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General

Understanding the Landscape of Lumbar Epidural Steroid Injections: A Review of Interlaminar, Transforaminal, and Caudal Approaches

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Purpose of the Review

Lumbar epidural steroid injections (ESIs) have been used for decades for managing lumbosacral pain, particularly in patients with radiculopathy and chronic low back pain. Despite frequent use, there remains debate regarding their overall effectiveness, fueled by variability in physician technique and differing opinions on the optimal approach. This narrative review examines the three primary methods of lumbar ESI administration—transforaminal, interlaminar, and caudal—to evaluate their respective advantages, limitations, and clinical applications.

Summary

Each ESI technique offers unique benefits and potential risks. The transforaminal approach provides targeted delivery to affected nerve roots but is associated with higher risks of complications such as nerve injury or vascular compromise. The interlaminar approach allows broader spread of injectate with a lower technical complexity but may lack precision in targeting the specific source of pain. The caudal approach, typically reserved for patients with altered spinal anatomy or prior lumbar surgery, offers the safest trajectory but often the least precise medication delivery. Outcomes with ESIs are highly variable, which contributes to the ongoing debate about their role in lumbosacral pain management.

Conclusion

Understanding the technical differences, risk profiles, and clinical indications of each lumbar ESI approach can help guide treatment planning and optimize outcomes. By tailoring the injection technique to the individual patient's anatomy and clinical presentation, physicians may improve both the efficacy and safety of epidural steroid injections in the treatment of lumbosacral pain.

INTRODUCTION

Although epidural steroid injections (ESIs) are not typically the first-line treatment for common back pain conditions, they have become a widely used option when conservative therapies have failed. Lumbar ESIs are indicated for the management of various conditions, including lumbosacral radiculopathy caused by herniated discs, spinal stenosis, and postlaminectomy syndrome.[1-3] Several techniques have been developed for depositing medication into the epidural space in the lumbar spine including transforaminal (TFESI), interlaminar (ILESI), and caudal approaches.[4-12] ESIs are commonly performed after preprocedural imaging review and under fluoroscopic guidance to ensure patient safety and procedural accuracy.[13] This review will explore the anatomical considerations, clinical indications, and key differences among the various techniques used for lumbar ESIs.

ANATOMICAL CONSIDERATIONS

The spinal cord and nerve roots are safeguarded within the spinal canal, which is formed by the vertebral body anteriorly, pedicles laterally, and laminae posteriorly.[14,15] The superior and inferior articular processes, which project from the junction of the pedicles and laminae, articulate with those of adjacent vertebrae to form the facet joints, contributing to spinal stability and allowing for limited mo-

tion.[14,15] The transverse processes extend laterally from the junction between the pedicles and lamina. Together, the vertebral bodies, pedicles, and lamina form the walls of the vertebral foramen which protects the spinal nerve roots.[14,15] The anatomical configuration of these foramina, laminae, and facet joints is central to understanding the different epidural injection techniques.

In the interlaminar approach (ILESI), the needle is inserted between two adjacent laminae, typically at the midline or just paramedian, traversing the supraspinous ligament, interspinous ligament, and ligamentum flavum before entering the posterior epidural space. This space lies just anterior to the ligamentum flavum and posterior to the dura mater and allows for the delivery of injectate that can spread cephalad and caudad within the epidural compartment.[4,6,16] In contrast, the transforaminal approach (TFESI) involves inserting the needle through the neural foramen to administer the injectate closer to the nerve roots.[10] This technique allows for precise delivery of medication directly to the site of nerve irritation or compression, making it ideal for focal radiculopathy. The needle typically passes through skin, subcutaneous tissue, paraspinal muscles, and is advanced under fluoroscopic guidance to avoid contact with vascular and neural structures.[10] The sacral hiatus is a key anatomical landmark for performing caudal ESIs. It is located at the lower end of the sacrum, where the laminae of the S4 and S5 vertebrae fail to fully fuse, creating an opening at the posterior aspect of the sacrum.[11,14,15] The caudal space, also known as the sacral canal, extends from the sacral hiatus and continues superiorly within the sacrum. This canal contains the terminal portion of the dural sac, nerve roots of the cauda equina, and fatty tissue. When performing a caudal epidural injection, a needle is introduced through the sacral hiatus into the caudal space, allowing for the delivery of medications, such as steroids or anesthetics, to the epidural space.[9,11,14,15] This technique is often preferred in patients with prior lumbar surgery or anatomical distortions that make interlaminar or transforaminal approaches challenging.

A thorough understanding of spinal anatomy and the anatomical variations affecting epidural space access is essential for selecting the most appropriate injection technique, reducing the risk of complications, and enhancing clinical outcomes. The following sections explore each of the three primary lumbar epidural steroid injection techniques—interlaminar, transforaminal, and caudal—in greater detail. Each approach offers unique clinical advantages and considerations based on patient-specific factors.

INTERLAMINAR EPIDURAL INJECTIONS

The interlaminar approach (ILESI) is a widely used technique for delivering medication into the lumbar epidural space. It is particularly well-suited for patients with multilevel pathology, central canal stenosis, or axial low back pain, as the injectate tends to spread more broadly within the posterior epidural space.

Anatomically, the posterior elements of the lumbar spine are composed of several ligaments that stabilize the spine and provide access landmarks for the interlaminar approach. The outermost supraspinous ligament travels vertically along the tips of each spinous process.[7,8] Deep to this, the interspinous ligament spans the space between adjacent spinous processes in the midsagittal plane. The inner ligament, the ligamentum flavum, attaches the posterior surface of the laminae and forms the posterior border of the epidural space.[6,7]

The interlaminar space is accessed for ILESI by identifying the level of pathology and guiding a needle through the skin, subcutaneous fat, supraspinous ligament, interspinous ligament, and ligamentum flavum between the two adjacent spinous processes at the midsagittal plane.[11,12] The loss of resistance (LOR) technique has traditionally been used to confirm entry into the epidural space, but studies have shown this method alone may result in inaccurate needle placement in up to 25% of cases, potentially leading to extradural injection resulting in decreased efficacy.[7] As a result, fluoroscopic guidance has become standard practice. Fluoroscopy allows for real-time visualization of bony landmarks, needle trajectory, and contrast spread, ensuring that the needle is placed at the correct spinal level and that the injectate is accurately delivered into the epidural space.[17]

ADVANTAGES

The interlaminar approach allows for a broader spread of the injectate in the dorsal epidural space, which may be particularly useful in patients with multilevel degenerative changes or stenosis. It is technically easier to perform than the transforaminal approach and generally better tolerated in cases requiring bilateral or central symptom management.

DISADVANTAGES

Despite its utility, the ILESI approach is less precise in targeting a specific nerve root or localized pathology. There is also a higher potential for complications such as dural puncture and inadvertent intrathecal injection, particularly if the ligamentum flavum is thin or disrupted. Furthermore, ILESI should be avoided at levels with prior laminectomy or surgical scarring, as the absence of normal anatomical landmarks increases the risk of complications and decreases the likelihood of successful injectate placement. Additionally, this technique may be less effective for focal radicular pain caused by foraminal stenosis or lateral disc herniation, where a more targeted delivery may be preferable.

TRANSFORAMINAL EPIDURAL INJECTIONS

While the interlaminar approach is useful for central or multilevel lumbar pathology, it may be less effective in cases where precise targeting of an affected nerve root is needed. The transforaminal approach (TFESI) is a targeted technique used to deliver medication targeting a specific nerve root. This method is especially useful in cases of

unilateral radiculopathy, focal disc herniation, or foraminal stenosis.[18,19]

The intervertebral foramen, where transforaminal injections are placed, is located between the superior and inferior vertebral notches of adjacent vertebrae pedicles. It is bordered by the vertebral bodies and intervertebral discs anteriorly and by the zygapophysial joint between the articular processes posteriorly.[14,15] Given the narrow anatomy and proximity to critical structures, fluoroscopic guidance is essential for accurate needle placement and to minimize the risk of complications such as vascular injection, nerve injury, or inadvertent disc puncture.[20,21]

There are two commonly referenced approaches when performing a lumbar transforaminal epidural steroid injection: the subpedicular or "safe triangle" approach and Kambin's triangle approach.[10,20,21] These techniques differ primarily in terms of needle placement and the proximity to neural and vascular structures.[22,23] While both are designed to optimize medication delivery while minimizing risk, the specific anatomical and technical distinctions between the two fall beyond the scope of this review.

During advancement of the needle for lumbar TFESIs it passes through several anatomical layers, including the skin, subcutaneous fat, posterior thoracolumbar fascia, lumbar paraspinal muscles, and the middle layer of the thoracolumbar fascia.[15,22,23] TFESIs carry a higher risk compared to other epidural approaches due to the proximity of vascular and neural structures. In rare cases, inadvertent vascular injection can lead to serious complications such as spinal cord infarction and paralysis.[22-24] Intradiscal injection is also possible, which may lead to discitis in rare cases.[25] Therefore, strict vigilance is necessary. The use of multiplanar fluoroscopic imaging and contrast injection is essential to confirm accurate needle placement and avoid intravascular administration.

ADVANTAGES

TFESIs offer precise, targeted delivery of corticosteroids and anesthetics directly to the affected nerve root, often resulting in superior symptom relief for patients with focal radiculopathy or foraminal pathology. Their targeted nature typically requires a lower total volume of injectate compared to other approaches. In addition to their therapeutic benefit, TFESIs also serve a diagnostic purpose—helping to confirm the symptomatic level of pathology, which can be particularly useful in surgical planning if conservative management fails.

DISADVANTAGES

Despite their benefits, TFESIs carry a higher risk profile compared to other ESI techniques. Potential complications include vascular injection, nerve injury, inadvertent disc entry, and, in rare cases, spinal cord infarction—particularly when anatomical variations are present or technical precision is lacking. The procedure is technically more complex, requiring detailed knowledge of spinal anatomy, careful fluoroscopic interpretation, and skillful needle manipulation to avoid critical structures while achieving accurate placement.

CAUDAL EPIDURAL INJECTIONS

Although the transforaminal approach offers the most precise medication delivery, it carries a higher risk of neural and vascular complications and may not be feasible in patients with distorted anatomy or prior surgeries. In these situations, the caudal approach offers a safer, more accessible route to the epidural space, particularly in those with complex lumbar anatomy. The caudal epidural approach accesses the epidural space through the sacral hiatus, an anatomical opening at the distal end of the sacrum where the laminae of the S4 and S5 vertebrae fail to fuse. This entry point provides access to the caudal epidural space, allowing for the delivery of medications to treat conditions such as lumbosacral radiculopathy, chronic low back pain, and persistent pain after spinal surgery.[9,11,26]

To perform a caudal epidural injection, the needle is inserted into the sacral canal under fluoroscopic guidance. This approach is especially beneficial for patients with altered lumbar anatomy, extensive post-surgical changes, or when interlaminar or transforaminal approaches are contraindicated or technically difficult. Fluoroscopy is used not only to guide the needle but also to confirm proper contrast spread within the epidural space, ensuring accurate medication delivery to the target region. Compared to other epidural techniques, caudal injections carry a lower risk of vascular or neural injury, making them a relatively safe and effective option, particularly in patients with complex spinal anatomy or prior surgical interventions.[11,27]

ADVANTAGES

The caudal approach is safer in patients with altered anatomy or prior lumbar surgery, as it avoids critical neural and vascular structures. It provides access to the epidural space when interlaminar or transforaminal routes are not feasible, and it carries a lower risk of dural puncture and nerve injury. Fluoroscopic guidance enhances safety and ensures appropriate injectate spread.

DISADVANTAGES

Caudal ESIs may result in less targeted delivery, especially for upper lumbar pathology, due to variable cranial spread. Larger injectate volumes are often required, which can reduce procedural efficiency. Catheter guided injections through the canal can be used but may be more challenging and requires increased procedural time. Anatomical variations or prior sacral surgeries may complicate access, and this technique may be less effective for focal radiculopathy compared to transforaminal approaches.

This table summarizes the key advantages and disadvantages of the three primary approaches for lumbar epidural steroid injections: caudal, interlaminar, and transforaminal. Each approach offers unique technical and clinical ben-

Table 1. Comparison of Lumbar Epidural Steroid Injection Approaches: Advantages and Disadvantages

Approach	Advantages	Disadvantages
Interlaminar (ILESI)	• Broader spread of injectate • Better for bilateral or central symptoms • Relatively easy to perform • Well-suited for multilevel pathology	• Less precise targeting • Potential for dural puncture • Potential for intrathecal injection • Should not be used in cases of prior laminectomy near the levels of interest • May be less effective in foraminal/anterior pathology
Transforaminal (TFESI)	• Targeted delivery to nerve root • Avoids midline structures, can be used in cases of prior laminectomy • Provides enhanced diagnostic value • Lower injectate volume needed	• Higher risk of nerve injury, spinal cord infarction, intradiscal injection, and vascular injection • Technically more challenging • May be more painful
Caudal	• Lower risk of dural puncture and neural injury • Safer in post-surgical or altered anatomy • Easier access via sacral hiatus	• Less targeted drug delivery • Variable cranial spread • Larger injectate volume may be needed (unless catheter is used)

efits, and the choice of technique should be based on patient anatomy, pathology, and procedural risk profile.

CONCLUSION

Lumbar ESIs remain a key component for non-surgical management of chronic lumbosacral pain and radiculopathy. This review highlights the three primary approaches—interlaminar, transforaminal, and caudal—each with distinct anatomical targets, technical considerations, and clinical advantages. The interlaminar approach allows for broad epidural spread and is often preferred for bilateral or central pathology. The transforaminal approach offers the most precise delivery to an affected nerve root, making it ideal for focal radiculopathy, though it carries a higher risk profile. The caudal approach, while less targeted, provides a safer alternative in patients with complex post-surgical anatomy or when other routes are not feasible. Understanding the strengths and limitations of each technique is essential for tailoring treatment to individual patient needs and optimizing outcomes. By selecting the appropriate approach based on anatomical, pathological, and patient-specific factors, clinicians can enhance both the efficacy and safety of epidural steroid injections.

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