International Journal of Medical Science in Clinical Research and Review
Online ISSN: 2581-8945
Available Online at http://www.ijmscrr.in Volume 7|Issue 03 (May-June) |2024 Page: 582-589

Review Paper

Evaluating Lumbar Spine Stenosis: A Meta-Analytical Review of Clinical Outcomes and Management Strategies.

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Article Received: 19-April-2024, Revised: 09-May-2024, Accepted: 29-May-2024

ABSTRACT:
Lumber spine stenosis is a physiological disorder in which there is the degeneration of the space within the spinal canal and it is mainly aggravated by walking or standing, especially in elderly patients. It is a common source of pain as it is associated with neurogenic deformities within the spine hence early diagnosis of stenosis is important. MRI, CT, and myelography are used to localize the site of a nerve root or any other form of stenosis and both nonoperative and operative treatment measures are used to treat LSS in the medical fields. Exercises and good posture are some of the nonoperative measures commonly used in patients with mild signs of stenosis. the need for individualized treatment plans for LSS, balancing the benefits of conservative management and the potential long-term advantages of surgical intervention. Future research should aim to refine diagnostic criteria and establish standardized treatment protocols to enhance patient care. This meta-analysis provides a comprehensive evaluation of LSS management, supporting clinicians in making informed, evidence-based decisions. Early diagnosis of stenosis in the lumbar spine helps to prevent any form of permanent neurologic complications in the spinal nerves.

Keywords: Stenosis, Lumber Spine, Medical Imaging, Clinical outcomes, Management strategies

INTRODUCTION:

Lumbar spine stenosis is a physiological disorder in which there is the degeneration of the intervertebral discs due to instability or hypermobility of the facet joints present in the superior articular process of the spine. It is an imaging diagnosis that is more common in the aging population. It is a result of neurogenic degenerative changes in the lumbar or cervical spinal vertebrae due to the weakening of the bones as a person grows older. The probability of the occurrence of lumber spine stenosis in people varies depending on the race, sex, physical activity, and geographical location of the respective patients. Various studies have been conducted over the past few years to determine the morbidity and mortality existence of the congenital malformation of stenosis in people of different races, and it was discovered that the resultant cause of hypertension and compressions around the nerve roots is associated with complex symptoms known as neurogenic intermittent claudication (NIC) [(1)]. CT and MRI represent accurate and effective diagnostic imaging technologies for Lumber spine stenosis. They can be used individually or together, but often in conjunction with myelography with each modality having its advantage when used solely but all of them having an incremental value when used together in a multi-test sequence[(2)].

Scope of the Review:

This review defines the anatomy, pathogenesis, etiology, and clinical diagnosis of lumber spine stenosis. This review discusses the different imaging evaluation modalities used and their respective clinical advantages and limitations in the diagnosis of LSS. The review also includes several case studies showing the prevalence of lumber spine stenosis, and clinical signs presented by the patients at the time of diagnosis. The cases included patients with severe back pains, herniated intervertebral discs, myelopathy, or any acute-onset sign related to stenosis. The clinical measures used for their treatment were also included respectively. The studies used in this literature review date back from 2013 to 2022. English

and non-English-language articles were used and all the retained articles were read independently[3].

History Perspective of Stenosis:

According to different sources, the first medical report of stenosis was discovered in the early 1800s by Antoine Portal, a French anatomist, who was the first to explain the formation of the structural deformity in the vertebral column. He postulated that back and leg pains resulted from pathological impingements of the spinal nerves and bones. Jules Déjerine, a French scientist, also expressed lumber stenosis as a neurogenic deformity in the spinal nerves that develops as the vertebrae column becomes weak with aging, causing mobility problems and later resulting in other complications in her study of psychoneuroses in 1911[4].

VanGelderen clarified spinal canal stenosis as spondylotic myelopathy. In this condition, there is a degeneration of the spinal cord due to the compression of the lumbar nerve in patients, resulting in the abnormal thickening of the Ligamentum flavum (hypertrophy), which might result in complicated forms of stenosis if left untreated. Sarpyener (a Turkish surgeon) also conducted a study involving 12 children who were presented with upper and lower motor neuron diseases. He discovered the formation of congenital strictures in the spinal canal of the children due to the degenerative changes in the lumbar and cervical vertebrae[5].

Henk Verbiest indicated the presence of myelographic blocks in the lumber spines that subsequently led to the narrowing of the spinal canal in the 7 elderly patients with whom he was involved in his study. The 7 patients showed clinical symptoms of bilateral motor and sensory disturbances in their legs as a result of walking and standing as a result of aging[6].

Kirkaldy-Wills and his colleagues studied the pathology and pathogenesis of lumber spine stenosis and spondylosis present in the intervertebral disc and the zygapophyseal joints of the spine. They found out that, the compression and rotation injuries led to the development of radial annular tears and internal disruptions in the intervertebral discs. The compressions resulted in the protrusion of the discs and also loss of disc height in the vertebral bones causing synovitis in the zygapophyseal joints, joint subluxation/instability, and degenerative sclerosis[7].

Lane, an English scientist, in 1893 proposed the use of decompressive laminectomy to treat patients with syndromes of cauda equina, which is mainly caused by stenosis. Bailey and Casamajor also stipulated in their 1911 study that spinal nerve symptoms were caused by the exostosis of the bone facets in the spine, which can cause significant compressions in the spinal canal, leading to stenosis and they also recommended the use of laminectomy to treat it.

Lumbar Spine Stenosis Correlation With other Affected Tissues in the Vertebral Column

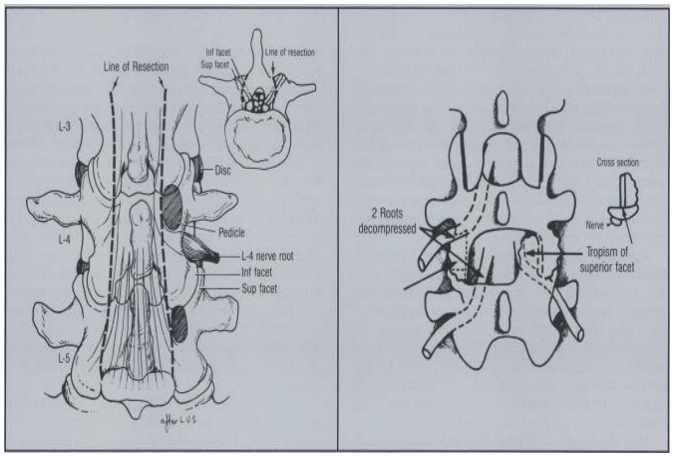


Figure: Lumber spine anatomy (From Ciricillo SF, Weinstein PR. Lumbar spinal stenosis. West J Med [5]

Lumbar spine stenosis is a clinical syndrome of the lower extremity or buttock that is associated with or without lower back pain resulting from the diminished space of the neurovascular elements in the spinal canal[8]. There are 33 spinal cord nerve segments in a human spinal cord and the lumber spine consists of five lumber vertebrae which articulates anterior to each other via a primary cartilaginous joint, and posteriorly via two synovial joints (facet joints). Each vertebra consists of a broad vertebral body and vertebral arch with an extending transverse process.

The lumber spine stenosis consists of the following structures:

- ✓ Three supporting ligaments: Supraspinous ligament, Interspinous ligament, and ligamentum

flavum. They support the spine by preventing the vertebrae from slipping out of the line as the body/spine moves.

- ✓ Intervertebral discs: One disc is present in all the vertebrae except in the first cervical segment, the atlas. Concentric rings of fibrocartilage surround the nucleus of the discs. They act as shock absorbers to reduce the tension between the vertebrae.
- ✓ Synovial Facet joints: They are present in the superior articular processes of the vertebra and also in the inferior articular process of the vertebra lying above it. Their purpose is to hold together the vertebrae to each other and allow slight movements within the joints.
- ✓ Cauda equina: it is a sack-like structure consisting of nerve roots where the spinal cord ends. They provide a neurologic link to the lower body part. In stenosis, there is an abrupt neural pathway causing late neural reactions in the patients.
- ✓ Medulla spinalis: These are long, thin tubular nerve tissues that run throughout the entire spine. They provide a means of communication between the brain and the rest of the body.
- ✓ Intervertebral foramen: it is an opening inside the spinal canal present between the vertebrae through which nerves exit. Allows nerve extension and elongation during movements.

The lumber spine is bordered laterally by the vertebral pedicles, posteriorly by the laminae of the ligamentum flavum, and anteriorly by the intervertebral discs[(9)].

Epidimiology of Stenosis:

Spinal stenosis can be categorized according to its pathogenesis and anatomy, and hence understanding the pathology and anatomy of the lumber spinal stenosis is crucial as it helps to correlate with the history, physical examination, and radiographic findings of the patients being assessed with clinical symptoms of lumbar spinal stenosis.

According to several sources, the probability of the occurrence of lumber stenosis in India is estimated to be between 5 and 11 cases per 100,000 live births (0.005% and 0.011% of live births). The prevalence of stenosis is much more common in elderly people between the age groups of <40 years and 60 years. According to a study by Physiopedia, the prevalence probability of stenosis relatively increases from 16.0% to 38.8% in people of age >40 and from 4.0% to 14.3% in the 60+ age group. Lumbar spine stenosis is hence an extensive problem in the elderly, as it is associated with lower back pains, disability, and even problems in movement[(10)].

In a small occurrence, some people are born with a small spinal canal "congenital stenosis," which results from abnormal anatomy of a reduced lumber sagittal diameter and is associated with degenerative symptoms. However, in some people, as they grow older, their spinal canal starts to narrow, this condition is mostly known as "acquired spinal stenosis," and it is common in people >50 years of age[(11)].

PATHOANATOMY AND CLASSIFICATION OF STENOSIS

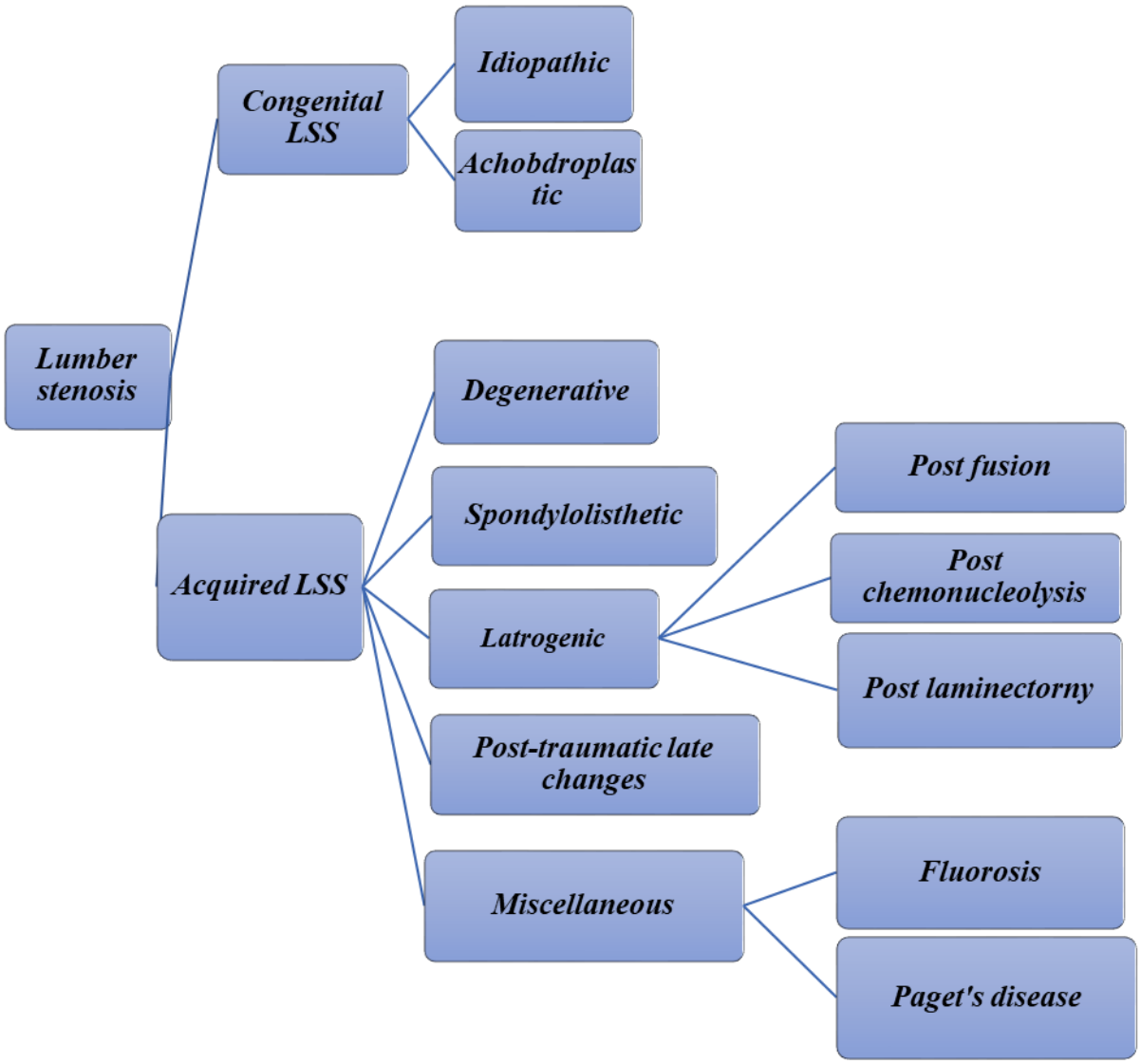
Anatomically, LSS is defined as either central canal stenosis, lateral canal stenosis, or foramina stenosis. Central canal stenosis is commonly found at the central intervertebral level, and it is mainly caused by the calcification of the Ligamentum flavum, where the Ligamentum flavum buckles up, intruding into the spinal nerves. Other causes of central canal stenosis include intervertebral disc protrusion, hypertrophic zygapophyseal joints, and degenerative spondylolisthesis.

Central stenosis is usually diagnosed using special imaging modalities such as MRI (magnetic resonance) and myelography, which can produce distinctive images showing the multiple layers of fat and bones in the region of interest of the central stenosis. In myelography, the images taken show 40% of the fats and muscles present within the central stenosis, together with the centrally compressed cauda equine viewed from the anterior-posterior side of the intervertebral disc.

The compression of the cauda equine is an indication of the bulging/protrusion of the ligamentum flavum or the zygapophyseal joint. This compromises the flow of blood (ischemia), this condition is usually associated with aging or applied mechanical stress. With aging, the ligamentum flavum becomes hypertrophied making the zygapophyseal joint protrude posteriorly. With aging, the ligamentum flavum undergoes fibrotic changes as there is a proliferation and ossification of the fibrocartilage. Park et al, in their study, (reference) indicated that there is a development of hypertrophy in the ligamentum flavum with the growth of the fibroblasts (TGF-B1)[(12)].

Central stenosis denotes mainly the space between the facet joint which is occupied by the dura mater and other CSF contents. The most common form of central stenosis is NIC where there is a compression in either one of the three zones of the nerve root canal. The three zones of the nerve root canal: are the lateral recess, foramina, and extraforaminal stenosis zones. The most susceptible zone is the lateral recess, also known as "Lee's entrance zone," as it is where the nerve roots exit the dura mater, and the main cause of stenosis in this region is the proliferation of fibrocartilage and lateral disc herniation. Pathologically, Spinal stenosis can be classified as either acquired or congenital, depending on the etiology and anatomy of the deformity[(13)].

Classification of Lumbar Spine Stenosis and Its Major Causes



Acquired stenosis is primarily caused by degenerative disease of the spine, spontaneous tears, degeneration and collapse of the discs, and fibrosis. These all consequently lead to the mechanical failure of the lumbar discs increasing the stress on the facet joints and ligamentous attachments causing sub-periosteal osteogenesis of the vertebral body lip. Other causes of acquired stenosis are vertebral deformities, osteophyte formation, and calcification of the soft tissues which is associated with Pott's disease (tuberculosis of the spine). Degenerative spondylosis is usually associated with hyperplasia and fibrosis in the posterior longitudinal ligament. This disease increases the thickness of the Ligamentum flavum from its normal 2mm diameter to 5mm. Hypertrophy of the Ligamentum flavum causes compression of the spinal neural elements, and it is the major cause of stenosis in some patients.

The vertebrae of patients with congenital stenosis are characterized by short and thick pedicles with a smaller diameter of the transverse interpediculate vertebral discs, less than the normal diameter of 25mm. Congenital stenosis is usually caused by the idiopathic reduction in the normal spine canal diameter or by achondroplastic dwarfism. Verbiest conducted a study on middle-aged men who had radicular symptoms in the lower extremities which were being aggravated by walking or standing. He found out that in all of the patients, the anteroposterior diameter of the lumbar spinal canal was 12mm or less, much smaller than the 17-25mm diameter in a normal spine canal[(14)].

In a review article on spinal stenosis by Schatzker and Penal*, they noted that in all types of stenosis, there is the shallowness of the lateral recess and a decrease in the anteroposterior diameter of the spinal canal. This results in the compression of the nerve roots or the cauda equine

causing neural dysfunction, structural damage of the neurons, intra-neuronal blood flow impairment, blockage of axon transport, and edema in complicated cases.

Clinical Presentation of Lumber Spine Stenosis:

Classically, lumber spinal stenosis is associated with some cruciate lower back pains which are exacerbated by prolonged standing and are usually relieved with the patients doing forward flexion activities in a standing position/prone position. The pain in the patients usually originates from the buttocks, things, or in the lower legs after standing or walking for some time, and hence the patient experiences functional disability and discomfort, limiting the patient's walking capacity.

In a study of a population of 100 patients by Amundsen et al[8], he found the occurrence of back pain and sciatica in 95%, and claudication in 91% of the patient population with most of them having bilateral leg complaints. The most common type of stenosis becomes more symptomatic after the seventh decade of life and it is more common in women than men.

In severe complications, there is a development of neurogenic bladder which is characterized by the change in the bowel and bladder urgency, functions, and urination frequency. Patients with lateral recess LSS have a risk of falling and may have more pain during rest and at night as the specific nerves are compressed. An evaluation study on age-weight-matched stenosis was conducted, and the test included two groups: 40 patients with symptomatic LSS and 40 patients with advanced osteoarthritis in their knees. The two groups' functional mobility abilities were compared in a six-meter walk and sit-to-stand exercises and it was noticed that the patients with symptomatic LSS had decreased mobility in both activities as compared to the osteoarthritis patients[15].

Patients with LSS may experience tingling and numbness in their entire leg which is always associated with low back pains and the symptoms are always bilateral and asymmetric. LSS patients may also report that walking upstairs is easier than walking downstairs as the back is always back flexed in the stairs climbing.

In very rare instances, LSS may be associated with priapism (a form of erectile dysfunction). This arises due to the compression of the lumbar spine nerves that control the various lower body functions including the sexual functions. The compression of these nerves results in the disruption of the nerve signaling and control causing priapism in rare cases.

Imaging Evaluation Of Lumber Spine Stenosis:

1. X-Ray Radiographs:

Plain X-ray radiographs are also useful in identifying fractures within the intervertebral discs and hence useful in the early identification of any possibility of stenosis. They evaluate any loss of disc height or any formation of bony lumps within the spine (osteophyte formation). They allow the detection of these defects in lateral, oblique, AP, and PA mid-sagittal views and other dynamic views with less patient discomfort. The anteroposterior view allows the assessment of osteophytes and scoliosis in L2-L3-L4 (apex of the spinal curve) where stenosis is usually found. Additionally, in patients with standing difficulties, AP views of the hip joints can be easily obtained with minimal patient rotations of not more than 10 to 15 degrees while in sitting positions with foam pads used for stability. Congenital stenosis can be inferred and easily identified in lateral view. This view also permits the diagnosis of facet osteoarthritis, disc height collapse, spondylolisthesis, and even osteophytes.

2. Computed Radiography:

CT scan performed with water-soluble myelography is also another useful way of evaluating the compressions in patients with dynamic stenosis or any severe spondylolisthesis[16]. It is also preferred if there is any contraindication to the patient being examined on the MRI, for example, the absence of any suitable diagnosis signs for MRI or in patients with metal implants and pacemakers (although the newer pacemakers versions in use can be MRI-compatible). It can be rapidly performed, allowing a better visualization of the bony confines of the spinal canal.

However, CT imaging is rarely used unless MRI is contraindicated as it gives an inaccurate assessment of the degree of the complications. CT also exposes patients to radiation and it cannot unequivocally distinguish CSF and spinal cord as both of them have the same density in CT imaging. It is also invasive as it involves the need for a lumber puncture procedure and hence MRI is usually preferred mostly.

3. Magnetic Resonance Imaging:

Magnetic resonance imaging (MRI) is a noninvasive and suitable method to evaluate both central and lateral recess stenosis in the radiology department as it can differentiate tissues and assess the patho-anatomy of the intervertebral discs. It is more viable as compared to computed tomography and more preferable by many patients. It is more accurate than myelography in diagnosing LSS and also more sensitive to identifying any disc proliferation/degeneration. When diagnosing central stenosis, T2-sagittal weighted images provide a clear midline sagittal view of the narrowing intervertebral canal. Additionally, T2-weighted fat-suppressed sequences can be used to obtain a myelographic image. T1-weighted images show the presence of any abnormal fats around the root canal indicating the presence of foramina stenosis. Any form of extraforaminal LSS is identified and viewed on axial T1-weighted images as the MRI machine can obliterate the fats between the discs and the nerve roots. MRI

allows for the visualization of both the nerve roots and surrounding fat.

Boden et al.[11], conducted a study on patients older than 60 years to identify any presence of stenosis or any complication and all patients were evaluated by MRI. After MRI scans, 57% of the MRI scans were abnormal findings with 36% of the patients having nucleus pulposus herniation and 21% having spinal stenosis. The findings of the MRI scans matched with the symptoms and signs of the patients with neurogenic complications/ claudication.

4. **Myelography**:

It is mostly preferred in patients with metallic implants making it impossible to render MRI or CT scan interpretations. This type of scan allows the assessment of the lumber spine with patients in standing positions and it is a noninvasive procedure. It involves exposing the patient to an iodinated contrast agent hence it is devoid of potentially severe or adverse effects in the form of an infection or an anaphylactic reaction[17].

Management:

A literature review to understand the relationship between the clinical outcomes in operative and non-operative treatments has shown that degenerative spinal diseases and stenosis respond favorably to non-operative management. Despite symptoms of back pain, neurogenic claudication, or any symptoms of stenosis, conservative measures are successful and therefore mostly recommended in patients for initial treatment[17].

Conservative measures include enough bed rest, the use of NSAIDs (Nonsteroidal anti-inflammatory drugs) and other opiate analgesics, exercise programs, and aerobic fitness. The use of exercise bicycles helps to strengthen the back and leg musculatures while the lumbar spine is flexed forward. Short-course use of epidural steroid injections, administered under fluoroscopic control, may benefit some patients with mobility difficulties. No large controlled studies have been published however addressing the efficacy of steroid therapy. Conservative treatment is specifically applicable in patients with moderate pain but operative treatment is recommended in those patients where conservative treatment has failed and have severe pain and complicated neurologic symptoms.

Conservative measures such as exercise programs and nonsteroidal anti-inflammatory medications help in strengthening the abdominal musculature and reducing lumbar lordosis. Although these treatments have been shown to diminish symptoms in patients with lateral recess LSS by providing temporary relief in patients, they do not prevent the recurrence of the painful effects of LSS and hence medical management may be the only alternative in those patients where surgical treatment is not contraindicated.

Surgical intervention is considered when medical management fails to help the patients relieve the intolerable pain they experience when they are doing their daily activities. It is primarily considered in patients with initial signs and symptoms of cauda equine dysfunction or any form of progressive neurologic deterioration and the goal of the approach is to decompress the existing nerve roots minimizing the possibility of spinal instability[18].

The degree of surgical decompression is usually assessed individually based on clinical, radiologic, and surgical observations. Widely, laminectomy with bilateral foraminotomies is the most used standard operative measure in the radiology department. The technique is used mostly in patients older than 35 years of age and it is associated with post-operative instability in the spinal cord hence fusion of the spine is not always necessary except in those older patients with degenerative spondylolisthesis where the likelihood of spinal instability is very high[19].

Patients with lateral recess are treated with interlaminar exposure and bilateral laminotomies to remove hypertrophic bones, ligamentous tissues, and osteophytes. Resection of the medial third of both the inferior[20].

Summary:

Lumbar spine stenosis (LSS), a degenerative condition causing the narrowing of the spinal canal in the lower back, results in significant pain and mobility issues. Diagnostic methods varied, with MRI identified as the most reliable tool due to its high sensitivity and specificity. The review compared conservative treatments—such as physical therapy, medications, and epidural steroid injections—with surgical interventions like decompressive laminectomy and spinal fusion. While conservative treatments provided moderate symptom relief, surgical interventions showed more substantial improvements in pain and functional outcomes. Despite the inherent risks of surgical procedures, such as potential complications, the benefits for carefully selected patients were significant. The review emphasizes the necessity of individualized treatment plans, highlighting that while conservative management is effective for some, others benefit more from surgical intervention. Future research should focus on refining diagnostic criteria and establishing standardized treatment protocols to optimize patient care. This comprehensive meta-analysis provides crucial insights to support clinicians in making evidence-based decisions for the effective management of LSS.

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