REVIEW

Epiduroscopy for Patients With Lumbosacral Radicular Pain

Jan Willem Kallewaard, MD, FIPP*; Pascal Vanelderen, MD, FIPP[†,‡]; Jonathan Richardson, MD, FFPMRCA, FRCP, FIPP[§]; Jan Van Zundert, MD, PhD, FIPP[†]; James Heavner, MD, FIPP[¶]; Gerbrand Jan Groen, MD, PhD**

**Department of Anesthesiology and Pre-operative Screening and Pain Center, Rijnstate Hospital Velp, Velp, The Netherlands; [†]Department of Anesthesiology and Multidisciplinary Pain Center, Ziekenhuis Oost-Limburg, Genk, Belgium; [‡]Department of Anesthesiology, Pain and Palliative Medicine, Radboud University Medical Center, Nijmegen, The Netherlands; [§]Department of Anesthesiology, Bradford Royal Infirmary, Bradford, U.K.; [¶]Department of Anesthesiology, TTUHSC, Lubbock, Texas U.S.A.; **Department of Anesthesiology and Pain Management, University Medical Center Groningen, Groningen, The Netherlands*

■ **Abstract:** Lumbosacral radicular pain is a pain in the distribution area of one of the nerves of the lumbosacral plexus, with or without sensory and/or motor impairment. A major source of lumbosacral radicular pain is failed back surgery, which is defined as persistent or recurrent pain, mainly in the region of the lower back and legs even after technically, anatomically successful spine surgeries. If lumbosacral radicular neuropathic pain fails to respond to conservative or interventional treatments, epiduroscopy can be performed as part of a multidisciplinary approach. Epiduroscopy aids in identifying painful structures in the epidural space, establishing a diagnosis and administering therapy. The novelty consists in the use of an epiduroscope to deliver therapies such as adhesiolysis and targeted administration of epidural medications. Clinical trials report favorable treatment outcomes in 30% to 50% of patients. Complications are rare and related to the rate or volume of epidural fluid infusion or inadvertent dural puncture. In patients with lumbosacral radicular pain, especially after back surgery, epiduroscopy with adhesiolysis may be considered (evidence rating 2 B+). ■

Address correspondence and reprint request to: Jan Willem Kallewaard, MD, FIPP, Department of Anesthesiology and Pre-operative Screening and Pain Center, Rijnstate Velp, President Kennedylaan 100, 6883 AZ Velp. E-mail: jkallewaard@rijnstate.nl.

Submitted: January 27, 2013; Revision accepted: June 03, 2013
DOI. 10.1111/papr.12104

Pain Practice, Volume ●●, Issue ●, 2013 ●●–●●

Key Words: epiduroscopy, adhesiolysis, evidence-based medicine, low back pain, systematic review

INTRODUCTION AND RATIONALE FOR THE USE OF EPIDUROSCOPY

This review on epiduroscopy is part of the series "Evidence-based Interventional Pain Medicine According to Clinical Diagnoses." Recommendations formulated in this article are based on "Grading strength of recommendations and quality of evidence in clinical guidelines" described by Guyatt et al.,[1] and adapted by van Kleef et al.[2] in the editorial accompanying the first article of this series (Table 1). The latest literature update was performed in May 2012.

Lumbosacral radicular pain defined as pain in the distribution area of one of the nerves of the lumbosacral plexus, with or without sensory and/or motor impairment.[3–6] In randomized trials, less than 50% of patients achieve adequate pain relief from drugs and side effects often dissuade their use. Moreover, medications

Table 1. Summary of Evidence Scores and Implications for Recommendation

Score	Description	Implication
1 A+	Effectiveness demonstrated in various RCTs of good quality. The benefits clearly outweigh risk and burdens	Positive recommendation
1 B+	One RCT or more RCTs with methodological weaknesses, demonstrate effectiveness. The benefits clearly outweigh risk and burdens	
2 B+	One or more RCTs with methodological weaknesses, demonstrate effectiveness. Benefits closely balanced with risk and burdens	
2 B□	Multiple RCTs, with methodological weaknesses, yield contradictory results better or worse than the control treatment. Benefits closely balanced with risk and burdens, or uncertainty in the estimates of benefits, risk and burdens.	Considered, preferably study-related
2 C+	Effectiveness only demonstrated in observational studies. Given that there is no conclusive evidence of the effect, benefits closely balanced with risk and burdens	
0	There is no literature or there are case reports available, but these are insufficient to prove effectiveness and/or safety. These treatments should only be applied in relation to studies.	Only study-related
2 C−	Observational studies indicate no or too short-lived effectiveness. Given that there is no positive clinical effect, risk and burdens outweigh the benefit	Negative recommendation
2 B−	One or more RCTs with methodological weaknesses, or large observational studies that do not indicate any superiority to the control treatment. Given that there is no positive clinical effect, risk and burdens outweigh the benefit	
2 A−	RCT of a good quality, which does not exhibit any clinical effect. Given that there is no positive clinical effect,risk and burdens outweigh the benefit	

RCT, randomized controlled trial.

effective in diabetic polyneuropathy and postherpetic neuralgia failed to demonstrate superiority over placebo in radicular neuropathic pain.[7–9] Failed back surgery syndrome (FBSS) is a major source of lumbosacral radicular pain[10] defined as persistent or recurrent pain, mainly in the region of the lower back and legs even after technically, anatomically successful spine surgeries.[11] Possible causes of FBSS are postoperative inflammation or epidural fibrosis.

If lumbosacral radicular neuropathic pain fails to respond to conservative treatment such as physical therapy and medication or interventional treatments such as transforaminal epidural corticosteroid injections, Racz procedure, or (pulsed) radiofrequency treatment adjacent to the dorsal root ganglion, epiduroscopy can be performed as part of a multidisciplinary approach before spinal cord stimulation is considered. Epiduroscopy offers several advantages: (1) confirmation of the diagnosis of radicular pain; (2) mechanical removal of adhesions; and (3) targeted administration of drugs.

As early as 1931, Burman[12] used arthroscopic equipment to examine the anatomy of the vertebral column removed from cadavers. A few years later, the American neurosurgeon, Pool,[13] reported on over 400 spinal endoscopies. Later, Ooi also applied the technique in patients.[14] These early studies specifically inspected the intrathecal space. Afterward, the technique was primarily used for examining the epidural space.[15,16] Shimoji et al.[17] added 2 important features to the technique, namely performing epiduroscopy under conscious sedation and identifying the affected nerve root by touching it and reproducing the patient's pain. In 1994, Saberski and Kitahata described the caudal approach, which greatly reduced the risk of dural puncture. They also were the first to describe the use of a flexible, steerable epiduroscope, and irrigation of the epidural space with saline to aid visualization.[18]

DIAGNOSIS

Epiduroscopy is first and foremost a diagnostic procedure that can assess the cause of radicular pain. Visualization of the epidural space allows for evaluation of nerve roots and identification of adhesions, inflammation, and other abnormalities. Epiduroscopy is more sensitive than MRI in detecting epidural fibrosis. In a recent study, in patients with failed back surgery syndrome, MRI showed epidural fibrosis in 16.1% whereas, with epiduroscopy, this was the case in 91% of the patients.[19] (See Table 2).

The added value of epiduroscopy for diagnosis is due to the functional nature of the procedure. Touching epidural structures with the tip of the scope enables assessment of the precise source of the radicular pain by reproducing the patient's pain. In this respect, epidu-

Table 2. Comparison of Epiduroscopy and MRI for the Diagnosis and Treatment of Chronic Radicular Pain

	Epiduroscopy	MRI Scan
Nerve root anatomy	+ (only details visible)	++
Nerve root perfusion	++	–
Nerve root inflammation	++	+/–
Excitability of nerve root	++	–
Locating the painful nerve root	++	–
Identifying scar tissue	++	+
Identifying herniated disk	– (structure in anterior epidural space)	++
Evaluating diameter of spinal canal	+/–	++
Excluding serious pathology	+/– (biopsy possible)	++
Therapeutic options	++	–

++ = highly valuable; + = valuable; +/– possibly useful—no added value.

roscopy is also superior to MRI or clinical examination.[20]

"Healthy" nerve roots are visualized through the dura and appear as white or pale pink structures (Figure 1) with a blood vessel longitudinally running along the surface. A healthy nerve root may show pulsations, which are conducted from the dural sac. The absence of pulsations may indicate the presence of edema or excessive adhesions. Inflamed nerves are red and swollen ("angry red swollen nerve"), do not usually pulsate, and are painful when touched (Figure 2).

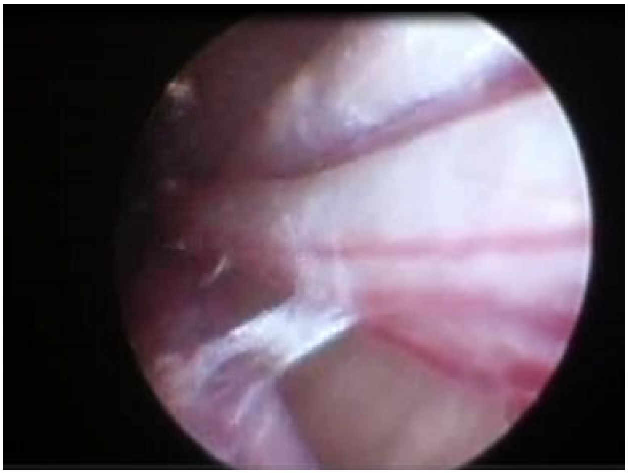

Figure 1. Visualization of a nerve root in the subarachnoid space; the nerves have a normal white aspect with a blood vessel running longitudinally.

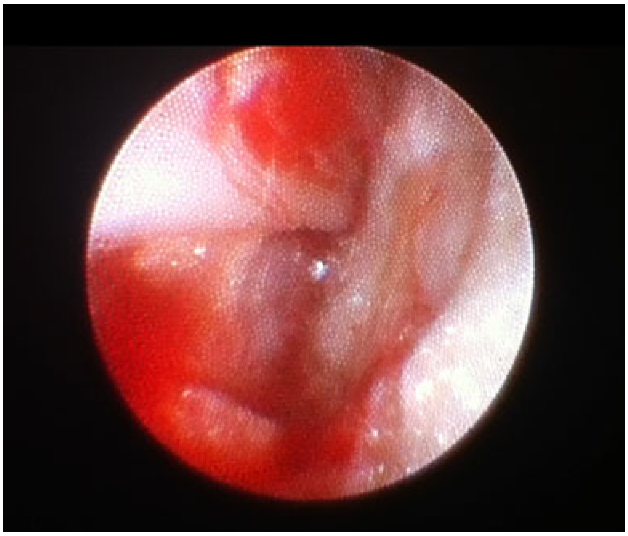

Figure 2. Visualization of an inflamed epidural space; note the peridural fatty tissue in the right lower quadrant; visualization of the dura with a roadmap of vessels running around it and visualization of an inflamed nerve In the middle lower quadrant.

The dura is a visible blue–gray structure covered by a "network" of small blood vessels and may pulsate.

Adhesions are white or gray, can completely cover the nerve, and are painful when touched near the affected nerve. Adhesions that develop following back surgery or because of inflammation may contain blood vessels when viewed before the scarring has fully matured. Touching adhesions can discriminate soft adhesions, which are easy to remove, from rigid adhesions, which are difficult to remove. This discrimination is important for determining the efficacy of adhesiolysis and therefore the outcome of the procedure.

MECHANISMS OF ACTION

Adhesiolysis

Adhesions attached to affected nerve roots or the dura can be removed by mechanically scraping off the fibrosis with the tip of a video-guided catheter or epiduroscope and/or by the hydrostatic pressure produced by saline flushes. Recent publications describe the use of Fogarty catheters and resablation to remove adhesions attached to the dura. The aim is to liberate the nerve or dura, in order to increase the mobility of the nerve, and hence restore the supply of nutrients (ie, nerve growth factor-NGF) and blood flow to the nerve.[21,22] Moreover, flushing of the epidural space with saline dilutes or washes out inflammatory mediators that have leaked from the damaged intervertebral disk or facet joints.[18,23–29]

Adhesions around nerves considered to be asymptomatic are left untouched. This procedure must be carried out carefully, in constant communication with the lightly sedated, cooperative patient. If the patient is in much pain or complains of nontransient paresthesias, severe pain, or neck pain, the adhesiolysis must be discontinued immediately.

Targeted Therapy

In FBSS patients, epidurally applied corticosteroids attain the intended level in 26% of cases.[30] A major advantage of epiduroscopy is that it allows for accurate placement of drug in the epidural space.[31,32]

Table 3 summarizes the proposed mechanisms for the therapeutic efficacy of epiduroscopy.

INDICATION(S) AND PATIENT SELECTION

Epiduroscopy can be considered in patients with chronic lumbosacral radicular pain, including FBSS patients, refractory to conservative therapy (physical therapy, medication) or minimally invasive therapeutic techniques (epidural corticosteroid injections, RACZ procedure, (pulsed) radiofrequency treatment adjacent to the dorsal root ganglion).

Flushing the epidural space and adhesiolysis are essential components of the procedure, which make this procedure particularly suited for the management of radicular pain due to fibroses and inflammation, which is often the case in patients with FBSS.

Patient selection depends on the duration of symptoms, the extent of adhesions, and the patient's history as illustrated in Figure 3.

Table 3. Proposed Mechanisms for the Therapeutic Efficacy of Epiduroscopy

Mechanism	References
Dilution or "washing out" of inflammatory mediators that have leaked from the damaged intervertebral disk and the facet joints	18,23–29
Accuracy of placement of a cocktail of corticosteroids and analgesics near the affected nerve	31,32
Adhesiolysis increases the mobility of the nerve, and hence restores the supplies of nutrients (NGF) and blood to the nerve	21,22
Partial denervation of nerve root and dura mater	41,43

ANATOMY OF THE EPIDURAL SPACE

Epidural space means the space surrounding the dura mater. It is sometimes also referred to as "extradural space" or "peridural space," while others use the term for the space surrounding the dural cuffs and nerve roots (ie, the space surrounding the dorsal root ganglion, (DRG)). See Figures 4 and 5.

The epidural space is bounded *anteriorly* by the posterior longitudinal ligament (PLL), the vertebral bodies, and the intervertebral disks, *laterally* by the intervertebral foramina and the pedicles of the vertebral arches, *posteriorly* by, alternatingly, the vertebral arches and the ligamenta flava, and at the level of the sacrum by the fused vertebral arches. As the dural sac ends at the level of the S2 vertebral body, the only tissue caudal to it is epidural fatty tissue with the filum terminale externum and the proximal parts of the nerve roots S2-Cocc1 (Figure 6).

The sacrococcygeal membrane forms the caudal boundary of the sacral epidural space. This membrane seals the sacral hiatus, but it is lacking in about 10% of cases and constitutes the conventional caudal access to the lumbosacral epidural space for epiduroscopy and caudal blocks. Its average anteroposterior diameter is about 4–5 mm, which is enough to allow the epiduroscope (with an external diameter of about 3 mm) to pass through it. However, anteroposterior diameters as small as 1 mm have been reported. This precludes epiduroscopy through the hiatus, and the procedure will then have to be discontinued.

Tissue Composition

The epidural tissue comprises loose areolar connective tissue and varying amounts of fatty tissue, which acts as a lubricant for the movements of the nerve roots in the spinal canal. Attention has recently been called to the presence of a peridural membrane.[20] The literature frequently reported the presence of ventral or dorsal septa in the epidural space. The ventral septa connect to the PLL. With dorsal septa, it remains unclear whether they separate the dorsal epidural space into compartments or should be regarded as locally condensed areas in the connective tissue. The consistency of the epidural space contents depends on the patient's medical history. In some cases, postoperative connective tissue fills up the entire epidural space and it becomes impossible to reach the space cranial to this tissue. Surgeons reported calcified connective tissue plates during repeat operations to

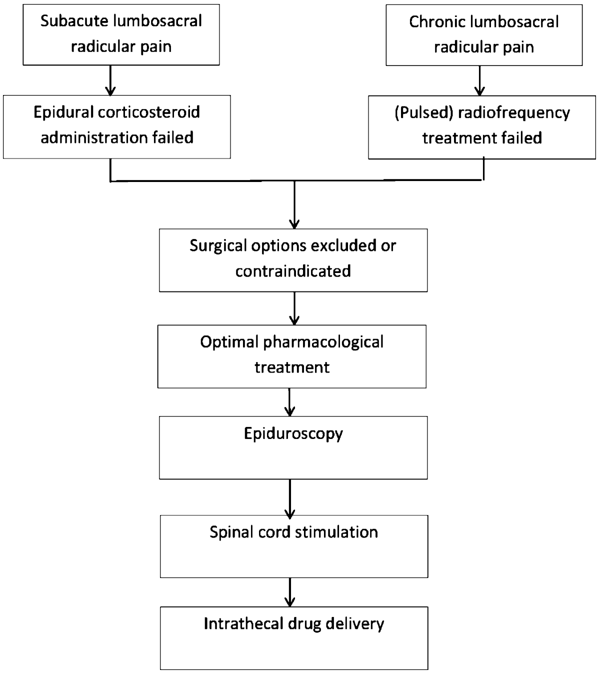

Figure 3. Algorithm for patient selection.

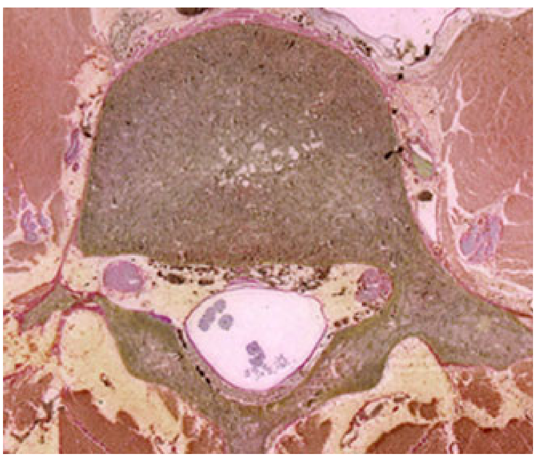

Figure 4. Transverse histological section at the level of vertebral body L3. At the left side, the intervertebral foramen L3-4 is shown with a crossing intraforaminal ligament, epidural fatty tissue, blood vessels dorsal root ganglion. On the right side, the exiting L3 nerve root is adjacent and medial to the pedicle. Mallory–Cason trichrome staining.

the spine after herniated disk surgery, a finding sometimes encountered during epiduroscopy.

The fatty tissue is mainly located in the anterolateral and dorsomedial parts of the epidural space. Laterally, the lumbosacral epidural space communicates with the fatty tissue adjoining the spinal column, via the intervertebral foramina. Some studies have reported that the

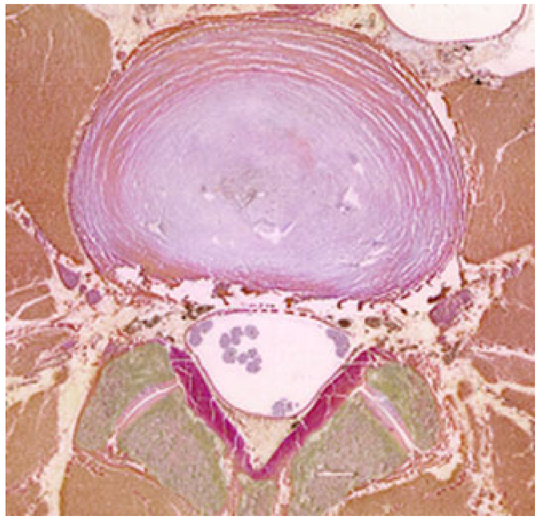

Figure 5. Transverse histological section at the level of intervertebral disk L3-4 just caudal to Figure 5. The dorsolateral dura lies directly adjacent to the flaval ligaments, which also form the anterior capsule of the facet joints. The L3 nerves are just outside the intervertebral formaina, whereas the L4 roots lie intradurally at 10 and 2 hours. The epidural fatty tissue is mainly located in the intervertebral foramen and dorsocentral between the dura and flaval ligaments. Mallory–Cason trichrome staining.

epidural space is laterally bounded by the so-called anterior dural ligaments or Hofmann's ligaments. Finally, intraforaminal ligaments have often been described in the intervertebral foramina, which are thought to serve mostly as fibrous conduits for the emerging nerves.

Blood Vessels

The epidural space contains arteries and veins supplying the spinal column. The arteries branch off from the segmental arteries. The veins interconnect, thus forming a venous plexus. This so-called Batson plexus comprises an anterior and a posterior venous part, which are interconnected (the internal vertebral venous plexus) and drain venous blood from the vertebral column, especially from the vertebral bodies. The anterior internal venous plexus is situated between the PLL and the corpora, while the posterior internal venous plexus lies in the posterior epidural space. In the lumbosacral part of the vertebral column, the ventral venous plexus is generally larger than the dorsal plexus, whereas the size of the dorsal plexus increases going from the high lumbar to the low thoracic vertebrae.

These venous plexuses are valveless. The plexuses communicate caudally with the pelvic veins, cranially

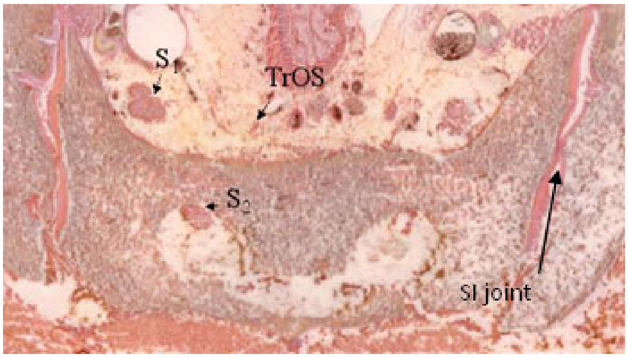

Figure 6. Transverse histological section at Level S2 and SI joint. Anterior is above in the figure. Mallory–Cason trichrome staining.

with the venous sinuses in the cranium and laterally, via the intervertebral foramina, with the segmental veins (lumbar veins and intercostal veins).

Nerves

All nerves supplying the epidural space branch from the sinuvertebral nerves (Luschka). They branch off the rami communicantes of the spinal nerves return to the epidural space via the intervertebral foramina located ventral to the nerve roots. There they form extensive networks, which provide sensory innervation to the internal parts of the spinal column: the PLL; the vertebral bodies; the intervertebral disks; and the ventral dura. The dorsal dura is sparsely innervated. In view of the relation with the sympathetic trunk (through the rami communicantes), these structures are also assumed to be sympathetically innervated. Sympathetic nerve fibers have indeed been recently identified in these networks.

Dura Mater

The dura mater is a strong connective tissue membrane surrounding the cerebral spinal fluid (CSF) space lined with the arachnoidea and sprouting side branches, which contain the anterior and posterior nerve roots, as well as the DRGs. These side branches constitute the dural sleeves or dural nerve root sleeves.

On a transverse section, the dural sleeves are located in the anterolateral quadrant of the spinal canal, at 10

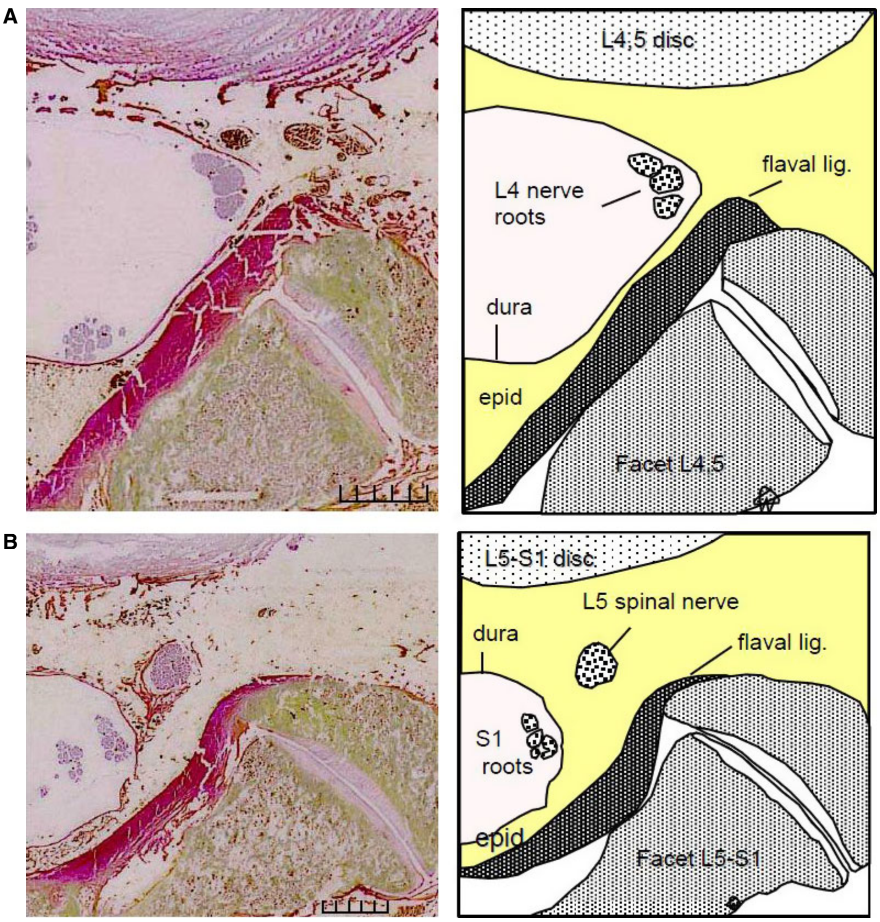

Figure 7. Histological cross-section at the level of intervertebral disk L4-5 (above) and L5-S1 (below) showing relationship between exiting nerve roots L4, L5, and S1, the dorsolateral intervertebral disk and the flaval ligaments plus facet joints; epid, epidural space. Mallory–Cason trichrome staining.

o'clock and 2 o'clock. (Figure 7a,b). The upper part is called the "shoulder," while the lower part is called the "axilla," corresponding to the shoulder and armpit parts of a jacket. The dural sleeve continues into the outer layer of the nerve, the epineurium. Within the intervertebral foramen, the dural sleeve is dorsally bounded by the ligamentum flavum, which is closely associated with the ventral capsules of the facet joints here (Figure 7).

MECHANISM OF RADICULAR PAIN

Radicular pain is not the result of nerve root compression.[24–28,33,34] Compression causes nerve dysfunction (sensory and/or motor deficits),[35] whereas pain requires an inflammatory reaction. This was demonstrated by a study of Howe[36] where compression of a normal peripheral nerve only induced action potentials for a short duration, whereas compression of an inflamed peripheral nerve led to prolonged firing of the nerve. However, pressure itself can cause inflammation with infiltration of macrophages and inflammatory cytokines.[37] Compression or fixation of the nerve root in the neuroforamen can lead to stretching, decreased intraneural microcirculation, and ischemia.[38] Damage to endoneural blood vessels leads to breakdown of the blood-nerve barrier and intraneural edema, which further compromises the microcirculation of the nerve root. The long-standing intraneural edema leads to a vicious cycle with infiltration of fibroblasts, even more scar tissue formation, thus further compromising nerve root blood supply. Moreover, compression of nerve roots leads to a change of axonal flow and altered metabolism of neurotransmitters hereby impairing nerve function.[37] Local demyelination sites will generate ectopic discharges and lead to altered sensations and/or spontaneous pain.[31] The nucleus pulposus of the intervertebral disk itself contains a range of proinflammatory interleukines.[25,29,34,38–40] A tear in the annulus fibrosis can cause large quantities of phospholipase A2 to be released into the epidural space, causing an inflammatory reaction further intensified by the release of TNF-α from mononuclear inflammatory cells.[24–28,33,34]

Spinal fibrosis is an important factor in nerve root compression and can be induced by spinal surgery itself. On the one hand, surgical repair can restore the nutritional status of the nerve (in terms of NGF supply), as it relieves the nerve root compression. However, it induces new tissue trauma, hemorrhage, and contamination with foreign materials, which may lead to renewed fibrosis formation. Epiduroscopy in patients with chronic radicular pain found fibrosis in nearly 100% of cases.[21,22] MRI scans have also shown that high levels of fibrosis correlate with high pain levels.[41]

A logical therapeutic step would appear to be adhesiolysis with the aim of releasing the entrapped nerves, creating enough space around the nerve to restore both blood supply and the supply of nutrients to the nerve root from the CSF.

EVIDENCE

Until now, 1 prospective double-blind randomized controlled trial,[42] 9 prospective studies,[21,22,43–49] and 3 retrospective studies[50–52] yielded positive results after epiduroscopy in terms of pain scores and functional status. Most studies included patients with failed back surgery syndrome, 1 study included patients with degenerative lumbar spinal canal stenosis, and 1 study included patients with sciatica. One controlled randomized trial in patients with sciatica failed to show improvement when comparing epiduroscopy with caudal epidurals.[53] Most of the reported epiduroscopy procedures used mechanical adhesiolysis by means of the epiduroscope or an endoscopic video-guided system followed by injection of a mixture of local anesthetic and steroids. A minority of the studies added clonidine or hyaluronidase. In one study, ozone and ciprofloxacin were injected.

In a prospective, randomized, double-blind study, Manchikanti et al.[42] included patients with chronic radicular pain who lasted for a minimum of 6 months and failed to respond to other conservative treatment strategies, including X-ray-guided epidural injections and percutaneous adhesiolysis ("Racz procedure"). Group 1 functioned as a control group. In this group, the epiduroscope was introduced to the level of the sacral canal, and a mixture of a corticosteroid and a local anesthetic was administered. No attempt for adhesiolysis at the appropriate level was undertaken. Group 2 underwent epiduroscopy and suitable adhesiolysis in the target area, after which the same mixture of corticosteroid and local anesthetic was placed. The outcome parameters were pain, functional status, and psychological and behavioral status. Thirteen of the 23 patients in group 2 (57%) showed significant improvements in terms of pain scores after 1, 3, and 6 months. All other outcome measures, including psychometric tests, had also improved significantly after 1, 3, and 6 months. The control group showed improvement at

1 month and none thereafter. The authors concluded that epiduroscopy is an effective treatment, especially for patients who fail to respond sufficiently to epidural injections and percutaneous adhesiolysis.

Geurts et al.[21] prospectively evaluated whether abnormalities identified on MRI scans could be confirmed with epiduroscopy and investigated whether targeted epidural injection of medication after adhesiolysis was able to reduce radicular pain. Epidural adhesions were found during the procedure in 19 of the 20 patients. In 8 of them, including 6 without a history of back surgery, these adhesions had not been observed on previous MRI scans. Six patients showed signs of nerve root inflammation. Eleven of the 20 patients showed a significant improvement in VAS scores after 3 and 12 months.

In a prospective study with 12 months follow-up by Richardson et al.,[22] 38 patients with chronic radicular pain showed significant improvement. Comparable outcomes were found in 2 retrospective evaluations by Manchikanti et al.,[50,51] based on 112 epiduroscopies in 85 patients with chronic radicular pain who had failed to respond to a conventional treatment including epidural corticosteroid injections. The epiduroscopy involved visualization of adhesions with subsequent adhesiolysis and the administration of a mixture of a corticosteroid and a local anesthetic. The results showed significant long-term effects and also confirmed the cost-effectiveness of the procedure.

Sakai et al.[44] performed epidural adhesiolysis followed by injection of steroids and local anesthetics in 19 patients with chronic sciatica. Adhesiolysis was successful in 16 patients. Pain and disability scores significantly improved following epiduroscopy. Furthermore, sensory nerve function measured by current perception threshold improved equally.

Avellanal and Diaz-Reganon[47] attempted an interlaminar approach for epiduroscopy. Although offering good pain relief (3 point VAS reduction) in 31.6% of patients at 6 months follow-up, the technique was hampered by 21% dural punctures.

Two research groups endeavored adhesiolysis techniques other than mechanical lysis with the epiduroscope. Raffaeli and Righetti[48] used a Res-ablator with 4 Mhz radiofrequency output to break down adhesions in 14 patients. Fifty-seven percent of patients stated > 90% improvement after 1 month. Ruetten et al.[45,46] used a Holmium:YAG laser in 2 prospective case series of 34 and 68 patients. Positive results (2 point VAS reduction) were obtained in 44% and 48.5% of patients, respectively, after 8 weeks. Although promising, these studies lack long-term follow-up and the results do not outmatch results of studies with "classic" mechanical adhesiolysis.

A recently published prospective, randomized study by Dashfield and colleagues appeared to yield unfavorable results.[53] However, several concerns need to be addressed. First, none of the patients in this study had a history of surgery or failed back surgery syndrome with patients suffering from radicular pain for a maximum of only 18 months. Moreover, epiduroscopy in these patients revealed little scar tissue. Second, the researchers specifically mentioned that they did not flush the epidural space and adhesiolysis was only performed in 3 patients. In the control group, a mixture of corticosteroid and local anesthetic was administered caudally, while in the epiduroscopy group, the same mixture was injected in the epidural space near the affected nerve root. No significant differences were found between the 2 groups, with both groups showing a significant favorable short-term effect. The authors concluded that there was no added value of epiduroscopy in the administration of epidural corticoids. In a letter to the editor, Richardson et al.[54] commented that flushing the epidural space and adhesiolysis are essential components of the procedure, and that the study by Dashfield et al. was therefore not comparable to any of the other studies of epiduroscopy published so far.

One study looked into the effect of epiduroscopy in patients with degenerative lumbar stenosis.[43] Based on symptoms, the patients (n = 58, mean age 71 years) were divided into 2 groups according to the number of affected nerve roots: a monosegmental group (n = 34) and a multisegmental group (n = 24). All patients underwent epiduroscopy and were evaluated in terms of VAS scores for back and leg pain. During epiduroscopy, the epidural space was flushed, adhesiolysis was applied, and a mixture of a corticosteroid and a local anesthetic was placed. Relief of backache was found in both groups up to 12 months after the intervention. Only the monosegmental group reported significant improvement after 12 months, while the effect had waned after 3 months in the multisegmental group. Other than one accidental dural puncture, no complications were reported in this study. Apart from a biochemically based effect of adhesiolysis on radicular pain, it is conceivable, especially in this group of patients, that nerves need a certain amount of space to accommodate flexion and extension.[55]

Five papers reviewed the literature concerning epiduroscopy, all yielding favorable conclusions.[56–60]

SIDE EFFECTS AND COMPLICATIONS

Reports of complications related to epiduroscopy are sparse and limited to the following case reports: retinal/vitreous hemorrhages[61,62] related to rapid or large volume infusions in the epidural space; intravascular injections[63]; intrathecal injection of contrast dye leading to encephalopathy; rhabdomyolysis (iotrolan);[64] and postdural puncture headache.

The risk for radiation exposure during the epiduroscopy procedure was assessed in an in vitro model.[65] While the calculated radiation dose for 1 epiduroscopy is below the threshold that could lead to organ injuries, care should be taken for accumulating exposure. Heavner and Bosscher,[66] in a letter to the editor, offered tips to reduce the radiation exposure.

Contraindications

Increased Intra-Abdominal Pressure. Situations in which the intra-abdominal pressure is greatly increased, with a significant rise in the amount of venous blood in the plexus (eg, during pregnancy), could be regarded as a relative contra-indication for epiduroscopy, although Igarashi et al.[23] have applied epiduroscopy in pregnant women.

Duration of the Procedure and Increased Epidural Pressure. The continuous inflow of saline may eventually lead to increased epidural pressure. If this results in a rise in the cerebrospinal fluid pressure to above arterial pressure, it affects the perfusion of the spinal cord and the nerve roots. Whether this necessitates continuous monitoring of the epidural pressure is still a subject of debate.

Increased epidural pressure can lead to an increased intracranial pressure around the anterior optic nerve, leading to macular hemorrhage and causing visual disturbances.[62] This serious complication has, however, mostly been reported with epidural injections and generally resolves. The current hypothesis states that momentary sudden pressure increases in the cerebrospinal fluid can arise from excessively rapid injection of unduly large volumes in the epidural space. This implies that the inflow of saline during epiduroscopy should be carried out slowly and in small volumes, as indeed goes for epidural injections generally.

Table 4. Summary of Evidence Grading

Technique	Assessment
Epiduroscopy with adhesiolysis and targeted therapy for FBSS	2 B+
Epiduroscopy without adhesiolysis low back pain without history of surgery	2 B−

Other contraindications are as follows: local infection at the entry site; coagulopathy or use of anticoagulants; bladder or bowel sphincter dysfunction; obesity (BMI > 35); inability to lie in prone position > 60 min; inability to give informed consent; and allergy for contrast dye or local anesthetics.

EVIDENCE GRADING

A summary of the evidence grading is given in Table 4

RECOMMENDATIONS

The use of epiduroscopy is recommended in patients with chronic lumbosacral radicular pain refractory to conservative or minimally invasive therapies. Surgical options must be exhausted or contraindicated and patients should have received optimal pharmacologic treatment. Epiduroscopy is best offered as part of a multidisciplinary approach with physiotherapy and/or psychological counseling as needed. Preferably, the procedure should be used in a research context in specialized centers.

CLINICAL PATHWAY

Correct performance of epiduroscopy requires special equipment and a trained multidisciplinary team. The clinical pathway described in Table 5 identifies the steps to be taken.

PROCEDURE

Epiduroscopy is performed after preprocedure antibiotic administration in sterile OR conditions under conscious sedation with continuous hemodynamic and respiratory monitoring. Generally, communication with the patient must be possible at all times during the intervention.

With the patient lying prone on the operating table, a pillow is placed underneath the abdomen to straighten the lumbar lordosis. The area around the sacral hiatus is disinfected and anesthetized with local anesthetic. After

Table 5. Multidisciplinary Clinical Pathway

Phase 0 Patient selection	Diagnosis: Lumbosacral radicular pain refractory to:
	Conservative treatment (physiotherapy, optimal pharmacologic treatment)
	Epidural infiltrations with corticosteroids
	RACZ procedure
	(Pulsed) radiofrequency therapy
	Neurosurgical evaluation: surgical options exhausted?
	Psychiatric evaluation: contra-indications (eg, major depression)
	Multidisciplinary paramedical evaluation:
	Pain nurse
	Psychologist
	Physiotherapist
Phase 1 Intake	Doctor:
	Patient information, sign informed consent
	Evaluation of comorbidities: coagulation disorders, allergies (eg, contrast dye)
	Neurological examination (eg, preoperative motor/sensory deficit)
	Pain Nurse:
	Repeat patient information with focus on:
	Procedure, equipment
	Fasting status
	Postoperative orders (eg showering, bath)
	Record VAS
	Blood clotting tests: PT, aPTT, thrombocyte count (optional)
Phase 2 Epiduroscopy procedure	Check patient identification
	Check fasting status
	Check informed consent
	Check lab results
	Proceed with epiduroscopy
	Postoperative orders:
	Postoperative antibiotic therapy according to local guidelines (optional)
	Postoperative pain medication
	Monitoring of motor- and sphincter function
Phase 3 Follow-up	Postprocedure:
	Check pain
	Check neurological status (eg. motor deficit-epidural hematoma)
	Postoperative day 1: (optional)
	Check wound
	Check pain: VAS, PGIC
	Neurological examination
	Postoperative day 7: (optional)
	Check wound
	Check pain: VAS, PGIC
	Neurological examination
	3 and 6 months postoperative:
	Check pain: VAS, PGIC
	Neurological examination
	If negative result, consider spinal cord stimulation

a sterile drape has been placed over the patient, a Tuohy needle is inserted through the sacral hiatus under lateral X-ray control. Next, a guide wire is threaded through the Tuohy needle under fluoroscopic guidance. Using a Seldinger technique, an introducer is advanced over the guidewire into sacral epidural space to a level between S2 and S3, where a baseline epidurogram (Figure 8) may

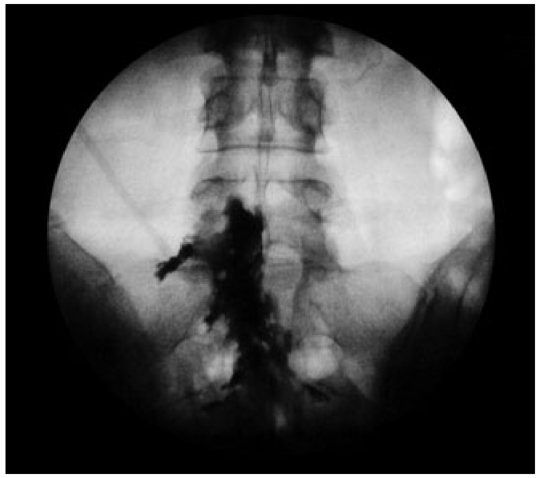

Figure 8. Baseline epidurogram with a filling defect on the right side.

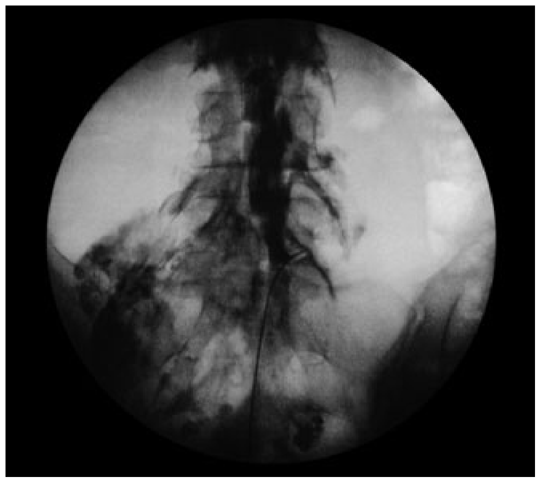

Figure 9. Postprocedure epidurogram with opening of the L4 and L5 nerve root on the right side.

be made. Thereupon, the video-guided catheter containing the flexible epiduroscope is inserted. The video-guided catheter with epiduroscope is steered cranially under direct vision in the epidural space to the level of expected pathology in combination with fluoroscopy. To obtain a good visual field, the epidural space is irrigated and distended with saline. Pressure in the epidural space can be monitored. Although there is no support in the literature, it seems logical that the epidural pressure should not exceed the mean blood pressure. Once at the expected level of pathology, gently touching the nerve root with the video-guided catheter should reproduce the patient's pain. Once adhesions are identified, attempts are made to rupture them mechanically by gentle movements of the video-guided catheter and by bolus injections of small amounts of saline. In some patients, adhesions are so solid that adhesiolysis is impossible. In these patients and in the absence of inflammation, the procedure is strictly diagnostic. If there is inflammation visible, flushing the epidural space with saline and the medication is thought to play an important role. A postprocedure epidurogram (Figure 9) is made to record the result of the adhesiolysis. Finally, a mixture of local anesthetics and depot steroids (potentially also hyaluronidase and clonidine) is injected at the culprit level. Saline flushing must be suspended immediately if the patient complains of neck pain or headache. If these complaints disappear within 5 minutes, the procedure may be resumed; if they persist, the procedure must be discontinued. The procedure must also be discontinued in case the patient experiences severe paresthesias and/or pain. After the intervention, patients are monitored at the recovery room.

CONCLUSION

According to the available evidence, epiduroscopy is a safe treatment with no mortality and little morbidity. There is reasonable evidence for short and long-term effect in patients with chronic radicular pain due to failed back surgery syndrome. More controlled trials are needed to confirm the efficacy of this treatment and its long-term effects.

ACKNOWLEDGEMENTS

This review was initially based on practice guidelines written by Dutch and Flemish (Belgian) experts that were assembled in a handbook for the Dutch-speaking pain physicians. After translation, the manuscript was updated and edited in cooperation with U.S./international pain medicine specialists.

The authors thank Nicole Van den Hecke for coordination and suggestions regarding the manuscript.

REFERENCES

1. Guyatt G, Gutterman D, Baumann MH, et al. Grading strength of recommendations and quality of evidence in clinical guidelines: report from an american college of chest physicians task force. *Chest*. 2006;129:174–181.
2. van Kleef M, Mekhail N, van Zundert J. Evidence-based guidelines for interventional pain medicine according to clinical diagnoses. *Pain Pract: Official J World Institute of Pain*. 2009;9:247–251.
3. Koes BW, van Tulder MW, Peul WC. Diagnosis and treatment of sciatica. *BMJ*. 2007;334:1313–1317.
4. Bennett GJ. Neuropathic pain: new insights, new interventions. *Hospital Practice*. 1998;33:95–98, 101–104, 107–110 passim.
5. Carey TS, Evans AT, Hadler NM, et al. Acute severe low back pain. A population-based study of prevalence and care-seeking. *Spine*. 1996;21:339–344.
6. Van Boxem K, Cheng J, Patijn J, et al. 11. Lumbosacral radicular pain. *Pain Practice*. 2010;10:339–358.
7. Baron R, Freynhagen R, Tolle TR, et al. The efficacy and safety of pregabalin in the treatment of neuropathic pain associated with chronic lumbosacral radiculopathy. *Pain*. 2010;150:420–427.
8. Khoromi S, Patsalides A, Parada S, Salehi V, Meegan JM, Max MB. Topiramate in chronic lumbar radicular pain. *J Pain*. 2005;6:829–836.
9. Khoromi S, Cui L, Nackers L, Max MB. Morphine, nortriptyline and their combination vs. placebo in patients with chronic lumbar root pain. *Pain*. 2007;130:66–75.
10. Thomson S, Jacques L. Demographic characteristics of patients with severe neuropathic pain secondary to failed back surgery syndrome. *Pain Practice*. 2009;9:206–215.
11. Leveque JC, Villavicencio AT, Bulsara KR, Rubin L, Gorecki JP. Spinal cord stimulation for failed back surgery syndrome. *Neuromodulation*. 2001;4:1–9.
12. Burman M. Myeloscopy or the direct visualisation of the spinal canal and its contents. *J Bone Joint Surg*. 1931;13:695–696.
13. Pool J. Myeloscopy: intraspinal endoscopy. *Surgery*. 1942;11:169–182.
14. Ooi Y, Morisaki N. Intrathecal lumbar endoscope. *Clin Orthop Surg (Japan)*. 1969;4:295–297.
15. Blomberg RG, Olsson SS. The lumbar epidural space in patients examined with epiduroscopy. *Anesth Analg*. 1989;68:157–160.
16. Heavner J, Chokhavatia S, Kizelshteyn G. Percutaneous evaluation of the epidural and subarachnoid space with a flexible fiberscope. *Reg Anesth*. 1991; 15(S):85.
17. Shimoji K, Fujioka H, Onodera M, et al. Observation of spinal canal and cisternae with the newly developed small-diameter, flexible fiberscopes. *Anesthesiology*. 1991;75:341–344.
18. Saberski LR, Kitahata LM. Direct visualization of the lumbosacral epidural space through the sacral hiatus. *Anesth Analg*. 1995;80:839–840.
19. Bosscher HA, Heavner JE. Incidence and severity of epidural fibrosis after back surgery: an endoscopic study. *Pain Practice*. 2010;10:18–24.
20. Ansari S, Heavner JE, McConnell DJ, Azari H, Bosscher HA. The peridural membrane of the spinal canal: a critical review. *Pain Practice*. 2012;12:315–325.
21. Geurts JW, Kallewaard JW, Richardson J, Groen GJ. Targeted methylprednisolone acetate/hyaluronidase/clonidine injection after diagnostic epiduroscopy for chronic sciatica: a prospective, 1-year follow-up study. *Reg Anesth Pain Med*. 2002;27:343–352.

22. Richardson J, McGurgan P, Cheema S, Prasad R, Gupta S. Spinal endoscopy in chronic low back pain with radiculopathy. A prospective case series. *Anaesthesia*. 2001;56:454–460.

23. Igarashi T, Hirabayashi Y, Shimizu R, Saitoh K, Fukuda H, Suzuki H. The fiberscopic findings of the epidural space in pregnant women. *Anesthesiology* 2000;92:1631–1636.

24. Olmarker K, Rydevik B, Nordborg C. Autologous nucleus pulposus induces neurophysiologic and histologic changes in porcine cauda equina nerve roots. *Spine*. 1993;18:1425–1432.

25. Omarker K, Myers RR. Pathogenesis of sciatic pain: role of herniated nucleus pulposus and deformation of spinal nerve root and dorsal root ganglion. *Pain*. 1998;78:99–105.

26. Kayama S, Konno S, Olmarker K, Yabuki S, Kikuchi S. Incision of the anulus fibrosus induces nerve root morphologic, vascular, and functional changes. An experimental study. *Spine*. 1996;21:2539–2543.

27. Otani K, Arai I, Mao GP, Konno S, Olmarker K, Kikuchi S. Experimental disc herniation: evaluation of the natural course. *Spine*. 1997;22:2894–2899.

28. Cornefjord M, Olmarker K, Rydevik R, Nordborg C. Mechanical and biochemical injury of spinal nerve roots: a morphological and neurophysiological study. *Eur Spine J*. 1996;5:187–192.

29. Rydevik B, Holm S, Brown MD, Lundborg G. Diffusion from the cerebrospinal fluid as a nutritional pathway for spinal nerve roots. *Acta Physiol Scand*. 1990;138:247–248.

30. Fredman B, Nun M, Zohar E. Epidural steroids for treating "failed back surgery syndrome": is fluoroscopy really necessary? *Anesth Analg*. 1999;88:367–372.

31. Devor M. Neuropathic pain and injured nerve: peripheral mechanisms. *Br Med Bull*. 1991;47:619–630.

32. Cooper RG, Mitchell WS, Illingworth KJ, Forbes WS, Gillespie JE, Jayson MI. The role of epidural fibrosis and defective fibrinolysis in the persistence of postlaminectomy back pain. *Spine*. 1991;16:1044–1048.

33. Olmarker K, Nordborg C, Larsson K, Rydevik B. Ultrastructural changes in spinal nerve roots induced by autologous nucleus pulposus. *Spine*. 1996;21:411–414.

34. Olmarker K, Blomquist J, Stromberg J, Nannmark U, Thomsen P, Rydevik B. Inflammatogenic properties of nucleus pulposus. *Spine*. 1995;20:665–669.

35. Lundborg G, Gelberman RH, Minteer-Convery M, Lee YF, Hargens AR. Median nerve compression in the carpal tunnel–functional response to experimentally induced controlled pressure. *J Hand Surg Am*. 1982;7:252–259.

36. Howe JF, Loeser JD, Calvin WH. Mechanosensitivity of dorsal root ganglia and chronically injured axons: a physiological basis for the radicular pain of nerve root compression. *Pain*. 1977;3:25–41.

37. Kobayashi S, Baba H, Uchida K, et al. Effect of mechanical compression on the lumbar nerve root: localization and changes of intraradicular inflammatory cytokines, nitric oxide, and cyclooxygenase. *Spine (Phila Pa 1976)*. 2005;30:1699–1705.

38. Rydevik B, Brown MD, Lundborg G. Pathoanatomy and pathophysiology of nerve root compression. *Spine*. 1984;9:7–15.

39. Kuslich SD, Ulstrom CL, Michael CJ. The tissue origin of low back pain and sciatica: a report of pain response to tissue stimulation during operations on the lumbar spine using local anesthesia. *Orthop Clin North Am*. 1991;22:181–187.

40. Yabuki S, Onda A, Kikuchi S, Myers RR. Prevention of compartment syndrome in dorsal root ganglia caused by exposure to nucleus pulposus. *Spine*. 2001;26:870–875.

41. 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: 855–861; discussion 861–853.

42. Manchikanti L, Boswell MV, Rivera JJ, et al. [ISRCTN 16558617] A randomized, controlled trial of spinal endoscopic adhesiolysis in chronic refractory low back and lower extremity pain. *BMC Anesthesiol*. 2005;5:10.

43. Igarashi T, Hirabayashi Y, Seo N, Saitoh K, Fukuda H, Suzuki H. Lysis of adhesions and epidural injection of steroid/local anaesthetic during epiduroscopy potentially alleviate low back and leg pain in elderly patients with lumbar spinal stenosis. *Br J Anaesth*. 2004;93:181–187.

44. Sakai T, Aoki H, Hojo M, Takada M, Murata H, Sumikawa K. Adhesiolysis and targeted steroid/local anesthetic injection during epiduroscopy alleviates pain and reduces sensory nerve dysfunction in patients with chronic sciatica. *J Anesth*. 2008;22:242–247.

45. Ruetten S, Meyer O, Godolias G. Application of holmium:YAG laser in epiduroscopy: extended practicabilities in the treatment of chronic back pain syndrome. *J Clin Laser Med Surg*. 2002;20:203–206.

46. Ruetten S, Meyer O, Godolias G. Endoscopic surgery of the lumbar epidural space (epiduroscopy): results of therapeutic intervention in 93 patients. *Minim Invasive Neurosurg*. 2003;46:1–4.

47. Avellanal M, Diaz-Reganon G. Interlaminar approach for epiduroscopy in patients with failed back surgery syndrome. *Br J Anaesth*. 2008;101:244–249.

48. Raffaeli W, Righetti D. Surgical radio-frequency epiduroscopy technique (R-ResAblator) and FBSS treatment: preliminary evaluations. *Acta Neurochirurgica Supplement*. 2005;92:121–125.

49. Donato AD, Fontana C, Pinto R, Beltrutti D, Pinto G. The effectiveness of endoscopic epidurolysis in treatment of degenerative chronic low back pain: a prospective analysis and follow-up at 48 months. *Acta Neurochirurgica Supplement*. 2011;108:67–73.

50. Manchikanti L. The value and safety of epidural endoscopic adhesiolysis. *Am J Anesthesiol*. 2000;27:275–278.

51. Manchikanti L, Pampati V, Bakhit CE, Pakanati RR. Non-endoscopic and endoscopic adhesiolysis in post-lumbar laminectomy syndrome: a one-year outcome study and cost effectiveness analysis. *Pain Physician*. 1999;2:52–58.

52. Saberski LR. A retrospective analysis of spinal canal endoscopy and laminectomy outcomes data. *Pain Physician.* 2000;3:193–196.

53. Dashfield AK, Taylor MB, Cleaver JS, Farrow D. Comparison of caudal steroid epidural with targeted steroid placement during spinal endoscopy for chronic sciatica: a prospective, randomized, double-blind trial. *Br J Anaesth*. 2005;94:514–519.

54. Richardson J, Kallewaard JW, Groen GJ. Spinal endoscopy for chronic sciatica. *Br J Anaesth*. 2005;95:275–276; author reply 276.

55. Miyamoto H, Dumas GA, Wyss UP, Ryd L. Three-dimensional analysis of the movement of lumbar spinal nerve roots in nonsimulated and simulated adhesive conditions. *Spine*. 2003;28:2373–2380.

56. Gillespie G, MacKenzie P. Epiduroscopy–a review. *Scott Med J*. 2004;49:79–81.

57. Boswell MV, Trescot AM, Datta S, et al. Interventional techniques: evidence-based practice guidelines in the management of chronic spinal pain. *Pain Physician*. 2007; 10:7–111.

58. Chopra P, Smith HS, Deer TR, Bowman RC. Role of adhesiolysis in the management of chronic spinal pain: a systematic review of effectiveness and complications. *Pain Physician*. 2005;8:87–100.

59. Hayek SM, Helm S, Benyamin RM, Singh V, Bryce DA, Smith HS. Effectiveness of spinal endoscopic adhesiolysis in post lumbar surgery syndrome: a systematic review. *Pain Physician*. 2009;12:419–435.

60. Trescot AM, Chopra P, Abdi S, Datta S, Schultz DM. Systematic review of effectiveness and complications of adhesiolysis in the management of chronic spinal pain: an update. *Pain Physician*. 2007;10:129–146.

61. Gill JB, Heavner JE. Visual impairment following epidural fluid injections and epiduroscopy: a review. *Pain Medicine*. 2005;6:367–374.

62. Moschos MM, Rouvas A, Papaspirou A, Apostolopoulos M. Acute visual loss and intraocular hemorrhages associated with endoscopic spinal surgery. *Clin Ophthalmol.* 2008;2:937–939.

63. Heavner J, Wyatt DE, Bosscher H. Lumbosacral epiduroscopy complicated by intravascular injection. *Anesthesiology*. 2007;107:347–350.

64. Mizuno J, Gauss T, Suzuki M, Hayashida M, Arita H, Hanaoka K. Encephalophaty and rhabdomyolysis induced by iotrolan during epiduroscopy. *Can J Anaesth*. 2007;54:49–53.

65. Komiya K, Igarashi T, Suzuki H, Hirabayashi Y, Waechter J, Seo N. In vitro study of patient's and physician's radiation exposure in the performance of epiduroscopy. *Reg Anesth Pain Med*. 2008;33:98–101.

66. Heavner JE, Bosscher H. Epiduroscopy and radiation exposure. *Reg Anesth Pain Med*. 2009;34:79; author reply 79.