



Do minimally invasive procedures have a place in the treatment of chronic low back pain?

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Chronic low back pain is the leading cause of disability in the industrialized world. Medical and surgical treatments remain costly despite limited efficacy. The field of 'interventional pain' has grown enormously and evidence-based practice guidelines are systematically developed. In this article, the vast, complex and contradictory literature regarding the treatment of chronic low back pain is reviewed. Interventional pain literature suggests that there is moderate evidence (small randomized, nonrandomized, single group or matched-case controlled studies) for medial branch neurotomy and limited evidence (nonexperimental one or more center studies) for intradiscal treatments in mechanical low back pain. There is moderate evidence for the use of transforaminal epidural steroid injections, lumbar percutaneous adhesiolysis and spinal endoscopy for painful lumbar radiculopathy and spinal cord stimulation and intrathecal pumps mostly after spinal surgery. In reality, there is no gold standard for the treatment of chronic low back pain, but these results appear promising.

Expert Rev. Neurotherapeutics 4(3), (2004)

Low back pain is defined as pain, muscle tension or stiffness localized below the costal margin and above the gluteal folds with or without leg pain [1]. The International Association of the Study of Pain recognizes chronic pain in general as any pain that persists for longer than 3 months, thus chronic low back pain (CLBP) theoretically is the pain that persists after the 91st day of its acute onset [1]. Since most cases of CLBP resolve within 6 weeks, the authors recommend that cases which persist and do not respond (e.g., <50% reduction in pain score) to conservative treatment, merit an interdisciplinary evaluation. This evaluation includes medical, anesthetic, surgical and psychological interventions and is performed provided that previous treatment has been managed in an appropriate manner [2].

Experienced physicians may feel confident in recognizing low back pain. However, research has shown little agreement on the reproducibility of physical signs between practitioners, and interexaminer scores are low [3]. Although the application of International Association for the Study of Pain taxonomy is

advocated to assure diagnostic and workup clarity, it is subject to dispute and its use in daily practice is questioned [4].

A major difficulty in making a correct diagnosis in patients suffering from CLBP is the lack of sufficient specificity and sensitivity of tests to differentiate between radicular and non-radicular pain, especially when they coexist. Radicular pain is of a neurogenic nature and is projected to an area supplied by a nerve root, such as a dermatome. Nonradicular pain originates from deep somatic structures such as spinal ligaments, intervertebral disc and dura, and is referred to areas related to the segmental innervation of these structures. Multisegmental innervation and an overlap similar to the dermatomal nerve supply will also lead to an overlap in deep somatic referred pain areas. Thus, a correct diagnosis can not always be made. The 'rule' that pain radiating below the knee should always be considered as radicular is not true and pain arising from the annulus fibrosus, posterior longitudinal ligament or ventral dura may mimic lumbosacral radicular pain [5].

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KEYWORDS:

chronic low back pain, cord stimulation, discography, epidural injections, facet joint pain, neural blockade, percutaneous epidural adhesiolysis, radiofrequency, spinal endoscopy, spinal intrathecal pumps

It should be emphasized that the usage of the term 'sciatica' when 'lumbosacral radicular pain' is meant, is no longer meaningful for its lack of specificity. It is now evident on physiological grounds, that referred pain and radicular pain are two distinct entities entailing a different diagnostic and therapeutic approach. This problem combined with a shared belief that chronic opioid use for CLBP will cause addiction and loss of personal control, has perpetuated the development of a plethora of alternative treatments. Nevertheless, one should be aware that retrospective analysis of the appropriateness of treatments is not always clear and remains open for bias.

Interventional pain management offers a spectrum of minimally invasive procedures with both diagnostic and therapeutic intent, borrowing improved technologies from many disciplines such as pacemaker, radiofrequency (RF) and endoscopic technologies as well as novel drugs with improved drug delivery systems. The purpose of this article is to review the multitude of minimally invasive procedures available for refractory CLBP. Patient and procedure selection and known outcome literature is focused on in order to facilitate an improved understanding of what can and can not be expected from these procedures.

Prevalence, costs & risk of chronicity

The prevalence of CLBP should be placed in the context of back pain in general. Many studies attest a frequency of up to 70–85% of all people having back pain at sometime in their life [6]. However, the annual prevalence of CLBP ranges between 15 and 45% in the USA and Europe [7]. A systematic review of the literature between 1966 and 1998 has shown point prevalence of CLBP to be 12–33%, 1-year prevalence 22–65%, lifetime prevalence 11–84% and an unknown prevalence in the elderly [8,9].

Back pain is the most common cause of activity limitation in adults younger than 45 years, the second most frequent reason for visits to the physician, the fifth ranking cause of admission to hospital and the third most common cause of surgical procedures. Musculoskeletal impairment is the most prevalent impairment in those aged up to 65 years, back and spine disorders being the most frequently-reported subcategories (52%). The incidence is higher in women than in men (70 vs. 57 per 1000) and in Caucasians than in Blacks (68 vs. 38 per 1000) [10].

The costs of unrelieved pain and disability arising from CLBP are staggering and pose a major burden to society. It has been estimated that in the USA, approximately 3 million people have been treated in over 3300 pain facilities at a cost of over US\$20 billion each year for back pain alone [11]. In The Netherlands, the total costs of back pain in 1991 were estimated to be €4.5 billion (1.7% of the Gross National Product) 93% of these costs are indirect due to absenteeism and workers compensation [12]. The National Council on Compensation Insurance in Healthcare estimates that the costs of work-related low back pain is US\$8.8 billion, not taking into account lost work, lost tax revenue, indemnity or incalculable human suffering [13]. The most costly services are diagnostic procedures (25%), surgery (21%) and physical therapy (20%). The costs for behavioral therapy and other psychological interventions remain unknown.

In general, the clinical course of an episode of low back pain appears to be favorable and approximately 75–90% of these episodes will resolve spontaneously within 1 to 5 months [14]. However, recent studies have shown that 62% of patients still reported pain after 12 months, 16% on sick-leave. Of these patients, 60% experienced repeated episodes of pain and 33% continue to be absent from work. The prevalence of CLBP in cases with previous episodes increase to an incidence of 56%, compared with 22% for those without a prior history of low back pain and less than half of patients who have been off work for 6 months will return to employment. These findings show that low back pain does not resolve itself when ignored and after 2 years of work absenteeism the chance of returning to work is virtually zero [15].

Since the principal risk factor for the development of a disability associated with CLBP is psychosocial, notably the avoidance of activity for fear of aggravating pain or worsening pathology, preventing activity withdrawal, encouraging patients to repeat graded exposures to stimuli and providing cognitive skills via cognitive-behavioral support, are the basic therapeutic strategies in avoiding the chronification of pain and development of associated disability [16].

Conservative treatments

Over 600 randomized controlled studies evaluating all types of conservative or complementary treatments have been published [17]. In 1997, the establishment of the Cochrane Back Review Group was an important step in promoting systematic collection, review and synthesis of low back pain literature. Reviews and protocols devised can be found at [101].

There is no single treatment for CLBP and although it remains one of the most common health problems, it is still difficult to choose between medical and surgical treatments. As previously mentioned, individuals who do not recover in a timely fashion only recover slowly, their demand on healthcare system becomes large and costly and they turn into a major source of disability [18]. Thus, it is not surprising that there is a huge palette of monotherapies, all of which have been evaluated in the literature. Bed rest compared with activity may have a harmful effect on low back pain and patients should be advised to continue to remain active [19]. Carefully selected and presented information and advice on back pain can have a positive effect on patient's belief and clinical outcome [20]. Limited evidence exists that back-school and supervised programs are more effective than no intervention and that an improvement on fear-avoidance questionnaires was found when groups were given the correct instruction on back anatomy and pacing of exercises. The cost-effectiveness of back to school programs remains unknown [21].

Exercises are not necessarily more effective than inactive sham treatments, however, they are better than no treatment at all and patient deconditioning is usually not a problem [22]. In some cases, exercises may improve surgical outcome although it is extremely difficult to dissociate the benefits of exercise and

other cointerventions. The only exercise therapy shown to achieve lasting reductions in pain are directed at the coactivation of abdominal and multifidus muscles [23].

Bearing in mind that CLBP includes either radicular neuropathic pain (with or without loss of nerve function) or referred nociceptive pain (due to inflammation or degenerative disease) or most commonly both, the evaluation of the efficacy of pharmacotherapy remains extremely difficult [24]. There are no recent randomized controlled studies (RCTs) that specifically deal with the results and efficacy of pharmacotherapy in relation to CLBP. Antidepressants may have an antinociceptive effect when neuropathic pain exists – gabapentine in the presence of chronic radicular pain may be beneficial [25,26]. Nonsteroidal anti-inflammatory drugs (NSAIDs) are effective for short-term symptomatic relief and are advantageous in reducing initial pain levels, while natural recovery occurs but does not impact on the natural history of the disease, return to work rate or development of chronic pain [27]. Nothing is known about the effects of γ -aminobutyric acid (GABA)-antagonists, *N*-methyl-*D*-aspartate receptor antagonists, local anesthetics and α_2 receptor agonists.

There is an indication that tramadol may relieve the neuropathic pain component of CLBP [28]. As for the use of opioids, no controlled trials have proved their efficacy and there is no evidence upon which guidelines can be based. A recent large crossover RCT compared patient satisfaction between transdermal fentanyl and slow-release morphine in a mixed population of patients exhibiting combined neuropathic and nociceptive low back pain. In total, 65% of patients preferred fentanyl due to its superior pain relief [29]. In cases of debilitating back pain for which there is no other sensible option, opioids can be used judiciously.

In high-quality RCTs, there is no evidence that acupuncture provides a greater analgesic effect than placebo. Moreover, the higher the quality of the study, the more likely the results on acupuncture efficacy will be negative [30]. Other physical modalities, such as transcutaneous electrical stimulation, therapeutic heat or cold although frequently recommended for self-care, have not been shown to be useful [31].

In general, behavioral therapy concentrates on reducing patient disability by eliminating negative attitudes, negative beliefs, psychological distress and illness behavior. This can be performed either by

positive reinforcement of positive coping strategies (operant conditioning), modifying patients response to pain (respondent treatment such as relaxation) or modifying patients thoughts and feelings about pain (cognitive behavioral). Behavioral therapy as a single therapy for CLBP is better than placebo but is not more effective than other interventions and is insufficient to constitute a primary or exclusive therapy [32]. There is evidence that it has a moderate effect on pain intensity, functional status and behavioral outcome when compared with waiting-list controls or no treatment groups [33]. Data for other injection therapies, such as trigger point injections and prolotherapy are lacking and the botulinum toxin, which has an effect greater than placebo, is of limited duration [34,35]. Other treatments, such as back belts and magnets have not been shown to be efficacious [36,37].

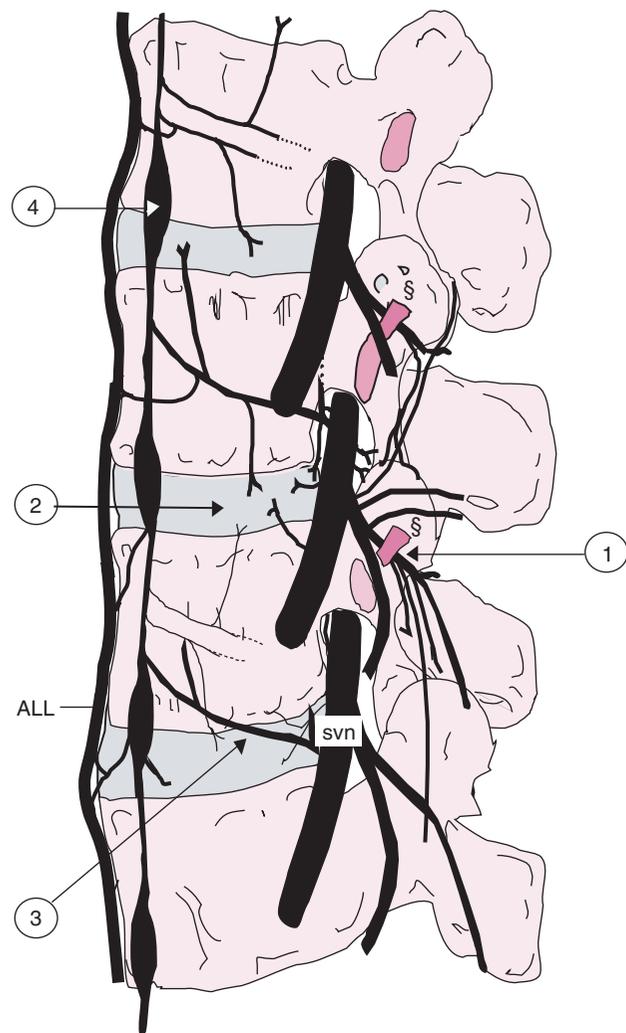


Figure 1. Schematic drawing of lumbar spine nerve supply. After Paris (1983).

§Mamillo-accessory ligament.

1: Medial branch dorsal ramus; 2: Intervertebral disc; 3: Communicating ramus; 4: Sympathetic trunk.
ALL: Anterior longitudinal ligament; svn: Sinu-vertebral nerve.

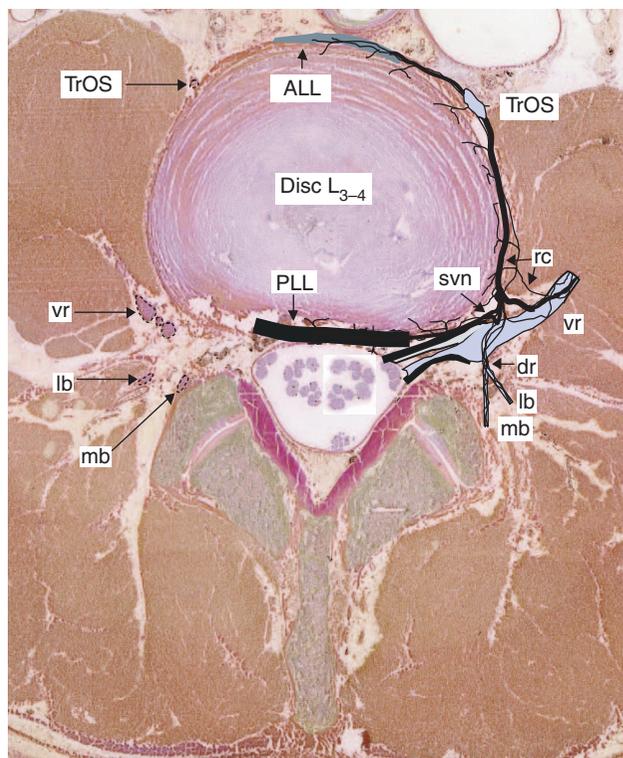


Figure 2. Schematic drawing of lumbar spine nerve supply [63]. Superimposed on a histological cryomacrotome section (28µm) at intervertebral disc L₃₋₄. ALL: Anterior longitudinal ligament; dr: Dorsal ramus; lb: Lateral branch dorsal ramus; mb: Medial branch dorsal ramus; PLL: Posterior longitudinal ligament; rc: Communicating rami; svn: Sinu-vertebral nerve (meningeal branch of spinal nerve); TrOS: Sympathetic trunk; vr: Ventral ramus.

Surgical treatments

The past 20 years have witnessed significant changes in the indications for, and use of, instrumentation in lumbar spine surgery. Between 1979 and 1990, there has been an increase of over 55% in the incidence of spine surgery for CLBP, with substantial variations in practice between countries [38]. A recent RCT comparing lumbar instrumented fusion with cognitive intervention and exercises in patients with CLBP due to disc degeneration was unable to detect any difference after 1 year in pain, analgesic consumption, satisfaction and return to work rate [39].

When evaluating surgical results, it is important to consider radiographic fusion and functional outcome separately, thus improvement rate following surgery remains nonconclusive. A comprehensive review suggests that 68% of patients have a satisfactory outcome following lumbar fusion, however, long-term follow-up of decompressive laminectomy for lumbar spinal stenosis has shown no difference in outcome between surgical and nonsurgical treatments [40,41]. An 18-year follow-up in patients with spondylolisthesis showed that surgical interventions are only indicated for acute radiculopathies [42]. As for lumbar fusion, one in three patients need to be reoperated on, pushing surgeons to less radical treatments such as bilateral partial laminectomy and transcutaneous discectomy [43]. In summary, reconstructive

lumbar fusion has been shown to improve symptoms in carefully-selected patients with incapacitating pain and although successful arthrodesis is the fundamental surgical goal in these cases, a successful fusion does not ensure clinical success.

Neurobiology

Understanding the plasticity of pain and analgesia may improve therapies. In CLBP, there are numerous putative 'pain generators'. These generators may allow normal transmission of nociception, suppress transmission, facilitate transmission or result in structural reorganization in the spinal cord and cortex, collectively referred as neuroplasticity [44]. It is this neuroplasticity of the CNS that results in the chronification of pain.

It is hypothesized that nerve root injury initiates a cascade of neuroimmune and neuroinflammatory events responsible for chronic pain. Recently, it has been shown that increased excitability and spontaneous activity of dorsal root ganglia neurons after axonal injury induce an accumulation and expression of sodium channels SNS/PN3 and SNS/NaN [45]. These new sodium channel subtypes, present only in chronic pain and may be novel therapeutic targets.

The local production of proinflammatory cytokines, such as TNF α may induce central sensitization and inhibit the inhibitory neuron at the dorsal horn level. The presence of wide dynamic range neurons in the dorsal horn, which respond not only to nociceptive but also to nonnociceptive stimuli, hampers the finding of the tissue-source pain. Similarly, the projection of multiple pain generators to multiple levels in the spinal cord make it difficult to identify the exact level affected [46].

External integrity of the disc distinguishes internal disc disruption (IDD) from disc protrusion and herniation. Severe disturbances in stress distribution within the disc can be painful and therefore, can serve as the diagnostic basis for provocative discography [47]. If annulus integrity is compromised, the disc may secrete extracellular glutamate into the dorsal root ganglion, which may predispose the patient to persistent pain. Matrix metalloproteinase-7 and cathepsin G may increase macrophage migration, which is responsible for disc resorption, inducing an intense painful inflammatory response [48,49].

Clinical anatomy

The importance of structural abnormalities is relative. Many individuals who have never suffered from pain have severe anatomical pathologies and debilitated patients have all but slight signs than can explain their pain. Unfortunately, there is no causal relationship between anatomical abnormalities and painful states. FIGURES 1 & 2 summarize the various anatomical sites targeted for diagnostic blocks. For further information the reader is referred elsewhere [50].

Diagnosis

Taking a detailed and appropriate patient history is the most critical component in the assessment of patients with CLBP. Of paramount concern is the detection or exclusion of 'red flag' conditions, namely fractures, infections, tumors or cauda

equina syndrome. This may lead practitioners to investigate 'just in case', the caveat being that false-negative results of low-sensitive and low-specific tests, may lead to a false sense of security. Red flag conditions are rare – they are suspected on the basis of history, not tests and certain conditions will be missed due to early disease, which defies resolution. A checklist for red flag clinical indicators can be used (TABLE 1).

As found for lumbosacral radicular pain, its diagnosis primarily depends upon patient history. Signs and symptoms include one or more of the following: irradiating pain into one or more lumbar or sacral dermatomes, positive nerve root tension signs (e.g., straight leg raise, Bragard, Kemp and Naffziger sign) and/or neurological deficits (e.g., sensory loss, decreased strength, absent or decreased ankle or knee tendon reflexes and urinary incontinence) [51]. A compressed root dermatomal distribution of pain has a sensitivity of 90% (odds ratio [OR] 3.8; $p < 0.001$), dermatomal coldness in the leg has a specificity of 80% (OR 1.8; $p = 0.03$) and increased pain on coughing, sneezing or straining an OR of 2.0 ($p = 0.004$). Presence of abnormal walking on toes, on heels, paresis, absence of ankle/knee tendon reflex and finger-floor distance of more than 25 cm showed a specificity of 98, 93, 93, 93 and 73%, respectively [51].

As for imaging, plain films of the lumbar spine should not be used unless a red flag condition is suspected and may infer increased disability secondary to positive reinforcement of pain behavior [52]. Magnetic resonance imaging is the test of choice in identifying various spinal pathologies (e.g., disc protrusion, herniation and internal disc disruption), although their causality in back pain remains uncertain. A feature is the high-intensity zone observed on T2-weighted images associated with Grade III–IV annular fissures [53]. End plate changes are also associated with painful discs.

Electromyogram and electrodiagnostic studies have no place in the investigation of CLBP since it is difficult to determine the precise spinal nerve level associated with the pathology due to multisegmental muscle innervation. Radicular pain cannot be explained by neurophysiological testing and there is no gold standard against which such a test can be compared.

A psychosocial assessment alternatively known as 'yellow flags', constitutes a weak correlation with back pain but a strong correlation with the disability attributed to it and as such has a strong influence on subjective pain relief measurements. Negative beliefs and behaviors pertaining to physical activity, domestic responsibility and social interaction should be actively sought and treated. However, it is beyond the scope of this review to elaborate on the various psychological tools and the reader is referred elsewhere [54].

From an interventional point of view there are several key questions that construct the rationale of treatment and include:

- Is the patient suffering from back pain? Leg pain? Or both?
- Is the pain mostly nociceptive? Neuropathic? Or mixed?
- Are there signs of true or pseudoradiculopathy?
- Can the imagery explain the pain?
- Has this back been operated upon?

The interventional pain techniques described in this review are minimally-invasive procedures that have a diagnostic and therapeutic value. They do not replace surgery when indicated or medical (noninvasive) treatment is efficient. These are complementary procedures, which may increase the sensitivity and sensibility of certain tests (e.g., selective nerve root blocks, discography and epiduroscopy) but can assist in persistent pain syndromes where medication side effects (mostly NSAIDs and opioids) are unwarranted or intolerable.

Mechanical low back pain

The diagnosis and treatment of mechanical low back pain remains a challenge. The essential features the clinician seeks in diagnostic tests are accuracy, safety and reproducibility. When there is no gold standard with which to compare, the prevalence of disease affects the meaningfulness of test results. Despite a plethora of classifications regarding the origin of CLBP it is thought that referred somatic back pain with or without leg pain may emanate from three major sources: IDD in 40% of cases, facet arthropathy in 15–20% and sacroiliac joint pain in 15–20% of CLBP patients [55].

Internal disc disruption, discography & intradiscal therapies

The clinical features of IDD are pain at rest due to chemical nociception and pain aggravated by movements due to mechanical nociception, without radiological abnormalities. Thus, the sole diagnostic tool designed to identify a painful

Table 1. Checklist for red flag indicators.

Presence of	Other organic disease risk factors		
Trauma	Y N	Cough	Y N
Night sweats	Y N	Hematuria	Y N
Recent surgery	Y N	Retention	Y N
Catheterization	Y N	Stream problem	Y N
Vein puncture	Y N	Menstrual problem	Y N
Occupational exposure	Y N	Hemopoetic problem	Y N
Hobby exposure	Y N	Corticoids	Y N
Sporting exposure	Y N	Pain elsewhere	Y N
Overseas travel	Y N	Neurological signs	Y N
Illicit drug use	Y N	Skin infection	Y N
Weight loss	Y N	Rash	Y N
History of cancer	Y N	Diarrhea	Y N

Adapted from Bogduk N, McGuirk B. *Medical Management of Acute and Chronic Low Back Pain, Pain Research Clinical Medical Management. Volume 13.* Elsevier, Amsterdam, The Netherlands (2002).
N: No; Y: Yes.

intervertebral disc is provocative discography [56]. Contrast material is injected in the nucleus pulposus in order to reproduce pain and followed by a postdiscography computerized tomography scan, which has the ability to reveal internal disc disruption. Discogenic pain can be validated if an adjacent healthy disc serves as a control and does not produce pain upon injection. Fortunately, potential complications such as epidural hematoma or abscess, discitis and inadvertent dural puncture with consequent headache, as with all lumbar interventional procedures are extremely rare. Provocative discographies remain a subject of debate in the literature.

With the improved ability to identify and image painful discs and since surgery may not always represent the optimal treatment for discogenic pain, numerous percutaneous intradiscal treatments have been developed. Intradiscal electrotherapy is a percutaneous procedure using RF energy as a heat source in order to induce collagen changes within the disc which in turn decreases disc protrusion and nociceptor denervation of the posterior annulus secondary to the heating effect. Several prospective trials (n = 57) showed moderate evidence for short-term pain relief as seen on the visual analog scale (VAS), Ostwestry, Beck and Short Form-36 questionnaires. Clear-cut evidence of its long-term efficacy has yet to be determined, however, no segmental instability has been shown after the procedure and outcome data are not inferior to that of surgical fusion [58].

Nucleoplasty is a percutaneous disc decompression technique using coblation technology. Two prospective and two retrospective trials showed decreased VAS scores, however, no functional data were obtained limiting the evidence of this technique [59]. Only one study showed a successful outcome with chymopain nucleolysis and it has been abandoned due to severe allergic side effects associated with the use of this substance [60]. Intradiscal RF lesioning has been shown to be ineffective and no literature other than abstract presentations are found on percutaneous manual nucleotomy, thermal vaporization by laser and RF lesioning of the posterior annulus of the disc [61]. Currently, all the studies published suggest that discogenic pain may be diminished by intradiscal therapies, however, methodological flaws, namely nonrandomization, limit the evidence of all these treatments [62].

Zygapophysial (Facet & zygapophysial joints) blocks & RF lesions

The facet joints are innervated by the medial branches of the two adjacent lumbar dorsal rami and have been shown to be capable of being a source of pain [63]. Pain relief following an anesthetic block of these medial branches under fluoroscopic control with as little as 0.3 ml of local anesthetic, constitutes evidence that the joints involved are the source of pain. To avoid false-positive responses, single diagnostic blocks are avoided and at least two concordant responses are necessary. However, in both circumstances, leakage of the local anesthetic may be an extra source of false-positive findings. Safety has been established and complications related to incorrect needle placement are extremely rare [64].

Lumbar median branch blocks are not designed as a therapeutic intervention and medial branch neurotomy by RF thermolesioning is considered as the next step in treatment. The rationale for the application of RF denervation is the assumption that selectively heating nervous structures can impede nociceptive input. Practically, this is achieved by percutaneous application of small-sized electrodes at target neural tissues, resulting in size-controlled lesions at different anatomical positions.

When responses to diagnostic blocks are unequivocal and RF neurotomy is performed meticulously, it can achieve clinically significant and satisfying periods of pain relief. However, recent systematic reviews differ between moderate-to-strong evidence of efficacy, attributed to methodological and technical flaws associated with the treatment, as well as critique regarding the meta-analysis [65,66].

Sacroiliac joint blocks

Pain relief following anesthesia of the sacroiliac joint (SIJ) constitutes evidence that the joint is the source of pain, yet the predictive value of this block is unknown. The difficult access of SIJ injection has promoted the use of computerized tomography guidance. Only two uncontrolled studies describe the use of RF lesioning for SIJ pain [67].

In summary, all interventions are based on the premise that precise anatomical diagnosis can provide a rational approach to pain management. However, due to the multisegmental innervation of spinal structures and overlap of referred pain areas, its accuracy may not be reliable, perhaps partly explaining why interventional therapies do not work under all circumstances. Morphological information can be obtained by placing radio-opaque contrast material into various elements of the spine. Sound knowledge of the various anatomical structures involved in the pain process whilst using an image intensifier, along with directional steering of curved, blunted-tip needles allow the injection of limited amounts of local anesthetics for accurate diagnosis and subsequent treatment.

Painful lumbar radiculopathy

In radicular pain it is essential to differentiate between operated versus nonoperated backs since the suspicion of the presence of epidural fibrosis alters the therapeutic yield of injections [FIGURE 3].

Epidural interventions

Injection therapy with anesthetics and/or steroids has shown conflicting results regarding its efficacy for the treatment of CLBP; nevertheless, it remains the single most common procedure performed. It has been subjected to much controversy and a literature review between 1966 and 1999 has warranted their use in patients who have failed on treatment with conservative therapy [66]. However, it is clear that this is a treatment expressly for radicular and not back pain.

If the effect of epidural steroid injections is local, a direct effect on the injured nerve root or on the 'leaky disc' is essential so that the steroid can reach the site of injury. Historically,

epidural steroid injections have been performed 'blindly', without any radiological guidance, however, many factors may prohibit steroids from reaching the intended nerve root, such as scarring, adhesions, adipose tissue and septa, which may be present in the operated and nonoperated backs. Thus, theoretically, drugs injected into a scarred epidural space will follow the path of least resistance, away from the painful site.

Percutaneous epidural neuroplasty (Racz procedure)

It appears rational to assume that mobilization or dissolution of fibrosis may remove barriers that prevent the application of drugs. Epidural neuroplasty (also known as the Racz procedure) consists of accessing the epidural space in a caudal or transforaminal approach, injecting nonionic contrast material (thus performing an epidurogram) in order to detect filling defects in the epidural space. This is followed by gentle manipulation of a metal reinforced catheter in order to liberate adhesions (filling the defects) and then injecting the targeted medication [68]. This procedure, which allows prolonged pain relief in refractory cases, has the advantage of targeted drug delivery but has the disadvantage of an indirect, two dimensional vision of the presumed pathology.

This procedure, which involves an epidurographic diagnosis of spine pathology may be followed by neurolysis with the injection of corticosteroids, hypertonic saline and/or hyaluronidase. Two RCT and three retrospective evaluations showed pain relief of up to 1 year, with cost-effectiveness gains of up to US\$8127 per year per patient. When performed by appropriately skilled personnel, this procedure has a low complication rate, however, dural puncture, spinal cord compression, catheter shearing, hypertonic saline toxicity, infection and bleeding remain worrisome [69].

Spinal endoscopy

When an injection is performed under fluoroscopy, the image obtained is two-dimensional and can be misleading. Due to individual anatomic variations, epidural endoscopy provides a three-dimensional, real-time, color view of anatomy/pathology in the epidural space.

Access to the epidural space with a flexible fiberoptic catheter via the sacral hiatus appears to be safe and efficient [70]. The procedure is performed under local anesthesia while continuously monitoring intraepidural pressures and the patients response. When touched, normal nerve roots cause paraesthesia and diseased nerve roots cause pain, therefore, patient feedback is essential while gently performing adhesiolysis. The technique allows examination of the epidural space and its contents, targeted injection of medication, lysis of scar tissue (adhesiolysis) and (potentially) retrieval of foreign bodies [71]. As technology grows, exciting, new possibilities such as minimally invasive

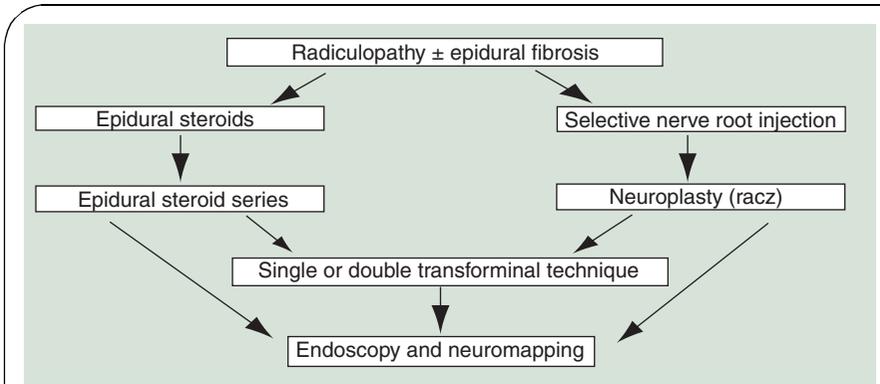


Figure 3. An interventional approach algorithm for painful lumbar radiculopathy associated with (right arrow) or without (left arrow) epidural fibrosis.

surgery, intraoperative nerve stimulation and immunobiological interference evolve, promising an important and exciting role of spinal endoscopy in the treatment of spinal pain.

In a prospective case series, all patients undergoing epiduroscopy suffered from adhesions between nerve roots, dura and ligamentum flavum, 41% were very dense and associated with previous surgery. If fibrosis is a result of chronic radiculitis, neurogenic inflammation impaired fibrinolysis, then repeat surgery will aggravate the situation and is ill advised. The authors hypothesize that adhesions obstruct radicular veins and interfere with the nervi vasorum, creating intraneural edema and abnormal pain transmission. Dilution or 'washing out' phospholipase A2 and synovial cytokines may also contribute to symptom improvement [72].

Pulsed radiofrequency

Neuropathic pain is usually considered a contraindication for the use of RF thermolesioning since it makes little sense in performing a neurodestructive procedure in the presence of altered neural function, risking aggravating neural pathology (i.e., differentiation pain and neural damage). While this has been a paradigm for years, RF thermolesion in trigeminal neuralgia, a clear example of a neuropathic pain, has been the treatment of choice [73]. This may be related to differences in the origin of the neuropathic state between trigeminal neuralgia and lumbosacral nerve root neuropathy.

Pulsed RF (PRF), where short bursts of RF energy are applied to the nerve, is thought to be a safer alternative to the classical thermocoagulation by RF and currently, there is no clinical evidence of neural damage [74]. The PRF is basically performed exactly as thermal RF, with an apparatus capable of transmitting the appropriate energy. The mechanism by which PRF works remains unclear, although some studies suggest that the analgesic effect is neuromodulatory rather than a neurodestructive one [75]. No placebo-controlled trials have been published on its efficacy in CLBP.

Failed back surgery syndrome

The most difficult condition to assess and manage is persistent and at times worsened back pain following spinal surgery,

colloquially known as failed back surgery syndrome (FBSS). Possible causes include correct operation, wrong diagnosis; correct diagnosis, wrong operation and wrong diagnosis, wrong operation. Thus, FBSS constitutes a heterogeneous group of patients which have either their original cause of pain amenable to treatment, their original cause of pain nonamenable to surgery due to induced anatomical changes or a new cause of pain due to neuroma formation, nerve injury, epidural scarring or arachnoiditis. It is in these cases 'when all else failed' that the utilization of implantable devices, such as spinal cord stimulators (SCS) and implantable intrathecal (IT) pumps are advocated. This group of patients represents a 'therapy-resistant' group where the chronic pain state results from a disinhibition of the descending inhibitory noxious control, respondent to SCS and IT therapy.

Spinal cord stimulation

The premise of SCS is based upon the Gate Control Theory where stimulation of low-threshold primary afferent fibers 'close the gate' to nociceptive input. SCS is not opioid mediated since it is not reversed by naloxone, however, inhibitory neurotransmitters concentration, such as GABA, substance P, serotonin, glycine and adenosine, are increased after SCS and excitatory glutamate and aspartate concentrations are reduced [76]. Moreover, the GABA antagonist bicuculline counteracts the SCS analgesic effect, while lioresal and adenosine potentiates it [77].

Maximal conservative treatments always precede the use of SCS. Since there is no controlled data on the efficacy of SCS for mechanical back pain, its role would appear to be best limited to the palliation of leg pain in patients with FBSS. Due to the invasiveness of the procedure and the inability to provide blinded treatment, all studies are case-control investigations. Review of two prospective control studies demonstrated pain reduction over 50% in two-thirds of trialed patients, however, no improvements in functional status were found. In a RCT between SCS and reoperation comparison, crossover design at 6 months suggested that patients who failed surgery opted for SCS but not vice versa [78]. Pooled evidence show that SCS in correctly selected patients can provide long-term relief and is superior to reoperation and is cost-effective, however, it is an invasive, interventional procedure, not devoid of procedure-related complications [79].

The procedure consists of implantation of percutaneous or plate-type electrodes which are quadri- or octopolar. First, a trial stimulus on a conscious patient under local anesthesia is performed where the electrode is placed epidurally and connected to an external, reusable pulse-generator. A test period between 5 days to 3 weeks, ensures that the stimulation (perceived by the patient as vibration) covers the painful area. If pain scores, mood changes, sleeping pattern and general comfort are ameliorated, a subcutaneous implantation of the pulse-generator is performed. The percutaneous technique offers the advantage of being easily removed if the test period is negative, which is not the case when plated electrodes are used.

Psychological screening, pain characteristics and a test period prior to definitive implantation impact on the response to SCS [80]. SCS appears to be better with single root injury or mononeuropathy (60–75% pain reduction) than with arachnoiditis, although 50–60% pain relief has been obtained. Predominant axial pain is more difficult to treat and may require a dual electrode system implantation.

Intrathecal opioids

IT drug delivery systems are used when all other common routes of administration (i.e., oral and transdermal) have failed to improve pain or when treatment side effects are intolerable. Although the use of opioids in the treatment of nonmalignant pain remains controversial, the use of IT opioids is common. The safety and efficacy of IT delivery of opioids is based on retrospective observational cohort studies and the available prospective studies, although well-designed, they often include only a small number of patients. Thus, further research is required to optimize treatment in terms of drug selection, dosage, efficacy and safety. Three randomized studies have shown that IT opioid therapy has a place in the treatment of chronic noncancer pain, however, when restricting inclusion criteria to CLBP patients, data are less compelling [81].

The rationale behind the use of the IT route is that it offers better analgesia and fewer side effects. Somnolence, constipation, euphoria and mental clouding are reduced when compared with the oral route and provide superior pain relief when combined with local anesthetics such as bupivacaine. Implantation of IT drug delivery systems harbors risks associated to surgery itself, such as infection and bleeding, spinal injury from catheter insertion and the short- and long-term side effects of the various infused medications. Albeit rare, all these must be considered when consenting a patient who is often 'ready to do anything that would reduce pain'. The costs of IT drug delivery systems have been evaluated and dosing algorithms exist [82].

Expert opinion

Acute pain, the subjective response to injury, is something we may be able to comprehend and accept as a necessary and even welcome signal, to avoid imminent and future injury. By contrast, chronic severe pain, separated from its essential protective context, can become a meaningless burden. In time, the sufferer may seek 'no matter what kind of treatment'. If this desperation of the patient is also shared by the physician, the decision-making in pain management becomes difficult. Many factors profoundly influence this decision, including physician's attitudes, beliefs, medical knowledge and training, patient age, overall health, functional status, psychosocial factors, ethnocultural and religious beliefs as well as preference, regulatory forces, facilities and economic factors.

It is important to remember that all medical interventions are associated with risks and benefits, which compromise of a risk-benefit ratio. All interventions have alternatives (including no intervention) and each alternative possesses its own risk-benefit ratio. Thus, clinical decision-making involves

comparing and contrasting the risk–benefit ratio of the procedure and also the alternative intervention. Unfortunately, results of controlled trials and systematic reviews of various monotherapies for CLBP are disappointing.

In a multidisciplinary approach one must bear in mind that it is essentially a simultaneous application of different interventions each provided by a different professional from a different discipline. If minimally invasive pain therapies are seen in this perspective, their role may become more important in the future.

Five-year view

Interventional pain management offers a spectrum of minimally invasive procedures with both diagnostic and therapeutic intent. It has borrowed improved technologies from many disciplines, such as pacemaker, RF and endoscopic technologies as well as novel drugs with improved drug delivery systems. The advances we can foresee in the field of interventional pain for the near future are:

- Improved sensory testing to determine the presence of neuropathic pain using tools such as Quantative Sensory Testing or cerebral imagery using functional magnetic resonance imaging or positron emission tomography scans
- Improved mobile biplanar imagery (C arm fluoroscopy) with higher resolution, digital subtraction and 3D reconstruction capacities or open magnetic resonance imaging machines with better definitions to facilitate percutaneous approaches
- Improved intradiscal systems for thermal lesioning and improved artificial discs to retain segmental mobility
- Improved PRF systems, hybridized with percutaneous adhesiolysis catheters (a hybrid system known as PASHA is currently under development)
- Improved endoscopic systems to improve *in situ* vision accompanied by mini surgical devices to perform percutaneous neurolysis or nerve root stimulation
- Improved electrode technology for spinal cord stimulation with eight to 16 active poles, accompanied with computerized stimulation algorithms and improved generator technology with prolonged battery life
- Improved pump technology with smaller more ergonomic designs
- Other drug delivery systems such as intranasal, iontophoresis, lollipops and matrix transdermal systems

Key issues

- Chronic lower back pain (CLBP) continues to be an epidemic in the industrialized world.
- The direct and indirect cost of CLBP are staggering.
- Medical and surgical treatments remain costly despite limited efficacy.
- The field of 'interventional pain', providing 'minimally invasive techniques' has grown enormously and evidence-based practice guidelines are systematically developed.
- There is moderate evidence in small randomized, nonrandomized or case controlled studies that medial branch neurotomy by radiofrequency may help in CLBP.
- There is limited evidence in nonexperimental single or multicenter studies that intradiscal treatments may help in mechanical low back pain due to internal disc disruption.
- There is moderate evidence in small randomized, nonrandomized or case controlled studies that transforaminal epidural steroid injections, lumbar percutaneous adhesiolysis and spinal endoscopy may help in painful lumbar radiculopathy.
- There is moderate evidence in small randomized, nonrandomized or case controlled studies that spinal cord stimulation and intrathecal pumps may help in painful lumbar radiculopathy mostly after spinal surgery.
- In a reality where there is no gold standard for the treatment of CLBP, these results appear promising.

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