegia after lumbosacral nerve root block: report of three cases. *The spine journal :*

official journal of the North American Spine Society. 2002;2(1):70-75.
33. Manchikanti L. Transforaminal lumbar epidural steroid injections. *Pain physician.* 2000;3(4):374-398.
34. Manchikanti L, Staats PS, Singh V, et al. Evidence-based practice guidelines for interventional techniques in the management of chronic spinal pain. *Pain physician.* 2003;6(1):3-81.
35. Stohr M, Mayer K. [Nerve-root damage from local injections (author's transl)]. *Dtsch Med Wochenschr.* 1976;101(33):1218-1220.
36. Kambin P, Sampson S. Posterolateral percutaneous suction-excision of herniated lumbar intervertebral discs. Report of interim results. *Clinical orthopaedics and related research.* 1986(207):37-43.
37. Murthy NS, Maus TP, Behrns CL. Intraforaminal location of the great anterior radiculomedullary artery (artery of Adamkiewicz): a retrospective review. *Pain Med.* 2010;11(12):1756-1764.
38. Levi D, Horn S, Corcoran S. The Incidence of Intradiscal, Intrathecal, and Intravascular Flow During the Performance of Retrodiscal (Infraneural) Approach for Lumbar Transforaminal Epidural Steroid Injections. *Pain Med.* 2016;17(8):1416-1422.
39. Smuck M, Paulus S, Patel A, Demirjian R, Ith MA, Kennedy DJ. Differential Rates of Inadvertent Intravascular Injection during Lumbar Transforaminal Epidural Injections Using Blunt-Tip, Pencil-Point, and Catheter-Extension Needles. *Pain Med.* 2015;16(11):2084-2089.
40. Ozcan U, Sahin S, Gurbet A, Turker G, Ozgur M, Celebi S. Comparison of blunt and sharp needles for transforaminal epidural steroid injections. *Agri.* 2012;24(2):85-89.
41. Trinh KH, Gharibo CG, Aydin SM. Inadvertent Intradiscal Injection with TFESI Utilizing Kambin's Retrodiscal Approach in the Treatment of Acute Lumbar Radiculopathy. *Pain practice : the official journal of World Institute of Pain.* 2016;16(4):E70-73.
42. Provenzano DA, Fanciullo G. Cervical transforaminal epidural steroid injections: should we be performing them? *Regional anesthesia and pain medicine.* 2007;32(2):168; author reply 169-170.
43. Choi E, Nahm FS, Lee PB. Comparison of contrast flow and clinical effectiveness between a modified paramedian interlaminar approach and transforaminal approach in cervical epidural steroid injection. *British journal of anaesthesia.* 2015;115(5):768-774.
44. Hoang JK, Apostol MA, Kranz PG, et al. CT fluoroscopy-assisted cervical transforaminal steroid injection: tips, traps, and use of contrast material. *AJR. American journal of roentgenology.* 2010;195(4):888-894.
45. Wagner AL. CT fluoroscopic-guided cervical nerve root blocks. *AJNR. American journal of neuroradiology.* 2005;26(1):43-44.
46. Richarme D, Thevenin FS, Chevrot A, et al. *Cervical radiculopathy: efficiency of CT-guided cervical facet joint corticosteroid injection*. Chicago, IL: Radiological Society of North America; 2008.
47. Kim KH, Choi SH, Kim TK, Shin SW, Kim CH, Kim JI. Cervical facet joint injections in the neck and shoulder pain. *Journal of Korean medical science.* 2005;20(4):659-662.
48. Bureau NJ, Moser T, Dagher JH, et al. Transforaminal versus intra-articular facet corticosteroid injections for the treatment of cervical radiculopathy: a randomized, double-blind, controlled study. *AJNR. American journal of neuroradiology.* 2014;35(8):1467-1474.
49. Eckel TS, Bartynski WS. Epidural steroid injections and selective nerve root blocks. *Techniques in vascular and interventional radiology.* 2009;12(1):11-21.
50. Kao SC, Lin CS. Caudal Epidural Block: An Updated Review of Anatomy and Techniques. *BioMed research international.* 2017;2017:9217145.
51. Benyamin RM, Manchikanti L, Parr AT, et al. The effectiveness of lumbar interlaminar epidural injections in managing chronic low back and lower extremity pain. *Pain physician.* 2012;15(4):E363-404.
52. Olmarker K, Rydevik B, Holm S. Edema formation in spinal nerve roots induced by experimental, graded compression. An experimental study on the pig cauda equina with special reference to differences in effects between rapid and slow onset of compression. *Spine.* 1989;14(6):569-573.
53. Rydevik B, Brown MD, Lundborg G. Pathoanatomy and pathophysiology of nerve root compression. *Spine.* 1984;9(1):7-15.
54. Lin;JH, Chiang YH, Chen CC. Lumbar radiculopathy and its neurobiological basis. *World J Anesthesiol.* 2014;3(2):162-173.
55. Abram SE, O'Connor TC. Complications associated with epidural steroid injections. *Regional anesthesia.* 1996;21(2):149-162.
56. Derby R, Lee SH, Date ES, Lee JH, Lee CH. Size and aggregation of corticosteroids used for epidural injections. *Pain Med.* 2008;9(2):227-234.

57. Johansson A, Hao J, Sjolund B. Local corticosteroid application blocks transmission in normal nociceptive C-fibres. *Acta anaesthesiologica Scandinavica.* 1990;34(5):335-338.
58. Kantrowitz F, Robinson DR, McGuire MB, Levine L. Corticosteroids inhibit prostaglandin production by rheumatiod synovia. *Nature.* 1975;258(5537):737-739.
59. Saal JS, Franson RC, Dobrow R, Saal JA, White AH, Goldthwaite N. High levels of inflammatory phospholipase A2 activity in lumbar disc herniations. *Spine.* 1990;15(7):674-678.
60. Chou R, Hashimoto R, Friedly J, et al. *Pain Management Injection Therapies for Low Back Pain*. Rockville (MD)2015.
61. Bicket MC, Gupta A, Brown CHt, Cohen SP. Epidural injections for spinal pain: a systematic review and meta-analysis evaluating the "control" injections in randomized controlled trials. *Anesthesiology.* 2013;119(4):907-931.
62. Kaufmann TJ, Geske JR, Murthy NS, et al. Clinical effectiveness of single lumbar transforaminal epidural steroid injections. *Pain Med.* 2013;14(8):1126-1133.
63. MacVicar J, King W, Landers MH, Bogduk N. The effectiveness of lumbar transforaminal injection of steroids: a comprehensive review with systematic analysis of the published data. *Pain Med.* 2013;14(1):14-28.
64. Manchikanti L, Buenaventura RM, Manchikanti KN, et al. Effectiveness of therapeutic lumbar transforaminal epidural steroid injections in managing lumbar spinal pain. *Pain physician.* 2012;15(3):E199-245.
65. Byrod G, Otani K, Brisby H, Rydevik B, Olmarker K. Methylprednisolone reduces the early vascular permeability increase in spinal nerve roots induced by epidural nucleus pulposus application. *Journal of orthopaedic research : official publication of the Orthopaedic Research Society.* 2000;18(6):983-987.
66. Hayashi N, Weinstein JN, Meller ST, Lee HM, Spratt KF, Gebhart GF. The effect of epidural injection of betamethasone or bupivacaine in a rat model of lumbar radiculopathy. *Spine.* 1998;23(8):877-885.
67. Lee HM, Weinstein JN, Meller ST, Hayashi N, Spratt KF, Gebhart GF. The role of steroids and their effects on phospholipase A2. An animal model of radiculopathy. *Spine.* 1998;23(11):1191-1196.
68. Minamide A, Tamaki T, Hashizume H, Yoshida M, Kawakami M, Hayashi N. Effects of steroid and lipopolysaccharide on spontaneous resorption of herniated intervertebral discs. An experimental study in the rabbit. *Spine.* 1998;23(8):870-876.
69. Olmarker K, Nutu M, Storkson R. Changes in spontaneous behavior in rats exposed to experimental disc herniation are blocked by selective TNF-alpha inhibition. *Spine.* 2003;28(15):1635-1641; discussion 1642.
70. Lundin A, Magnuson A, Axelsson K, Nilsson O, Samuelsson L. Corticosteroids peroperatively diminishes damage to the C-fibers in microscopic lumbar disc surgery. *Spine.* 2005;30(21):2362-2367; discussion 2368.
71. Manchikanti L, Knezevic NN, Boswell MV, Kaye AD, Hirsch JA. Epidural Injections for Lumbar Radiculopathy and Spinal Stenosis: A Comparative Systematic Review and Meta-Analysis. *Pain physician.* 2016;19(3):E365-410.
72. Ye L, Xie W, Strong JA, Zhang JM. Blocking the mineralocorticoid receptor improves effectiveness of steroid treatment for low back pain in rats. *Anesthesiology.* 2014;121(3):632-643.
73. Friedly JL, Comstock BA, Turner JA, et al. A randomized trial of epidural glucocorticoid injections for spinal stenosis. *The New England journal of medicine.* 2014;371(1):11-21.
74. Manchikanti L, Kaye AD, Manchikanti K, Boswell M, Pampati V, Hirsch J. Efficacy of epidural injections in the treatment of lumbar central spinal stenosis: a systematic review. *Anesthesiology and pain medicine.* 2015;5(1):e23139.
75. MacMahon PJ, Eustace SJ, Kavanagh EC. Injectable corticosteroid and local anesthetic preparations: a review for radiologists. *Radiology.* 2009;252(3):647-661.
76. Arner S, Lindblom U, Meyerson BA, Molander C. Prolonged relief of neuralgia after regional anesthetic blocks. A call for further experimental and systematic clinical studies. *Pain.* 1990;43(3):287-297.
77. Cassuto J, Sinclair R, Bonderovic M. Anti-inflammatory properties of local anesthetics and their present and potential clinical implications. *Acta anaesthesiologica Scandinavica.* 2006;50(3):265-282.
78. Kaye AD, Manchikanti L, Abdi S, et al. Efficacy of Epidural Injections in Managing Chronic Spinal Pain: A Best Evidence Synthesis. *Pain physician.* 2015;18(6):E939-1004.
79. Lavoie PA, Khazen T, Filion PR. Mechanisms of the inhibition of fast axonal transport by local anesthetics. *Neuropharmacology.* 1989;28(2):175-181.
80. Manchikanti L, Abdi S, Atluri S, et al. An update of comprehensive evidence-based guidelines for

interventional techniques in chronic spinal pain. Part II: guidance and recommendations. *Pain physician.* 2013;16(2 Suppl):S49-283.
81. Manchikanti L, Benyamin RM, Falco FJ, Kaye AD, Hirsch JA. Do Epidural Injections Provide Short- and Long-term Relief for Lumbar Disc Herniation? A Systematic Review. *Clinical orthopaedics and related research.* 2015;473(6):1940-1956.
82. Manchikanti L, Nampiaparampil DE, Manchikanti KN, et al. Comparison of the efficacy of saline, local anesthetics, and steroids in epidural and facet joint injections for the management of spinal pain: A systematic review of randomized controlled trials. *Surgical neurology international.* 2015;6(Suppl 4):S194-235.
83. Pasqualucci A. Experimental and clinical studies about the preemptive analgesia with local anesthetics. Possible reasons of the failure. *Minerva anestesiologica.* 1998;64(10):445-457.
84. Moen GH, Moen A, Schistad EI, Gjerstad J. Local up-regulation of interferon-gamma (IFN-gamma) following disc herniation is involved in the inflammatory response underlying acute lumbar radicular pain. *Cytokine.* 2017;97:181-186.
85. Linton SJ, Boersma K, Jansson M, Svard L, Botvalde M. The effects of cognitive-behavioral and physical therapy preventive interventions on pain-related sick leave: a randomized controlled trial. *The Clinical journal of pain.* 2005;21(2):109-119.
86. Kim J, Burke SM, Kryzanski JT, et al. The Role of Liposomal Bupivacaine in Reduction of Postoperative Pain After Transforaminal Lumbar Interbody Fusion: A Clinical Study. *World neurosurgery.* 2016;91:460-467.
87. Rabinovitch DL, Peliowski A, Furlan AD. Influence of lumbar epidural injection volume on pain relief for radicular leg pain and/or low back pain. *The spine journal : official journal of the North American Spine Society.* 2009;9(6):509-517.
88. Manchikanti L, Cash KA, McManus CD, Pampati V, Fellows B. Fluoroscopic caudal epidural injections with or without steroids in managing pain of lumbar spinal stenosis: one-year results of randomized, double-blind, active-controlled trial. *Journal of spinal disorders & techniques.* 2012;25(4):226-234.
89. Racz GB, Day MR, Heavner JE, Scott J. Lysis of epidural adhesions: the racztechnique. In: Waldman SD, ed. *Pain Management*. 2nd edition ed. Philadelphia, PA: Elsevier Saunders; 2011:1258-1272.
90. Wolff MW, Levine LA. Cervical radiculopathies: conservative approaches to management. *Physical medicine and rehabilitation clinics of North America.* 2002;13(3):589-608, vii.
91. Murakibhavi VG, Khemka AG. Caudal epidural steroid injection: a randomized controlled trial. *Evidence-based spine-care journal.* 2011;2(4):19-26.
92. Hooten WM, Cohen SP. Evaluation and Treatment of Low Back Pain: A Clinically Focused Review for Primary Care Specialists. *Mayo Clinic proceedings.* 2015;90(12):1699-1718.
93. Brzezicki G, Jankowski R, Blok T, et al. Postlaminectomy osteopontin expression and associated neurophysiological findings in rat peridural scar model. *Spine.* 2011;36(5):378-385.
94. Fritsch EW, Heisel J, Rupp S. The failed back surgery syndrome: reasons, intraoperative findings, and long-term results: a report of 182 operative treatments. *Spine.* 1996;21(5):626-633.
95. Law JD, Lehman RA, Kirsch WM. Reoperation after lumbar intervertebral disc surgery. *Journal of neurosurgery.* 1978;48(2):259-263.
96. Manchikanti L, Boswell MV, Singh V, et al. Comprehensive evidence-based guidelines for interventional techniques in the management of chronic spinal pain. *Pain physician.* 2009;12(4):699-802.
97. Manchikanti L, Manchukonda R, Pampati V, Damron KS, McManus CD. Prevalence of facet joint pain in chronic low back pain in postsurgical patients by controlled comparative local anesthetic blocks. *Archives of physical medicine and rehabilitation.* 2007;88(4):449-455.
98. Osterman H, Sund R, Seitsalo S, Keskimaki I. Risk of multiple reoperations after lumbar discectomy: a population-based study. *Spine.* 2003;28(6):621-627.
99. Ross JS, Robertson JT, Frederickson RC, et al. Association between peridural scar and recurrent radicular pain after lumbar discectomy: magnetic resonance evaluation. ADCON-L European Study Group. *Neurosurgery.* 1996;38(4):855-861; discussion 861-853.
100. Waddell G, Kummel EG, Lotto WN, Graham JD, Hall H, McCulloch JA. Failed lumbar disc surgery and repeat surgery following industrial injuries. *The Journal of bone and joint surgery. American volume.* 1979;61(2):201-207.
101. Manchikanti L, Singh V, Cash KA, Pampati V, Datta S. Fluoroscopic caudal epidural injections in managing post lumbar surgery syndrome: two-year results of a randomized, double-blind, active-control trial.

International journal of medical sciences. 2012;9(7):582-591.
102. Yousef AA, AS EL-D, Al-Deeb AE. The role of adding hyaluronidase to fluoroscopically guided caudal steroid and hypertonic saline injection in patients with failed back surgery syndrome: a prospective, double-blinded, randomized study. *Pain practice : the official journal of World Institute of Pain.* 2010;10(6):548-553.
103. Collighan N, S G. *Continuing Education in Anaesthesia Critical Care & Pain.* Vol 10; 2009.
104. Friedrich JM, Harrast MA. Lumbar epidural steroid injections: indications, contraindications, risks, and benefits. *Current sports medicine reports.* 2010;9(1):43-49.
105. Narouze S, Benzon HT, Provenzano D, et al. Interventional Spine and Pain Procedures in Patients on Antiplatelet and Anticoagulant Medications (Second Edition): Guidelines From the American Society of Regional Anesthesia and Pain Medicine, the European Society of Regional Anaesthesia and Pain Therapy, the American Academy of Pain Medicine, the International Neuromodulation Society, the North American Neuromodulation Society, and the World Institute of Pain. *Regional anesthesia and pain medicine.* 2018;43(3):225-262.
106. White AH, Derby R, Wynne G. Epidural injections for the diagnosis and treatment of low-back pain. *Spine.* 1980;5(1):78-86.
107. Desmond FA, Harmon D. Ultrasound-guided symphysis pubis injection in pregnancy. *Anesthesia and analgesia.* 2010;111(5):1329-1330.
108. Kalin A, Woods D. Neuraxial blockade in a patient with hepatitis C. *Can J Anesthesia.* 2008;Supplement vol. 55.
109. Abram SE. Treatment of lumbosacral radiculopathy with epidural steroids. *Anesthesiology.* 1999;91(6):1937-1941.
110. American College of Radiology. ACR practice parameter for continuing medical education (CME). 2017; Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CME.pdf. Accessed January 24, 2018.
111. Johnson BA. Image-guided epidural injections. *Neuroimaging clinics of North America.* 2000;10(3):479-491.
112. Watanabe AT, Nishimura E, Garris J. Image-guided epidural steroid injections. *Techniques in vascular and interventional radiology.* 2002;5(4):186-193.
113. Mathis JM. Epidural steroid injections. *Neuroimaging clinics of North America.* 2010;20(2):193-202.
114. Paulson EK, Sheafor DH, Enterline DS, McAdams HP, Yoshizumi TT. CT fluoroscopy--guided interventional procedures: techniques and radiation dose to radiologists. *Radiology.* 2001;220(1):161-167.
115. Fenster AJ, Fernandes K, Brook AL, Miller T. The Safety of CT-Guided Epidural Steroid Injections in an Older Patient Cohort. *Pain physician.* 2016;19(8):E1139-E1146.
116. Lazarus MS, Forman RB, Brook AL, Miller TS. Radiation Dose and Procedure Time for 994 CT-guided Spine Pain Control Procedures. *Pain physician.* 2017;20(4):E585-E591.
117. Amrhein TJ, Schauberger JS, Kranz PG, Hoang JK. Reducing Patient Radiation Exposure From CT Fluoroscopy-Guided Lumbar Spine Pain Injections by Targeting the Planning CT. *AJR. American journal of roentgenology.* 2016;206(2):390-394.
118. Wagner AL. CT fluoroscopy-guided epidural injections: technique and results. *AJNR. American journal of neuroradiology.* 2004;25(10):1821-1823.
119. Viola RJ, Nguyen GB, Yoshizumi TT, Stinnett SS, Hoang JK, Kranz PG. Effect of Body Habitus on Radiation Dose During CT Fluoroscopy-Guided Spine Injections. *Interventional neuroradiology : journal of peritherapeutic neuroradiology, surgical procedures and related neurosciences.* 2014;20(5):525-532.
120. Jee H, Lee JH, Kim J, Park KD, Lee WY, Park Y. Ultrasound-guided selective nerve root block versus fluoroscopy-guided transforaminal block for the treatment of radicular pain in the lower cervical spine: a randomized, blinded, controlled study. *Skeletal radiology.* 2013;42(1):69-78.
121. Bartynski WS, Grahovac SZ, Rothfus WE. Incorrect needle position during lumbar epidural steroid administration: inaccuracy of loss of air pressure resistance and requirement of fluoroscopy and epidurography during needle insertion. *AJNR. American journal of neuroradiology.* 2005;26(3):502-505.
122. Benzon HT, Huntoon MA, Rathmell JP. Improving the safety of epidural steroid injections. *Jama.* 2015;313(17):1713-1714.
123. Kim YU, Kim D, Park JY, et al. Method to Reduce the False-Positive Rate of Loss of Resistance in the Cervical Epidural Region. *Pain research & management.* 2016;2016:9894054.
124. Saberski LR, Kondamuri S, Osinubi OY. Identification of the epidural space: is loss of resistance to air a safe technique? A review of the complications related to the use of air. *Regional anesthesia.* 1997;22(1):3-15.

125. Goodman BS, Posecion LW, Mallempati S, Bayazitoglu M. Complications and pitfalls of lumbar interlaminar and transforaminal epidural injections. *Current reviews in musculoskeletal medicine.* 2008;1(3-4):212-222.
126. Bolger MP, MacMahon PJ, Kavanagh EC. Is There a Need for Contrast and Local Anesthetic in Cervical Epidural Steroid Injections? *AJNR. American journal of neuroradiology.* 2016;37(9):E61.
127. Ryan TM, Kavanagh EC, MacMahon PJ. Is there a need for contrast administration prior to CT-guided cervical nerve root block? *AJNR. American journal of neuroradiology.* 2013;34(4):E45.
128. Hong JH, Kim SY, Huh B, Shin HH. Analysis of inadvertent intradiscal and intravascular injection during lumbar transforaminal epidural steroid injections: a prospective study. *Regional anesthesia and pain medicine.* 2013;38(6):520-525.
129. Lee MH, Yang KS, Kim YH, Jung HD, Lim SJ, Moon DE. Accuracy of live fluoroscopy to detect intravascular injection during lumbar transforaminal epidural injections. *The Korean journal of pain.* 2010;23(1):18-23.
130. McLean JP, Sigler JD, Plastaras CT, Garvan CW, Rittenberg JD. The rate of detection of intravascular injection in cervical transforaminal epidural steroid injections with and without digital subtraction angiography. *PM & R : the journal of injury, function, and rehabilitation.* 2009;1(7):636-642.
131. Chang A, Pochert S, Romano C, Brook A, Miller T. Safety of 1000 CT-guided steroid injections with air used to localize the epidural space. *AJNR. American journal of neuroradiology.* 2011;32(9):E175-177.
132. International Electrotechnical Commission. Medical electrical equipment - parta 1: general requirements for basic safety and essential performance. 2005; Available at: http://www.ele.uri.edu/courses/bme484/iec60601-1ed3.0_parts.pdf. Accessed January 24, 2018.
133. Benzon HT, Chew TL, McCarthy RJ, Benzon HA, Walega DR. Comparison of the particle sizes of different steroids and the effect of dilution: a review of the relative neurotoxicities of the steroids. *Anesthesiology.* 2007;106(2):331-338.
134. MacMahon PJ, Huang AJ, Palmer WE. Spine Injectables: What Is the Safest Cocktail? *AJR. American journal of roentgenology.* 2016;207(3):526-533.
135. MacMahon PJ, Shelly MJ, Scholz D, Eustace SJ, Kavanagh EC. Injectable corticosteroid preparations: an embolic risk assessment by static and dynamic microscopic analysis. *AJNR. American journal of neuroradiology.* 2011;32(10):1830-1835.
136. Gharibo CG, Fakhry M, Diwan S, Kaye AD. Conus Medullaris Infarction After a Right L4 Transforaminal Epidural Steroid Injection Using Dexamethasone. *Pain physician.* 2016;19(8):E1211-E1214.
137. Friedly JL, Comstock BA, Heagerty PJ, et al. Systemic effects of epidural steroid injections for spinal stenosis. *Pain.* 2018.
138. Mathis JM, Golovac S, Cho CH. Pharmaceuticals used in image-guided spine interventions. *Neuroimaging clinics of North America.* 2010;20(2):215-222.
139. Owlia MB, Salimzadeh A, Alishiri G, Haghighi A. Comparison of two doses of corticosteroid in epidural steroid injection for lumbar radicular pain. *Singapore medical journal.* 2007;48(3):241-245.
140. Kang SS, Hwang BM, Son HJ, et al. The dosages of corticosteroid in transforaminal epidural steroid injections for lumbar radicular pain due to a herniated disc. *Pain physician.* 2011;14(4):361-370.
141. Krunic AL, Wang LC, Soltani K, Weitzul S, Taylor RS. Digital anesthesia with epinephrine: an old myth revisited. *Journal of the American Academy of Dermatology.* 2004;51(5):755-759.
142. Leone S, Di Cianni S, Casati A, Fanelli G. Pharmacology, toxicology, and clinical use of new long acting local anesthetics, ropivacaine and levobupivacaine. *Acta bio-medica : Atenei Parmensis.* 2008;79(2):92-105.
143. Foster AH, Carlson BM. Myotoxicity of local anesthetics and regeneration of the damaged muscle fibers. *Anesthesia and analgesia.* 1980;59(10):727-736.
144. Hogan Q, Dotson R, Erickson S, Kettler R, Hogan K. Local anesthetic myotoxicity: a case and review. *Anesthesiology.* 1994;80(4):942-947.
145. Zink W, Graf BM. Local anesthetic myotoxicity. *Regional anesthesia and pain medicine.* 2004;29(4):333-340.
146. Sisk AL. Vasoconstrictors in local anesthesia for dentistry. *Anesthesia progress.* 1992;39(6):187-193.
147. Narouze S, Benzon HT, Provenzano DA, et al. Interventional spine and pain procedures in patients on antiplatelet and anticoagulant medications: guidelines from the American Society of Regional Anesthesia and Pain Medicine, the European Society of Regional Anaesthesia and Pain Therapy, the American Academy of Pain Medicine, the International Neuromodulation Society, the North American Neuromodulation Society, and the World Institute of Pain. *Regional anesthesia and pain medicine.* 2015;40(3):182-212.
148. Nickalls RW, Kokri MS. The width of the posterior epidural space in obstetric patients. *Anaesthesia.* 1986;41(4):432-433.

149. Reina MA, Franco CD, Lopez A, De Andres JA, van Zundert A. Clinical implications of epidural fat in the spinal canal. A scanning electron microscopic study. *Acta anaesthesiologica Belgica.* 2009;60(1):7-17.
150. Igarashi T, Hirabayashi Y, Shimizu R, Saitoh K, Fukuda H, Mitsuhata H. The lumbar extradural structure changes with increasing age. *British journal of anaesthesia.* 1997;78(2):149-152.
151. Wu HT, Schweitzer ME, Parker L. Is epidural fat associated with body habitus? *Journal of computer assisted tomography.* 2005;29(1):99-102.
152. Cohen SP, Gupta A, Strassels SA, et al. Effect of MRI on treatment results or decision making in patients with lumbosacral radiculopathy referred for epidural steroid injections: a multicenter, randomized controlled trial. *Archives of internal medicine.* 2012;172(2):134-142.
153. Maus T. Imaging the back pain patient. *Physical medicine and rehabilitation clinics of North America.* 2010;21(4):725-766.
154. Maus TP, El-Yahchouchi CA, Geske JR, et al. Imaging Determinants of Clinical Effectiveness of Lumbar Transforaminal Epidural Steroid Injections. *Pain Med.* 2016;17(12):2176-2184.
155. Smith CC, Lin JL, Shokat M, Dosanjh SS, Casthely D. A report of paraparesis following spinal cord stimulator trial, implantation and revision. *Pain physician.* 2010;13(4):357-363.
156. Igarashi T, Hirabayashi Y, Shimizu R, et al. Inflammatory changes after extradural anaesthesia may affect the spread of local anaesthetic within the extradural space. *British journal of anaesthesia.* 1996;77(3):347-351.
157. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for Prevention of Surgical Site Infection, 1999. Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. *American journal of infection control.* 1999;27(2):97-132; quiz 133-134; discussion 196.
158. American College of Radiology. ACR–SIR practice parameter for sedation/analgesia. 2015; Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/sed-analgesia.pdf?la=en. Accessed January 24, 2018.
159. Rathmell JP, Michna E, Fitzgibbon DR, Stephens LS, Posner KL, Domino KB. Injury and liability associated with cervical procedures for chronic pain. *Anesthesiology.* 2011;114(4):918-926.
160. Amis ES, Jr., Butler PF, Applegate KE, et al. American College of Radiology white paper on radiation dose in medicine. *Journal of the American College of Radiology : JACR.* 2007;4(5):272-284.
161. Miller DL, Balter S, Wagner LK, et al. Quality improvement guidelines for recording patient radiation dose in the medical record. *Journal of vascular and interventional radiology : JVIR.* 2004;15(5):423-429.
162. Stecker MS, Balter S, Towbin RB, et al. Guidelines for patient radiation dose management. *Journal of vascular and interventional radiology : JVIR.* 2009;20(7 Suppl):S263-273.
163. American College of Radiology. ACR–SIR–SPR practice parameter for the reporting and archiving of interventional radiology procedures. 2014; Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/reporting-archiv.pdf?la=en. Accessed January 24, 2018.
164. American College of Radiology. ACR–SIR–SPR practice parameter on informed consent for image-guided procedures. 2016; Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/informedconsent-imagguided.pdf?la=en. Accessed January 24, 2018.
165. Society of Interventional Radiology. Proposal of a new adverse event classification by the society of interventional radiology standards of practice committee. 2017; Available at: https://www.jvir.org/article/S1051-0443(17)30576-6/pdf. Accessed July 24, 2019.
166. Manchikanti L, Hirsch JA, Cohen SP, et al. Assessment of methodologic quality of randomized trials of interventional techniques: development of an interventional pain management specific instrument. *Pain physician.* 2014;17(3):E263-290.
167. Manchikanti L, Hirsch JA, Heavner JE, et al. Development of an interventional pain management specific instrument for methodologic quality assessment of nonrandomized studies of interventional techniques. *Pain physician.* 2014;17(3):E291-317.
168. Manchikanti L, Cash KA, McManus CD, Pampati V, Smith HS. One-year results of a randomized, double-blind, active controlled trial of fluoroscopic caudal epidural injections with or without steroids in managing chronic discogenic low back pain without disc herniation or radiculitis. *Pain physician.* 2011;14(1):25-36.
169. Manchikanti L, Malla Y, Cash KA, McManus CD, Pampati V. Fluoroscopic epidural injections in cervical spinal stenosis: preliminary results of a randomized, double-blind, active control trial. *Pain physician.* 2012;15(1):E59-70.
170. Manchikanti L, Cash KA, McManus CD, Damron KS, Pampati V, Falco FJ. A randomized, double-blind controlled trial of lumbar interlaminar epidural injections in central spinal stenosis: 2-year follow-up. *Pain*

physician. 2015;18(1):79-92.
171. Manchikanti L, Cash KA, McManus CD, Pampati V, Benyamin RM. A randomized, double-blind, active-controlled trial of fluoroscopic lumbar interlaminar epidural injections in chronic axial or discogenic low back pain: results of 2-year follow-up. *Pain physician.* 2013;16(5):E491-504.
172. Manchikanti L, Cash KA, McManus CD, Pampati V, Benyamin RM. Thoracic interlaminar epidural injections in managing chronic thoracic pain: a randomized, double-blind, controlled trial with a 2-year follow-up. *Pain physician.* 2014;17(3):E327-338.
173. Manchikanti L, Cash KA, McManus CD, Pampati V, Fellows B. Results of 2-year follow-up of a randomized, double-blind, controlled trial of fluoroscopic caudal epidural injections in central spinal stenosis. *Pain physician.* 2012;15(5):371-384.
174. Manchikanti L, Cash KA, McManus CD, Pampati V. Fluoroscopic caudal epidural injections in managing chronic axial low back pain without disc herniation, radiculitis, or facet joint pain. *Journal of pain research.* 2012;5:381-390.
175. Manchikanti L, Cash KA, Pampati V, Falco FJ. Transforaminal epidural injections in chronic lumbar disc herniation: a randomized, double-blind, active-control trial. *Pain physician.* 2014;17(4):E489-501.
176. Manchikanti L, Cash KA, Pampati V, Malla Y. Two-year follow-up results of fluoroscopic cervical epidural injections in chronic axial or discogenic neck pain: a randomized, double-blind, controlled trial. *International journal of medical sciences.* 2014;11(4):309-320.
177. Manchikanti L, Cash KA, Pampati V, Wargo BW, Malla Y. A randomized, double-blind, active control trial of fluoroscopic cervical interlaminar epidural injections in chronic pain of cervical disc herniation: results of a 2-year follow-up. *Pain physician.* 2013;16(5):465-478.
178. Manchikanti L, Singh V, Cash KA, Pampati V, Falco FJ. A randomized, double-blind, active-control trial of the effectiveness of lumbar interlaminar epidural injections in disc herniation. *Pain physician.* 2014;17(1):E61-74.
179. Manchikanti L, Cash KA, Pampati V, Wargo BW, Malla Y. Management of chronic pain of cervical disc herniation and radiculitis with fluoroscopic cervical interlaminar epidural injections. *International journal of medical sciences.* 2012;9(6):424-434.
180. Manchikanti L, Singh V, Cash KA, Pampati V, Falco FJ. The role of fluoroscopic interlaminar epidural injections in managing chronic pain of lumbar disc herniation or radiculitis: a randomized, double-blind trial. *Pain practice : the official journal of World Institute of Pain.* 2013;13(7):547-558.
181. Manchikanti L, Singh V, Cash KA, Pampati V, Damron KS, Boswell MV. Effect of fluoroscopically guided caudal epidural steroid or local anesthetic injections in the treatment of lumbar disc herniation and radiculitis: a randomized, controlled, double blind trial with a two-year follow-up. *Pain physician.* 2012;15(4):273-286.
182. Ghai B, Kumar K, Bansal D, Dhatt SS, Kanukula R, Batra YK. Effectiveness of Parasagittal Interlaminar Epidural Local Anesthetic with or without Steroid in Chronic Lumbosacral Pain: A Randomized, Double-Blind Clinical Trial. *Pain physician.* 2015;18(3):237-248.
183. Manchikanti L, Cash KA, McManus CD, Pampati V. Assessment of effectiveness of percutaneous adhesiolysis in managing chronic low back pain secondary to lumbar central spinal canal stenosis. *International journal of medical sciences.* 2013;10(1):50-59.
184. Manchikanti L, Singh V, Cash KA, Pampati V. Assessment of effectiveness of percutaneous adhesiolysis and caudal epidural injections in managing post lumbar surgery syndrome: 2-year follow-up of a randomized, controlled trial. *Journal of pain research.* 2012;5:597-608.
185. North RB, Kidd DH, Petrucci L, Dorsi MJ. Spinal cord stimulation electrode design: a prospective, randomized, controlled trial comparing percutaneous with laminectomy electrodes: part II-clinical outcomes. *Neurosurgery.* 2005;57(5):990-996; discussion 990-996.
186. Kumar K, Taylor RS, Jacques L, et al. Spinal cord stimulation versus conventional medical management for neuropathic pain: a multicentre randomised controlled trial in patients with failed back surgery syndrome. *Pain.* 2007;132(1-2):179-188.
187. Bellini M, Barbieri M. Systemic effects of epidural steroid injections. *Anaesthesiology intensive therapy.* 2013;45(2):93-98.
188. Abdi S, Datta S, Trescot AM, et al. Epidural steroids in the management of chronic spinal pain: a systematic review. *Pain physician.* 2007;10(1):185-212.
189. McGrath JM, Schaefer MP, Malkamaki DM. Incidence and characteristics of complications from epidural

steroid injections. *Pain Med.* 2011;12(5):726-731.
190. Schellhas KP, Pollei SR, Johnson BA, Golden MJ, Eklund JA, Pobiel RS. Selective cervical nerve root blockade: experience with a safe and reliable technique using an anterolateral approach for needle placement. *AJNR. American journal of neuroradiology.* 2007;28(10):1909-1914.
191. Pobiel RS, Schellhas KP, Eklund JA, et al. Selective cervical nerve root blockade: prospective study of immediate and longer term complications. *AJNR. American journal of neuroradiology.* 2009;30(3):507-511.
192. Huston CW, Slipman CW, Garvin C. Complications and side effects of cervical and lumbosacral selective nerve root injections. *Archives of physical medicine and rehabilitation.* 2005;86(2):277-283.
193. Ma DJ, Gilula LA, Riew KD. Complications of fluoroscopically guided extraforaminal cervical nerve blocks. An analysis of 1036 injections. *The Journal of bone and joint surgery. American volume.* 2005;87(5):1025-1030.
194. Trentman TL, Rosenfeld DM, Seamans DP, Hentz JG, Stanek JP. Vasovagal reactions and other complications of cervical vs. lumbar translaminar epidural steroid injections. *Pain practice : the official journal of World Institute of Pain.* 2009;9(1):59-64.
195. Everett CR, Baskin MN, Speech D, Novoseletsky D, Patel R. Flushing as a side effect following lumbar transforaminal epidural steroid injection. *Pain physician.* 2004;7(4):427-429.
196. Botwin KP, Gruber RD, Bouchlas CG, et al. Complications of fluoroscopically guided caudal epidural injections. *American journal of physical medicine & rehabilitation.* 2001;80(6):416-424.
197. DeSio JM, Kahn CH, Warfield CA. Facial flushing and/or generalized erythema after epidural steroid injection. *Anesthesia and analgesia.* 1995;80(3):617-619.
198. Cicala RS, Westbrook L, Angel JJ. Side effects and complications of cervical epidural steroid injections. *Journal of pain and symptom management.* 1989;4(2):64-66.
199. Goldstein NP, McGuckin WF, McKenzie BF, Mattox VR. Experimental intrathecal administration of methylprednisolone acetate in multiple sclerosis. *Transactions of the American Neurological Association.* 1970;95:243-244.
200. Nelson DA, Vates TS, Jr., Thomas RB, Jr. Complications from intrathecal steroid therapy in patients wsith multiple sclerosis. *Acta neurologica Scandinavica.* 1973;49(2):176-188.
201. Kotani N, Kushikata T, Hashimoto H, et al. Intrathecal methylprednisolone for intractable postherpetic neuralgia. *The New England journal of medicine.* 2000;343(21):1514-1519.
202. Manchikanti L, Malla Y, Wargo BW, Cash KA, Pampati V, Fellows B. A prospective evaluation of complications of 10,000 fluoroscopically directed epidural injections. *Pain physician.* 2012;15(2):131-140.
203. Manchikanti L, Benyamin RM. Key safety considerations when administering epidural steroid injections. *Pain management.* 2015;5(4):261-272.
204. Manchikanti L, Hirsch JA. Neurological complications associated with epidural steroid injections. *Current pain and headache reports.* 2015;19(5):482.
205. Matsui H, Tsuji H, Kanamori M, Kawaguchi Y, Yudoh K, Futatsuya R. Laminectomy-induced arachnoradiculitis: a postoperative serial MRI study. *Neuroradiology.* 1995;37(8):660-666.
206. Abhinav K, Bradley M, Aquilina K, Patel NK. Spinal arachnoiditis and cyst formation with subarachnoid haemorrhage. *British journal of neurosurgery.* 2012;26(4):574-575.
207. Etchepare F, Roche B, Rozenberg S, Dion E, Bourgeois P, Fautrel B. Post-lumbar puncture arachnoiditis. The need for directed questioning. *Joint, bone, spine : revue du rhumatisme.* 2005;72(2):180-182.
208. Food and Drug Administration. FDA drug safety communication: FDA requires label changes to warn of rare but serious neurologic problems after epidural corticosteroid injections for pain. 2014; Available at: https://www.fda.gov/downloads/Drugs/DrugSafety/UCM394286.pdf. Accessed May 15, 2018.
209. Food and Drug Administration. FDA briefing document: anesthetic and analgesic drug products advisory committee meeting 2014; Available at: https://www.pharmamedtechbi.com/~/media/Supporting%20Documents/The%20Pink%20Sheet%20DAILY/2014/N Accessed May 15, 2018.
210. Horlocker TT, Bajwa ZH, Ashraf Z, et al. Risk assessment of hemorrhagic complications associated with nonsteroidal antiinflammatory medications in ambulatory pain clinic patients undergoing epidural steroid injection. *Anesthesia and analgesia.* 2002;95(6):1691-1697, table of contents.
211. Shah RV, Kaye AD. Bleeding risk and interventional pain management. *Current opinion in anaesthesiology.* 2008;21(4):433-438.
212. Gustafsson H, Rutberg H, Bengtsson M. Spinal haematoma following epidural analgesia. Report of a patient with ankylosing spondylitis and a bleeding diathesis. *Anaesthesia.* 1988;43(3):220-222.

213. Endres S, Shufelt A, Bogduk N. The risks of continuing or discontinuing anticoagulants for patients undergoing common interventional pain procedures. *Pain Med.* 2016.
214. Goodman BS, House LM, Vallabhaneni S, Mallempati S, Willey M, Smith M. Anticoagulant and antiplatelet management for spinal procedures: a prospective, descriptive study. *Pain Med.* 2016.
215. Reitman CA, Watters W, 3rd. Subdural hematoma after cervical epidural steroid injection. *Spine.* 2002;27(6):E174-176.
216. Ain RJ, Vance MB. Epidural hematoma after epidural steroid injection in a patient withholding enoxaparin per guidelines. *Anesthesiology.* 2005;102(3):701-703.
217. Benyamin RM, Vallejo R, Wang V, Kumar N, Cedeno DL, Tamrazi A. Acute Epidural Hematoma Formation in Cervical Spine After Interlaminar Epidural Steroid Injection Despite Discontinuation of Clopidogrel. *Regional anesthesia and pain medicine.* 2016;41(3):398-401.
218. Benzon HT, Wong HY, Siddiqui T, Ondra S. Caution in performing epidural injections in patients on several antiplatelet drugs. *Anesthesiology.* 1999;91(5):1558-1559.
219. Loomba V, Kaveeshvar H, Dwivedi S. Paraplegia After Thoracic Epidural Steroid Injection. *A & A case reports.* 2016;7(5):118-121.
220. Page J, Moisi M, Oskouian RJ. Lumbar Epidural Hematoma Following Interlaminar Fluoroscopically Guided Epidural Steroid Injection. *Regional anesthesia and pain medicine.* 2016;41(3):402-404.
221. Xu R, Bydon M, Gokaslan ZL, Wolinsky JP, Witham TF, Bydon A. Epidural steroid injection resulting in epidural hematoma in a patient despite strict adherence to anticoagulation guidelines. *Journal of neurosurgery. Spine.* 2009;11(3):358-364.
222. Kovesi T, Royston D. Is there a bleeding problem with platelet-active drugs? *British journal of anaesthesia.* 2002;88(2):159-163.
223. Rozin L, Rozin R, Koehler SA, et al. Death during transforaminal epidural steroid nerve root block (C7) due to perforation of the left vertebral artery. *The American journal of forensic medicine and pathology.* 2003;24(4):351-355.
224. Wallace MA, Fukui MB, Williams RL, Ku A, Baghai P. Complications of cervical selective nerve root blocks performed with fluoroscopic guidance. *AJR. American journal of roentgenology.* 2007;188(5):1218-1221.
225. Ziai WC, Ardelt AA, Llinas RH. Brainstem stroke following uncomplicated cervical epidural steroid injection. *Archives of neurology.* 2006;63(11):1643-1646.
226. Craig DB, Habib GG. Flaccid paraparesis following obstetrical epidural anesthesia: possible role of benzyl alcohol. *Anesthesia and analgesia.* 1977;56(2):219-221.
227. Feasby TE, Hahn AF, Gilbert JJ. Neurotoxicity of bacteriostatic water. *The New England journal of medicine.* 1983;308(16):966-967.
228. Hahn AF, Feasby TE, Gilbert JJ. Paraparesis following intrathecal chemotherapy. *Neurology.* 1983;33(8):1032-1038.
229. Hetherington NJ, Dooley MJ. Potential for patient harm from intrathecal administration of preserved solutions. *The Medical journal of Australia.* 2000;173(3):141-143.
230. Chiluka VL, Banji D, Banji OJF, Sollu M, Pandra SB. Glucocorticoid induced osteoporosis. *Intern J Pharm Sci Rev.* 2010;53:124-131.
231. Kang SS, Hwang BM, Son H, Cheong IY, Lee SJ, Chung TY. Changes in bone mineral density in postmenopausal women treated with epidural steroid injections for lower back pain. *Pain physician.* 2012;15(3):229-236.
232. Kim S, Hwang B. Relationship between bone mineral density and teh frequent administration of epidural steroid injections in postmenopausal women with low back pain. *Pain research & management.* 2014;19(1):30-34.
233. Yi Y, Hwang B, Son H, Cheong I. Low bone mineral density, but not epidural steroid injection, is associated with fracture in postmenopausal women with low back pain. *Pain physician.* 2012;15(6):441-449.
234. Bouvard B, Legrand E, Audran M, Chappard D. Glucocorticoid-induced osteoporosis: A review. *Clin Rev Bone Miner Metab.* 2010;8:15-26.
235. Van Staa TP, Leufkens HG, Cooper C. The epidemiology of corticosteroid induced osteoporosis: a meta-analysis. *Osteoporos Int.* 2002;13:777-787.
236. Mandel S, Schilling J, Peterson E, Rao DS, Sanders W. A retrospective analysis of vertebral body fractures following epidural steroid injections. *The Journal of bone and joint surgery. American volume.* 2013;95(11):961-964.

237. Carreon LY, Ong KL, Lau E, Kurtz SM, Glassman SD. Risk of Osteoporotic Fracture After Steroid Injections in Patients With Medicare. *Am J Orthop (Belle Mead NJ).* 2017;46(5):E293-E300.
238. Even JL, Crosby CG, Song Y, McGirt MJ, Devin CJ. Effects of epidural steroid injections on blood glucose levels in patients with diabetes mellitus. *Spine.* 2012;37(1):E46-50.
239. Gonzalez P, Laker SR, Sullivan W, Harwood JE, Akuthota V. The effects of epidural betamethasone on blood glucose in patients with diabetes mellitus. *PM & R : the journal of injury, function, and rehabilitation.* 2009;1(4):340-345.
240. Zufferey P, Bulliard C, Gremion G, Saugy M, So A. Systemic effects of epidural methylprednisolone injection on glucose tolerance in diabetic patients. *BMC research notes.* 2011;4:552.
241. Botwin KP, Gruber RD. Lumbar epidural steroid injections in the patient with lumbar spinal stenosis. *Physical medicine and rehabilitation clinics of North America.* 2003;14(1):121-141.
242. Younes M, Neffati F, Touzi M, et al. Systemic effects of epidural and intra-articular glucocorticoid injections in diabetic and non-diabetic patients. *Joint, bone, spine : revue du rhumatisme.* 2007;74(5):472-476.
243. Millefert JF, Aho S, Huguenin MC. Systemic effects of epidural dexamethasone injections. *Rev Rhum Engl Ed.* 1995;62:429-432.
244. Hsu D, Fu P, Gyermek L, Tan C. Comparison of plasma cortisol and ACTH profile after a single lumbar epidural dose of triamcinolone 40 mg, 80 mg respectively in low back pain patients. *Anesthesia and analgesia.* 1996;82:S191.
245. Camacho M, Mugnier B, Foutrier MC, Roux H. Glucocorticoid induced spinal epidural lipomatosis. *Rev Rhum Ed Fr.* 2001:648-653.
246. Danielson KD, Harrast MA. Focal spinal epidural lipomatosis after a single epidural steroid injection. *PM & R : the journal of injury, function, and rehabilitation.* 2011;3(6):590-593.
247. Fessler RG, Johnson DL, Brown FD, Erickson RK, Reid SA, Kranzler L. Epidural lipomatosis in steroid-treated patients. *Spine.* 1992;17(2):183-188.
248. Koch CA, Doppman JL, Patronas NJ, Nieman LK, Chrousos GP. Do glucocorticoids cause spinal epidural lipomatosis? When endocrinology and spinal surgery meet. *Trends in endocrinology and metabolism: TEM.* 2000;11(3):86-90.
249. Moller J, Girschick HJ, Hahn G, Pessler F. [Steroid-induced spinal epidural lipomatosis in pediatric patients]. *Zeitschrift fur Rheumatologie.* 2010;69(5):447-449.
250. Russell NA, Belanger G, Benoit BG, Latter DN, Finestone DL, Armstrong GW. Spinal epidural lipomatosis: a complication of glucocorticoid therapy. *The Canadian journal of neurological sciences. Le journal canadien des sciences neurologiques.* 1984;11(3):383-386.
251. Brill S, Swartz A, Brill G. Epidural steroid injections do not induce weight gain. *Current drug safety.* 2007;2(2):113-116.

*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

Development Chronology for this Practice Parameter

2019 (Resolution 14)

Amended 2020 (Resolution 8)

Amended 2022 (Resolution 41f)

Amended 2023 (Resolution 2c, 2d)