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INTERVENTIONAL MSK PROCEDURES SPECIAL FEATURE: REVIEW ARTICLE

A review of percutaneous techniques for low back pain and neuralgia: current trends in epidural infiltrations, intervertebral disk and facet joint therapies

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ABSTRACT

Low back pain and neuralgia due to spinal pathology are very common symptoms debilitating numerous patients with peak prevalence at ages between 45 and 60 years. Intervertebral discs and facet joints act as pain sources in the vast majority of the cases. Diagnosis is based on the combination of clinical examination and imaging studies. Therapeutic armamentarium for low back pain and neuralgia due to intervertebral discs and/or facet joints includes conservative therapy, injections, percutaneous therapeutic techniques and surgical options. Percutaneous, therapeutic techniques are imaging-guided, minimally invasive treatments which can be performed as outpatient procedures. In cases of facet joint syndrome, they include, apart from injections, neurolysis with radiofrequency/cryoablation, MR-guided high-intensity focused ultrasound and percutaneous fixation techniques. In case of discogenic pain, apart from infiltrations, therapeutic techniques can be classified in to two main categories: decompression (mechanical, thermal, chemical) techniques and biomaterials implantation/disc cell therapies. Strict sterility measures are a prerequisite and should include extensive local sterility and antibiotic prophylaxis. This article will report clinical and imaging findings for each pathology type and the association with treatment decision. In addition, we will describe in detail all possible treatment techniques for low back pain and neuralgia, and we will report recently published results of these techniques summarizing the data concerning safety and effectiveness as well as the level of evidence. Finally, we will try to provide a rational approach for the therapy of low back pain and neuralgia by means of minimally invasive imaging-guided percutaneous techniques.

INTRODUCTION

There is a controversy concerning the original substrate of low back pain and neuralgia because of spinal pathology. There are evolutionary theories suggesting that the vertical support structure works but not as well as the horizontal structure of a quadruped which denotes a "walking bridge".¹ On the other hand, more recent studies blame spinal stress, lack of exercise and poor posture for spinal symptoms because of degeneration.² The fact is that degeneration in the spine is quite common with resultant low back pain, with or without lower extremity pain. Spinal pathology pain is governed by 54–80% lifetime prevalence and 15–45% annual prevalence.³ Low back pain and neuralgia constitute a major portion of pain syndromes with significant social and economic costs and are the most common disability causes in ages <45 years.^{4,5} Intervertebral discs and facet joints act as pain sources in the vast majority of the cases.^{5–7}

Despite the high prevalence of low back pain and neuralgia, it is often difficult to reach a definite diagnosis which on most cases is based upon a combination of clinical examination and imaging studies.^{8–10} Imaging studies include non-invasive modalities such as X-rays, CT and MRI or minimally invasive techniques such as myelography, percutaneous discography and diagnostic infiltrations.⁵

Proposed therapies for low back pain and neuralgia due to intervertebral discs and/or facet joints include conservative therapy, injections (interlaminar, caudal or transforaminal and intra-articular), percutaneous (minimally invasive) techniques and surgical treatments.^{10–17} In case of facet joint syndrome, therapeutic armamentarium includes apart from conservative therapies and injections, neurolysis with radiofrequency (RF)/cryoablation, MR-guided high-intensity focused ultrasound (HIFU) and percutaneous fixation techniques.^{16–22} In case of discogenic pain, alternatives to

conservative therapy and injections include percutaneous minimally invasive therapeutic techniques and surgical options. The former can be classified in to two main categories: decompression (mechanical, thermal, chemical) techniques and biomaterials implantation/disc cell therapies.^{12,16,17,23,24}

Strict sterility measures and informed consent are a prerequisite. Surgical skin preparation is necessary, and the operative field should be draped with sterile sheets. Prophylactic antibiotics should be administered in disc decompression techniques, facet joint denervation and fixation techniques. Absolute contraindications include a patient unwilling to consent to the procedure and local or systemic infection. Haemorrhagic diathesis should be corrected, and anticoagulant therapy should be interrupted according to international guidelines.^{16,17}

Supplies for spinal injections include needles of various gauges (18–25 G), lengths (88–150 mm) and tip shapes (Crawford or Tuochy). Anesthetics used include short- or long-acting agents (e.g. lidocaine 1–2%, bupivacaine 0.25–0.5% etc.) depending on the operator's preference. Steroid preparations include particulate or non-particulate agents (e.g. methylprednisolone suspension, triamcinolone, betamethasone injectable suspension, cortivasol etc.). As far as steroids are concerned only preservative-free agents should be used in order to avoid arachnoiditis in case of inadvertent extension in the sub-arachnoid space. Concerning contrast medium for the verification of correct needle placement, only agents approved for myelography should be used in order to avoid complications in case of inadvertent intrathecal injection. In our department, we perform all our spinal injections with 22 G diameter, 90- to 120-mm length tuochy spinal needle; in our practice, we perform a maximum of four injection sessions per year with a maximum of two injections per session.

This article will report clinical and imaging findings for each pathology type and the association to treatment decision. In addition, we will describe in details all possible treatment techniques for low back pain and neuralgia (due to facet joint and intervertebral disc pathology), and we will report recently published results on these techniques summarizing the data concerning safety and effectiveness as well as the level of evidence. Finally, we will try to provide a rational approach for the therapy of low back pain and neuralgia (due to facet joint and intervertebral disc pathology) by means of minimally invasive imaging-guided percutaneous techniques.

FACET JOINTS

Facet joints are innervated by the medial branches of the dorsal rami; in lumbar facet joints, there are free and encapsulated nerve endings as well as nerves containing substance P and calcitonin gene-related peptide.^{7,25,26} The symmetry and correct orientation of facet joints seem to be fundamental for correct disc function and its protection from abnormal stress, mainly during twisting. Lumbar facet joints constitute a common source of pain accounting for 27–40% of low back pain.²⁷ Degeneration affecting facet joints results in remodeling as an effort of surface increase.²⁸ Imaging findings suggestive of facet joint syndrome include joint space narrowing, intra-articular vacuum

phenomenon or fluid, osteophytes (usually at the upper articular surface of the lower vertebra), synovial cyst formation and hypertrophy of flaval ligaments.^{5,29} Patients complain of low back pain radiating to the thigh, iliac crest and rarely to the groin; pain is exacerbated during pressure, hyperextension, torsion and lateral bending or is worse when waking up from bed or trying to stand after prolonged sitting.^{5,7}

Percutaneous techniques for symptomatic facet joint syndrome include injections, neurolysis with RF/cryoablation, MR-guided HIFU and percutaneous fixation techniques.^{16–22} The initial approach in symptomatic patients with facet joint syndrome should always be standard conservative therapy [non-steroidal anti-inflammatory drugs (NSAIDs), analgesics, physical therapies and/or bracing]. This course can be combined to intra-articular or median branch injections. Alternatively, percutaneous injections can be performed as an intermediate step between conservative therapy, percutaneous techniques (denervation or fixation) and surgical options.

Percutaneous injections

Facet joint injections in the lumbar spine are indicated for diagnostic purposes (in order to differentiate symptomatic from asymptomatic facet joint alterations) or for pain reduction and mobility improvement in cases of painful facet joint syndrome, synovial cysts or spondylolysis.^{5,7,16,17,30} In the vast majority of the reported studies, the injected mixture contains a long-acting corticosteroid (either soluble or non-soluble) with local anesthetic.^{7,16,17} Efficacy of corticosteroids is based upon their anti-inflammatory and antioedematous effect, their immunosuppressive action and the inhibition of neural transmission within the C fibers.^{7,31} Concerning painful facet joint syndrome, intra-articular injection of steroids is effective with a slight superiority over intramuscular route of administration.³²

Special attention must be given to a patient's medical record; infiltrations with corticosteroids might worsen diabetes in a patient, changing the disease from non-insulin to insulin dependent whilst in patients with HIV under antiretroviral therapy rarely Cushing symptoms emerge after steroid infiltration.^{32,33} Alternative injected solutions described in the literature for facet joints include local anaesthetic alone, normal saline or dextrose, ozone or hyaluronic acid.^{7,30,34–37} However, it must be noted that all these injected substances have not been studied as extensively as the mixture of corticosteroid with local anaesthetic.

Imaging guidance for facet joint injections increases technical and clinical efficacy and at the same time decreases potential complications rate.^{16,17,30} Concerning facet joint injections, imaging modalities used for guidance include fluoroscopy, ultrasound, CT and MRI.^{16,17,30,38,39} Owing to the difficulty in image interpretation by operators unfamiliar with the complex spinal sonography, navigation and reconstruction systems are used to generate and fuse sonographic images with the collected CT data sets facilitating multiplanar imaging of ultrasound-guided spine injections.³⁸ The ideal target point is the inferior portion of the joint where the posterior joint recess lies (slightly

Figure 1. Oblique (“Scottie dog”) fluoroscopy view during facet joint infiltration: needle (white dot) is within the L5–S1 left facet joint—contrast medium (white arrow) injection verifies correct intra-articular needle position.

inferolateral to the inferior articular process) (Figure 1). Facet joint injections are performed as outpatient procedures; patients should be accompanied home and avoid driving for the first hours since local anaesthetic could result in delayed reflexes. According to recent systematic reviews,⁷ there is good evidence for diagnostic facet joint infiltrations with 75–100% pain relief as the criterion standard and fair evidence for therapeutic infiltrations with 50–74% pain relief.

Medial branch infiltrations are performed by injecting corticosteroid mixed to local anesthetic right next to the medial branch of the dorsal ramus. Ideal target point is where the superior articular process connects to the base of the transverse process. Medial branch injections are performed not only for pain reduction but for diagnostic purposes as well in order to evaluate which patient could benefit from facet joint denervation by means of RF.

Facet joint denervation

Each facet joint in the lumbar spine is innervated by nerve fibers from medial branch nerves at two levels; for example, the L4–L5 facet joint is innervated by the L3 medial branch superiorly and the L4 medial branch inferiorly.⁴⁰ The ideal candidate for facet joint denervation is the patient who has experienced significant pain relief (even transient) from intra-articular or medial branch infiltrations. Medial branch of the dorsal ramus courses at the junction of the superior articular process with the transverse process (Figure 2). The nerve fibers at that level are destroyed by heat (RF ablation) or cold (cryoablation application). By destroying these fibers, there is a break in the communication link that signals pain from the spine to the brain. Owing to the dual nerve supply of a given facet joint, RF electrodes or cryoprobes are placed in two subsequent levels. Patients may experience significant pain reduction for a mean of 1–2 years, with pain relief success rate of 55–85% at 1 year.^{16,17,41–43}

Facet joint denervation is indicated in symptomatic patients who have exhausted or are unresponsive to conservative therapies (NSAIDs and analgesics, physical therapies) and are responsive to diagnostic blocks (with local anaesthetic) performed on the medial branches supplying the painful facet joints. Such a block is considered positive when there is definite improvement of low back pain over 50% for at least 3 h.⁴³

Facet joint denervation seems to be more effective than placebo in pain control and functional improvement, and there is evidence Level 1 concerning the practice of this technique.⁴⁴ When compared with percutaneous steroid infiltrations, both techniques are governed by favorable short- and midterm results in terms of pain relief and function improvement with a slight superiority of denervation; however, there are no data and evidence for cost-effectiveness.^{44,45}

An alternative, totally non-invasive approach of facet joint denervation is MR-guided HIFU during which the target point is the entire facet surface where nerve endings terminate to innervate the joint.¹⁹ Advantages of this technique include the lack of radiation and the total non-invasive character which eliminates the risk of bleeding and infection; on the other hand, the long duration of the technique, the limited availability and high cost along with the limited evidence for practice constitute significant disadvantages.¹⁹

Percutaneous fixation techniques

Recently, novice percutaneous approaches have been proposed for posterior facet joint fixation aiming to obtain near equivalent immediate stabilization of the lumbar spine.⁴⁶ These techniques

Figure 2. Oblique (“Scottie dog”) fluoroscopy view during facet joint denervation: radiofrequency electrodes have been placed at the junction of the superior articular process with the transverse process (in two subsequent levels) where medial branch of the dorsal ramus courses.

are performed under local anesthesia and/or mild sedation. Owing to their percutaneous nature, they do not need deep dissection preserving thus muscle anatomy and the adjacent facet joint.⁴⁷ Combined imaging guidance by means of C-arm and CT or fluoroscopy with cone beam CT enhances correct fixation placement and avoids soft-tissue or vascular damages by means of augmenting proper choice of the instrument's correct size, length and the orientation of the fixation.⁴⁸

The most commonly used technique for posterior percutaneous facet joint fixation is the transarticular screw fixation; alternatively, intra-articular implants have been proposed.⁴⁹ Fixation techniques could be considered the last resort of percutaneous approach.

INTERVERTEBRAL DISCS

Intervertebral disc herniation is associated with a rupture of the annulus fibrosus and subsequent release of nucleus pulposus. Pathophysiology of discogenic pain includes mechanical pressure effect, inflammatory reaction and neovascularization.⁶ Mechanical effect can be either due to direct pressure from the herniated disc or as an indirect effect resulting in ischaemia caused by pressure upon afferent arterioles and venous stasis. Inflammatory reaction is a cell-mediated autoimmune response associated with production of phospholipase A2, prostaglandin, leukotriene and matrix metalloproteinase.

Therapeutic armamentarium for low back pain and neuralgia due to intervertebral discs includes conservative therapy, injections (interlaminar, caudal or transforaminal), percutaneous therapeutic techniques and surgical options.^{6,12,14–18} Percutaneous therapies for discogenic pain, apart from injections, include techniques which can be classified in two main categories: decompression (mechanical, thermal, chemical) techniques and biomaterials implantation/disc cell therapies^{6,12,14–18,23,24} (Table 1). The initial approach in symptomatic patients with intervertebral disc herniation should always be a minimum of 4–6 weeks standard conservative therapy course with NSAIDs, analgesics, physical therapies and/or bracing. This course can be combined to epidural injections. Alternatively, percutaneous injections can be performed as an intermediate step between conservative therapy, percutaneous decompression techniques and surgical options.

Percutaneous decompression techniques

Percutaneous decompression techniques are based on the Hijkata theory (1975) which stated that "Reduction of intradiscal pressure reduced the irritation of the nerve root and the pain receptors in the annulus and peridiscal area" (Table 2).⁶ Based on the principle that the intervertebral disc is a closed hydraulic space, a small volume change inside the nucleus pulposus results in significant pressure change with subsequent inwards imploding of the herniated fragment.¹²

Ideal candidate is an adult (capable of providing informed consent) suffering from symptomatic contained, small- to medium-sized intervertebral disc herniation occupying less than one-third or half of the canal diameter at MRI.^{6,12,16,17,53} Ideally, there should be failure of 4–6 weeks conservative course therapy usually combined with at least one session of steroid infiltration.

Whenever low back pain and leg pain coexist, neuralgia should be of higher intensity. Finally, symptoms should be consistent with the segmental level where herniation is illustrated at MRI (for example, an L4–L5 right foraminal herniation is expected to produce right L4 root neuralgia).^{6,12,16,17,53}

Absolute contraindications for percutaneous techniques making the case a surgical emergency include sphincter dysfunction, extreme sciatica and progressive neurologic deficit.^{6,12,16,17,53} Other contraindications include an asymptomatic herniation, a sequestered disc fragment (which does not belong any more to a closed hydraulic system), local or systemic infection, spondylolisthesis and patient refusal to provide informed consent.^{6,12,16,17,53} Haemorrhagic diathesis should be corrected, and anticoagulant therapy should be interrupted according to international guidelines prior to percutaneous disc decompression techniques.

Under imaging guidance and percutaneous posterolateral approach, a trocar is inserted in the intervertebral disc. The trocar's final position should be at the middle between the two vertebral end-plates, towards the anterior third of the disc and on the midline. Concerning intervertebral disc approach, imaging modalities used for guidance include fluoroscopy, CT and MRI.^{6,12,16,17,57} Once in the desired position, through the trocar, any decompression device available in the market can be inserted in the disc (Figure 3).

Decompression devices can be classified as mechanical, thermal and chemical. Mechanical decompression devices include either a pneumatically or water-driven suction-cutting probe or a high rotation per minute device with spiral tips or metallic laminae which extract a portion of nucleus pulposus.^{6,12,16,17} Alternatively, a probe inserted through a curved cannula with lateral window can be used to extract hernia or portion of the hernia in order to decrease pressure upon the nerve root.⁵⁸ Thermal decompression devices include laser fibers, RF electrodes (for continuous or pulsed RF energy application), and nucleoplasty based on coblation technology.^{6,12,16,17,55–57,59} Thermal techniques modify intradiscal cytokines associated with disc degeneration, destroy nociceptors in the periphery of the annulus and fuse collagen annular fibers with resultant shrinkage at the disc's periphery.¹² Chemical decompression techniques include intradiscal injection of ozone or of a gellified ethyl alcohol.^{6,16,17,53,54,60,61} Ozone is an unstable irritating gas leading to breakdown of the nucleus pulposus, inflammation reduction and reduction of nerve root oedema. Gellified ethyl alcohol consists of 96% pure ethyl alcohol mixed with tungsten (radio-opaque element); intradiscal injection results in local necrosis of the nucleus pulposus. Injection of gellified ethyl alcohol is advised to be performed under continuous fluoroscopy.^{6,16,17}

Concerning percutaneous decompression techniques (of any kind) for the treatment of intervertebral disc herniation, significant pain reduction is achieved in 75–80% of patients with long-term stable effects.^{6,12,16,17} Comparison of mechanical decompression and conservative therapy favor the former with pain reduction effect being more significant and longer lasting in the patients treated with percutaneous technique.⁵² Complications are rarely encountered; the most fearsome complication is

Table 1. Percutaneous, imaging-guided intervertebral disc techniques

Technique	Method	Definition
Mechanical decompression	Different vendors in the market propose different devices	All these devices are percutaneously placed inside the nucleus pulposus of the intervertebral disc, and during function, they remove a part of the nucleus, decreasing thus the intradiscal pressure in order to allow the herniated fragment to implode inwards
	Mechanical high rotation per minute device with spiral tips	
	Mechanical high rotation per minute device with metallic laminae	Herniotome extracts hernia or portion of the hernia in order to decrease pressure upon the nerve root
	Water-driven suction-cutting probe	
	Pneumatically driven, suction-cutting probe	
	Herniotome	
Thermal decompression	Percutaneous laser decompression	Laser energy vaporizes a part of the nucleus pulposus
	Intradiscal electrothermal therapy	Flexible thermal resistive coil (electrode or catheter) coagulates the disc tissue with radiant heat
	Intervertebral disc nucleoplasty	Bipolar radiofrequency energy causes molecular dissociation and dissolves nuclear material
	Pulsed RF	Pulsed RF uses a high-frequency electric field administered in controlled pulses in order to disrupt the nerve cells carrying the pain signal
Chemical decompression	DiscoGel® (gelified ethanol)	Dehydration of nucleus pulposus
	Ozon therapy	Chemical breakdown of the nucleus pulposus
Biomaterial implantation	Hydrogel	Aim in intervertebral disc regeneration
Cellular therapies	Platelet-rich plasma, stem cell therapy	

RF, radiofrequency.

infection with spondylodiscitis being encountered in 0.24% of patients and 0.091% of disc level of the cases.⁶ Less frequently encountered complications include iatrogenic complications such as puncture of dura or nerve root and haemorrhage.⁶ Despite the fact that these techniques have been utilized for many years, the current evidence for percutaneous decompression techniques is limited to fair mainly because of a lack of literature (both randomized and observational).^{62–64}

Biomaterial implantation/disc cell therapies

There is a continuous interest increase upon cellular therapies aiming in regeneration of nucleus pulposus in a degenerated intervertebral disc. Requirements of such therapies include cells which produce proteoglycan-rich matrix in a challenging natural environment, as a degenerated intervertebral disc is with low cellular density of the intervertebral disc and low quality of nutritional pathway (vertebral end plate changes).^{65,66} Cellular sources (autologous or allogenic) for such therapies include nucleus pulposus cells, chondrocytes and mesenchymal stem cells derived from the bone marrow or adipose tissue.⁶⁶ Several agents have been intradiscally injected in animal studies with promising results including platelet-rich plasma, growth differentiation factor 5, osteogenic protein 1 and bone morphogenetic protein 2 and 17.⁶³ Preliminary results in a restricted number of clinical studies report no safety issues; however, long-term efficacy is still to be proven.⁶⁶ The quest for stem cell therapies aims in prolonged survival of these cells in the discal environment.

Biomaterials (in the form of hydrogel stick implants or any other form available) are percutaneously placed in the centre (nucleus pulposus) of a degenerated disc aiming to restore normal bio-mechanical function. Theoretically, these biomaterials are designed to increase disc height and at the same time retain their shape under pressure. Concerning biomaterial implantation inside the degenerated disc, long-term efficacy as well as safety and potential implant migration are still to be proven.⁶⁷ The quest for replacement of nucleus pulposus aims in biocompatible materials with load-bearing and anchoring capacities.

EPIDURAL INJECTIONS

The dural membrane which surrounds the spinal cord and nerve roots along with the osseous and ligamentous parts which form the vertebral canal is the actual anatomic boundary of the epidural space. The spinal canal is bordered by the spinous process, two vertebral laminae, two vertebral pedicles, two transverse processes and posterior vertebral wall. Inside the spinal canal, the epidural space lies anterior to the flaval ligaments and contains fat, areolar tissue, lymphatics, blood vessels, nerve roots and the thecal sac (Figure 4). The thecal sac divides the epidural space into the anterior compartment (bordered anteriorly by the vertebral body and intervertebral disc, and posteriorly by the longitudinal ligament) and the posterior compartment (bordered posteriorly by the flaval ligaments and vertebral laminae). The neural foramen is the lateral margin of the epidural space whilst the sacral hiatus is its inferior margin. A sleeve of dura and arachnoid matter covers

Table 2. Review of the literature

Condition studied	Technique studied	Study	Patient number	Conclusions
Facet joint syndrome	Injections	Lakemeier et al ⁴⁵	56	Favourable short- and midterm results in terms of pain relief and function improvement
		Ribeiro et al ³²	60	Slight superiority of the intra-articular injection of steroids over intramuscular injection
		Fotiadou et al ⁵⁰	55	Long-term pain improvement was achieved in 79%
	Denervation	Masala et al ²²	92	Medial branch RF neurotomy has a well-established effectiveness in pain and quality of life improvement
		Birkenmaier et al ⁴³	46	Medial branch cryodenervation is a safe and effective treatment for lumbar facet joint pain
	Fixation	Marcia et al ²⁰	38	VAS pain reduction—ODI improvement
		Manfre ⁴⁹	8	Fast and safe technique when facet posterior fixation is needed
		Amoretti et al ⁴⁸	107	Clinical results were classified as excellent in 92 (86%) and good in 15 (14%) patients
Intervertebral disc herniation	Injections	Gossner ⁵¹	231	Safe technique when non-particulate steroids are used
		Fotiadou et al ⁵⁰	31	Long-term pain improvement was achieved in 83%
	Decompression techniques	Erginousakis et al ⁵²	62	When compared with conservative therapy, PDD shows improved amelioration of symptoms at 12- and 24-month follow-up
		Muto et al ⁵³	2200	75% success rate at 18 months (intradiscal ozone)
		Léglise et al ⁵⁴	25	VNS for lumbar pain and radicular pain decreased in 42% and 50% of patients, respectively, after the use of DiscoGel®
		Fukui and Rohof ⁶⁵	15	The mean pain severity score (NRS) improved from 7.27 ± 0.58 pre-treatment to 2.5 ± 0.94 at the 6-month follow-up (pulsed RF)
		Gerszten et al ⁵⁶	90	Patients treated with coblation had significantly reduced pain and better quality of life scores than those treated using repeated injections

NRS, numeric rating scale; ODI, Oswestry Disability Index; PDD, percutaneous disc decompression; RF, radiofrequency; VAS, visual analogue scale; VNS, visual numeric scale.

the exiting nerves until the intervertebral foramen where it thins to become the epineurium. The margins of neural foramen include the facet joint (posterior margin), the vertebral pedicles (superior and inferior margin) and the vertebral body/intervertebral disc (anterior margin). In the lumbar spine, nerve and vessels exit the foramen in its anterior and cephalad part.

Interlaminar epidural infiltrations involve the insertion of a needle between the laminae of successive vertebral bodies (Figure 5).

Transforaminal epidural injections involve the insertion of a needle in the lateral and lower part of the intervertebral foramen. Caudal infiltrations involve the insertion of a needle inside the epidural space through the sacral hiatus. The choice of what approach to use should be made by the treating physician.⁶⁸

Indications for epidural injections include radiculopathy/radiculitis (degenerative, infectious or traumatic), spinal stenosis and spondylosis with axial pain. Epidural injections are

Figure 3. (a) T_2 weighted axial sequence illustration of a posterolateral L4–L5 intervertebral disc herniation (white dot) with pressure effect upon dural sac. (b, c) The same patient. Correct final trocar positioning inside the intervertebral disc—trocar (white arrows) should be located in the anterior third of the disc in the lateral fluoroscopy view (b) and towards the midline in anteroposterior projection (c). (d, e) The same patient. Lateral fluoroscopy (d) and anteroposterior projection (e) illustrating dispersion of DiscoGel® (white arrows) inside the L4–L5 intervertebral disc.

performed as outpatient procedures. Depending on the type of local anaesthetic used, the patient should be monitored in a recovery room for 15–60 min; the patient should be accompanied home and should avoid driving for the first hours since the local anaesthetic could result in delayed reflexes.

In symptomatic patients who are not surgical candidates, epidural injections can be combined with conservative therapy aiming to provide pain reduction and mobility improvement. Transforaminal approach can be performed for radicular pain diagnosis in cases of confusing imaging; in patients complaining of low back pain, transforaminal infiltrations have no diagnostic value because the injectate will affect not only the spinal nerve but also the dura, posterior longitudinal ligament, intervertebral disc and facet joint. Interlaminar or caudal infiltrations have no diagnostic efficacy. Concerning therapeutic purposes, transforaminal approach can be reserved for patients with unilateral symptoms or for patients who have had spinal surgery at the level to be treated. Interlaminar injections should be avoided at the level of prior laminectomy because of the increased chance of dural puncture. Especially in the cervical spine, dural puncture can lead to persistent cerebrospinal fluid leakage and headache. Caudal injections through the sacrococcygeal hiatus seem to be the safest approach to the epidural space with an extremely low risk for dural puncture (the thecal sac ends in the S1 or S2 level in most patients) and for negligible bleeding risk. Caudal approach requires a larger volume of injectate in order to deliver steroid to the pathological site. In case

of post-operative spine with tight stenosis, transforaminal and caudal injections seem to have better results than the interlaminar approach. Alternatively, in these patients, operators prefer a combined interlaminar and caudal approach.

Figure 4. Epidural space is a circumference bounded by the spinous process (white rectangle), flaval ligaments (white dots) and the posterior vertebral wall (white line). Inside the circumference lies the thecal sac which divides the epidural space into the anterior and posterior compartments.

Figure 5. (a) Lateral fluoroscopy view during epidural infiltration through the sacrococcygeal hiatus (caudal infiltration). Contrast medium injection verifies correct needle location and desired dispersion inside the epidural space. (b) Different patient. Lateral fluoroscopy view during epidural infiltration with an interlaminar approach. Contrast medium injection verifies correct needle location inside the epidural space and outside the dural sac as well as desired dispersion inside the epidural space. (c) Different patient. anteroposterior fluoroscopy view during epidural infiltration with a transforaminal approach. Needle should be located at the lateral and lower margin of the foramen. Contrast medium injection verifies correct needle location (intraforaminal, extravascular).

According to recently published Consensus Opinions from Multidisciplinary Working Group and National Organizations, all epidural injections in the lumbar spine should be performed under imaging guidance and a test dose of contrast medium.⁶⁸ Concerning epidural injections, imaging modalities used for guidance include fluoroscopy, CT and MRI.^{16,17,50,51,69–71} Ultrasound guidance with navigation systems can be used for periradicular (i.e. transforaminal) injections.³⁸ Blind epidural interlaminar injections without any imaging guidance result in incorrect needle placement in >25% of the cases.⁷²

Recent systematic reviews support that there is good evidence for epidural injections in cases of radiculitis due to intervertebral disc herniation and fair evidence in cases of radiculitis due to spinal stenosis; in all cases, there is evidence illustrating superiority of steroids mixed to local anaesthetic rather than local anaesthetic alone.^{13–15,69–71,73}

Epidural injections are rarely associated with minor complications and side effects, such as dural puncture, pain exacerbation, vasovagal reaction and headache; all these side effects and complications do not involve any permanent impairment.⁶⁸ However, rarely there are reported cases of catastrophic spinal cord injuries post epidural infiltrations with steroids and local anaesthetic; the number of these reported cases suggests that the risk is not negligible.^{68,74} Possible mechanisms for such injury include unintended intra-arterial injection of particulate steroids or vessel penetration resulting in perforation, pseudoaneurysm or vasospasm.^{68,74} The most possible injury mechanism is the unintended intra-arterial injection of particulate steroids which could act as embolization particles.^{68,74} Proper imaging guidance and use of contrast medium for verification of correct needle placement minimizes the risk of such catastrophic injury.^{68,74} In addition, one can use non-particulate steroids in the initial injection and extension tubing can be used to minimize the risk of needle being dislodged.⁶⁸

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