COMPARISON OF ENDOSCOPIC AND OPEN METHODS OF SURGICAL TREATMENT FOR LUMBOSACRAL SPINAL CANAL STENOSIS: A SYSTEMATIC LITERATURE REVIEW

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Objective. To analyze clinical outcomes and complication rates of transforaminal and interlaminar endoscopic decompression and open microsurgical operations performed for lumbosacral spinal canal stenosis.

Material and Methods. The data of 60 literature sources selected in accordance with the inclusion and exclusion criteria in the PubMed, Science Direct, Google Scholar and Cochrane Library databases were systematized by evaluating diagnostic methods, clinical pictures and surgical treatment of the lumbar spinal canal stenosis. Original studies, case series and reviews containing information on surgical methods for the treatment of spinal stenosis at the lumbar level were analyzed.

Results. The complication rate after transforaminal endoscopic decompression (relapses, infectious complications, damage to the dural membrane and spinal roots) does not exceed 2.7 %, which is significantly lower than that in open microsurgical operation (4.8—8.8 %). Endoscopic decompression and reconstruction of the spinal canal demonstrate good clinical outcomes, lower number of bed-days, readmissions, and good economic benefits. When stenosis is combined with instability of the spinal motion segment, performing only a decompressive operation in any volume does not give a significant clinical result, and stabilization surgery is required.

Conclusion. The introduction of endoscopic reconstructive surgery for spinal canal stenosis in the lumbosacral spine is associated not only with technical progress and improvement of endoscopic optics, but also with the search for the causes of unsatisfactory results of open operations. Endoscopic interventions showed good clinical outcomes and a decrease in the complication rate. However, the evidence base needs to be expanded due to the lack of randomized trials to compare open decompression and stabilization, and endoscopic reconstructive surgeries in patients with various manifestations of spinal stenosis.

Key Words: degenerative diseases of the spine, spinal canal stenosis, lumbosacral spine, endoscopic reconstruction of the spinal canal.

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Degenerative stenosis of the lumbosacral spine is an abnormal narrowing of the central canal, lateral recess, or intervertebral foramen that results in compression of the nerve and vascular elements by bone, cartilage, or soft tissue structures [1]. The overall quality of life of the patient worsens due to spinal canal stenosis of the lumbosacral spine.

The evolution of surgical techniques for the treatment of lumbar spinal stenosis has been in the direction of minimizing the surgical impact. First, decompressive laminectomy (hemilaminectomy) was performed with complete stabilization of the spinal motion segment (full fusion (360°). Later, surgeons switched to open decompression surgeries without stabilization and microsurgical decompression. Interlaminar and transforaminal endoscopic techniques of spinal canal restoration are a fairly new approach. The experience of endoscopic surgeries showed the first favorable clinical outcomes and a decrease in postoperative complications.

The present review summarizes the modern concepts of lumbar spinal stenosis and its various clinical forms (central, lateral, and foraminal). It also covers the issues of modern techniques for their surgical treatment.

The objective is to analyze clinical outcomes and complication rates of transforaminal and interlaminar endoscopic decompression and open microsurgical operations performed for lumbosacral spinal canal stenosis.

Material and Methods

The literature sources were searched in PubMed, Science Direct, Google Scholar, and Cochrane Library databases for the following keywords: spinal stenosis, lumbar spinal stenosis surgery, Endoscopic Spinal Surgery, and spine to compile the review.

Inclusion criteria. Studies assessing endoscopic procedures and microsurgical decompression surgeries with and without stabilization in patients with lumbosacral spinal canal stenosis from January 2000 to April 2021. Case descriptions, series of observations, original studies, and systematic reviews were included. The following characteristics were analyzed: clinical picture, diagnostic procedures, mode

and the extent of the surgery, duration of the surgery, the volume of intraoperative blood loss, number of bed days, complications, clinical outcomes, and the number of reoperations. Surgical outcomes were assessed according to MacNab criteria; back and leg pain according to VAS; trends in quality of life according to the Oswestry Disability Index (ODI) and EuroQol-5 (EQ-5D) quality of life measures. The data on the structure, age distribution, and classification of spinal canal stenoses in the lumbosacral region were analyzed. During the review, no distinction was made between the techniques of performing microsurgical decompression of stenoses.

Exclusion criteria. The publications in languages other than Russian, English, and German were not included, as well as those in which neither the abstract nor the full text of the study were available. Besides, papers devoted only to conservative treatment of spinal canal stenosis and primary stenosis caused by congenital anomalies or disorders developed in the postnatal period were excluded from the analysis.

The data obtained were grouped and analyzed using the Microsoft Excel spreadsheet software.

Results

A total of 60 publications were selected following the search criteria. Both the abstract and the full text were available in 25 of them. Observation series comprised 46 (76.7 %) papers; systematic review and meta-analysis – 12 (20.0 %) papers; Cochrane Database Systematic review – 2 (3.3 %) papers. The status of the article (published/submitted for printing/for review) was not considered. The level of evidence and the design of the articles were ignored.

Prevalence and age of patients

Lumbosacral spinal canal stenosis has become a very common condition in recent years. Its incidence increases significantly in people over 50: in persons aged 40 to 49 – 11.8– 13.6 % of cases; at the age of 50–65 – 17.9–31.0 %. It is, first and foremost, due to the improved quality of medical care and an increase in life expectancy [2].

The issues of surgical treatment of lumbar spinal stenosis become ever more urgent. In the USA, from 1979 to 1992, the frequency of operations for spinal canal stenosis increased 8 times in patients aged 65 and older [3]. It should be noted that lumbar spinal canal stenosis is the most common cause of spinal surgery in patients of this age group. We have used an official sample of inpatients for 1988–2001 and the USA census data based on demographic indicators corrected for age and gender to study trends [4]. However, it is currently considered that there is insufficient evidence of the surgical treatment effectiveness of lumbar stenosis in comparison with conservative therapy, placebo, or sham surgery [5].

Classification

There are two types of spinal canal stenosis: primary, caused by congenital anomalies or disorders developed in the postnatal period, and secondary (acquired), resulting from degenerative changes or local infection, injury, or surgery [6]. Primary stenoses are not considered in this review.

The first known and widespread classification of secondary degenerative stenosis belong to Verbiest [8]. He also introduced the concept of "neurogenic intermittent claudication" and described the procedure for performing laminectomy in this abnormality. Verbiest distinguished absolute and relative spinal canal stenosis at the lumbar level. According to the author, stenosis is considered relative when the size of the spinal canal is up to 12 mm, absolute – at 10 mm or less. The prevalence of relative and absolute stenosis was 20.0 % and 4.0 %, respectively; at the age from 60 to 69 – 47.2 % and 19.4 %, respectively [9].

Andersson [10] proposed to divide stenosis by localization into central – 20 %, lateral – 10 %, mixed/combined (central and lateral) – 70 %. Central stenosis includes spinal narrowing with compression of the dural sac due to hypertrophy of the facet joints, ligamentum flavum, decreased height, and prolapse of the intervertebral disc. Lateral stenosis involves narrowing in the area of root exit and passage of the in the region of the lateral recess and the intervertebral foramen.

According to Ishimoto et al. [11], lateral recess stenosis occurs in the population under 40 y.o. – in 0.1 % of cases, 40–50 y.o. – in 1.0 %, 50–60 y.o. – in 1.8 %, and 60–70 y.o. – in 3.6 % [11]. Lateral stenosis is divided according to the anatomical concept: stenosis of the entry zone – the posterolateral surface of the vertebral body and the superior articular process (the area of the lateral recess); stenosis of the middle zone is limited in front by the posterior surface of the vertebral body, in the back by the pars interarticularis (the transition of the lateral recess into the intervertebral foramen); stenosis of the nerve root exit – the frontiers are the subjacent intervertebral disc from the front; the outer sections of the facet joint (extraforaminal region) are from the back [12].

The degree of lateral recess narrowing is defined according to two indicators:

1) the anteroposterior size of the lateral recess (the distance between the edge of the superior articular process and the vertebral body) is usually about 5 mm [13]; its narrowing is most often caused by hypertrophy of ligamentum flavum, the superior articular process and/or lateral disc herniation [10]; a decrease to 3-4 mm results in stenosis and clinically significant compression of the root;

2) the lateral recess angle, that in stenosis is less than 30° [14].

Foraminal stenosis (intervertebral foramen narrowing; *Fig.*) develops when its height decreases to less than 15 mm and its width to less than 4 mm. It is also associated with articular-ligamentous apparatus hypertrophy and foraminal disc herniation [15–17]. The risk of root (ganglion) compression reaches 80 % at such intervertebral foramen values. The anatomical precondition for foraminal stenosis formation is the congenital small size of the intervertebral foramen [18–20].

Clinical picture

The most specific aggregate of symptoms for central spinal canal stenosis is

neurogenic intermittent claudication, manifested by sciatica pain, and by pain, numbness, and weakness in both legs. Lumbar spinal stenosis is diagnosed in 50 % of patients with back pain. The manifestation of these symptoms progresses when walking or standing and decreases when sitting or lying down. Patients usually complain of difficulty walking even for short distances and do so with a characteristic stoop or anthropoid posture in more advanced cases. This kyphotic standing posture is the result of lumbar lordosis straightening. Thereby, the size of the radicular foramen and lateral recess increases. It is significant to note that the severity of symptoms does not always correlate with the degree of lumbar spinal stenosis [21–24].

The clinical signs of unilateral radicular syndrome are more typical of lateral stenosis. All clinical manifestations of root compression are possible: radicular pain, numbness in a certain dermatome, and motor impairments [25]. Pain in lateral stenosis tends to reduce less when the patient is lying down (huddled) or sitting (on his hunkers with a tilted forward body). They do not increase with coughing and sneezing; the pain is less pronounced in the lumbar spine; the signs of Lasegue and Wassermann are not typical. The pain is permanent and rarely recurrent [26]. A specific symptom of lateral stenosis is painful myotonia in the area of the foot and lower leg on the affected side. The cramps occur when walking and at rest. They often manifest at night [19].

Diagnostics

Today, there is no gold standard for the diagnosis of lumbar spinal stenosis. The diagnostic search is largely empirical. The main instrumental diagnostic methods at present are X-ray of the lumbosacral spine with functional tests, CT, MRI, and electromyoneurography [22, 23]. A lumbosacral spine X-ray with functional tests is quite simple and accessible. Among other things, it can exclude instability of the spinal motion segment and unstable spondylolisthesis. CT allows for the assessment of the bone structures involved in root compression (osteophytes of vertebral bodies and hypertrophy in facet joints). During MRI, soft tissue components can be visualized: lateral disc herniation, synovial cysts, and ligamentum flavum hypertrophy. MRI provides the most accurate way to show changes in the anatomy of the spinal canal and classify stenoses [26].

Bartynski and Lin [27] compared the informative value of imaging technologies with intraoperative results. MRI, conventional myelography, and CT myelography of the lumbar spine was evaluated by imaging 58 lateral recesses at 38 lumbar levels in 26 patients. The nerve root compression in the lateral recess was rated on a scale from 0 to 3. MRI underestimated nerve root compression in 28–29 % of cases where this pathology was surgically confirmed. Conventional myelography underscored root compression only in 5–7 % of cases and correctly predicted compression in 93–95 %. CT myelography underestimated nerve root compression in 38% of surgically confirmed cases [28].

Currently, diffusion MRI performed by the Ep 2 diffusion resolve protocol is used to evaluate the condition of the nerve roots and ganglion. It is demonstrated that all structures of the intervertebral foramen are well visualized on oblique images: bone (superior and inferior articular processes, osteophytes), fat, vessels, nerve roots, ganglion, intervertebral disc, etc. [25].

Surgical treatment options

Today, ineffective conservative therapy for 2–3 weeks and the onset of neurological signs of nerve root compression (numbness, muscle weakness) are indications for surgical treatment. The aim of the operation is decompression of the spine in the spinal canal, lateral recess, and radicular foramen; in some cases, it is the elimination of instability of the spinal motion segment [4, 29–32]. The randomized cohort controlled study showed that patients who underwent surgery have significantly better clinical outcomes than patients who received only conservative treatment [33].

There is no single position and algorithm for the lumbar spinal stenosis treatment. All the techniques available to surgeons can be divided into two large groups. The first includes decompression with instrumental stabilization of the affected spinal motion segment using various implants. The second group is decompression without stabilization. Stabilization instrumentation systems are placed most often when stenosis is combined with instability and/or spondylolisthesis, as well as in the case when more than 50 % of the intervertebral joint is resected from one or two sides during decompression of nerve structures [34–36].

Decompression and circumferential stabilization – full fusion (360°)

There is much agreement on the stabilization technique of the spinal motion segment in the surgical treatment of spinal canal stenosis. The standard of treatment is circumferential stabilization – full fusion (360°) [7]. From 2004 to 2009, transpedicular fixation with transforaminal interbody fusion became widespread in patients without instability of the spinal motion segment. The frequency of such operations increased from 13.5 to 21.4 %, while the frequency of decompression alone decreased from 67.2 to 59.1 %. This reflected the absence of the common opinion on this issue among spinal surgeons [37].

In the systematic review of the most significant studies of spinal surgeons, Dijkerman et al. [38] showed the current insufficient evidence in favor of additional transpedicular spinal fusion to decompression for better clinical outcomes. The most important indicators of clinical outcomes evaluated on the ODI and VAS scale show comparable results. Isolated decompression as a less invasive and expensive surgical procedure is considered preferable in patients with stable spondylolisthesis and predominance of pain in the leg.

Ahmed et al. [39] conducted a meta-analysis of randomized controlled studies, as well as retrospective and prospective cohort studies considering the comparison of decompressive surgery and decompressive surgery with posterior fusion in lumbar stenosis. In the group of interventions with instrumental fixation, when evaluating ODI, the authors

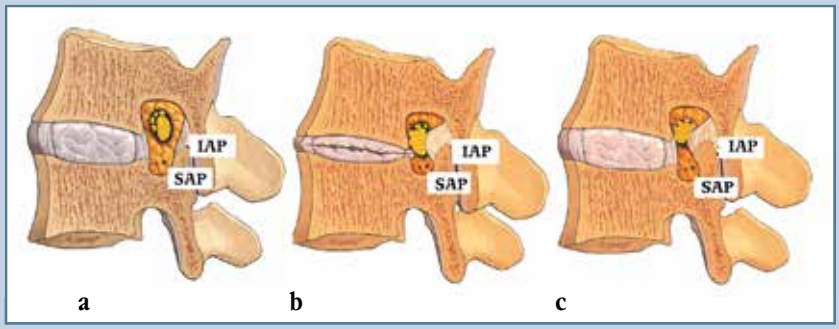

Fig.
Schematic representation of the intervertebral foramen and foraminal stenosis: SAP – superior articular process; IAP – inferior articular process: **a** – neuroforamen without foraminal stenosis; **b** – a variant of foraminal stenosis with a decrease in the disc space; **c** – a variant of foraminal stenosis with severe facet joint arthrosis

noted that the results were 2.55 times better than after isolated decompression.

Decompression surgeries without stabilization

Decompression surgeries for lumbar spinal stenosis can be divided into open and endoscopic ones. The open ones include laminectomy, hemilaminectomy, ipsi- and contralateral (over- the-top) decompression, single- and bilateral interlaminar microsurgical decompression, facetectomy, and foraminotomy. These procedures are the most widespread and often used [34, 40–42].

In a representative group (2,737 patients) with lumbar spinal stenosis without spinal motion segment instability, Bech-Azeddine et al. [43] statistically proved that microsurgical decompression without stabilization ensures good clinical outcomes for 12 months after surgery compared with the preoperative level ($p < 0.001$). There was a decrease in back pain (from 72.1 to 42.1), leg pain (from 71.2 to 41.3), and ODI (from 44.1 to 27.8) with an increase in EQ-5D from 0.35 to 0.61. Endoscopic transforaminal and interlaminar ipsi- and contralateral reconstructive techniques of the spinal canal are currently considered the most innovative.

Endoscopic decompression (full-endoscopic)

Endoscopic spine surgery (full-endoscopic) has been developed due to the rapid technological improvement of hardware and endoscopic viewing system. This made it possible to drill bones, to expand the central part of the spinal canal, the lateral recess, and the intervertebral foramen in a less traumatic and precise manner. Today, such surgery has begun to be popularized by spinal surgeons and is becoming a common minimally invasive decompression technique in patients with lumbar spinal canal stenosis and herniated intervertebral discs [44–46].

Percutaneous transforaminal endoscopic decompression in central and lateral stenosis

The main advantages of the endoscopic approach to the lumbar spinal canal stenosis treatment are the preservation of the axial stability of the spine and minimal injury to adjacent tissues, as well as the reduction of disc degeneration of the adjacent segment. The use of percutaneous transforaminal endoscopic decompression in this pathology has shown favorable clinical outcomes in several spinal surgery clinics [47, 48].

In lateral stenoses, the endoscopic transforaminal approach is used even more widely. A retrospective study of 220 patients treated by Lewandrowski [49, 50] showed that the technique is efficient in patients with mono radiculopathy associated with lateral stenosis in the mid and exit zone of the intervertebral foramen. Nevertheless, the experience of the surgeon performing such an operation should be sufficient to make an adequate expansion and reconstruction of the intervertebral foramen.

Ipsi- and contralateral interlaminar endoscopic decompression in central and lateral stenoses

Today, full-endoscopic techniques are used for both lateral and central spinal canal stenoses. One of such procedures is interlaminar endoscopic decompression, which allows decompression of neural structures with the help of various fraises and burrs both in stenoses (central and lateral) and in the large herniated intervertebral disc [51].

A total of 134 patients with single-level degenerative spinal canal stenoses took part in a comparative study by Wu et al. [52]. During the evaluation of the results of microsurgical decompression and the interlaminar endoscopic technique for central and lateral spinal canal stenoses, no significant difference was found between the two groups in terms of the average severity of leg pain according to VAS. The average back pain score according to VAS in the endoscopy group was significantly lower compared to the microsurgery group at the 1st week of follow-up. Nevertheless, there was no significant difference between the two groups after 6 months and later. Similarly, while evaluating the Oswestry index and the EuroQol-5 quality of life, there was no significant difference between the two groups after 6 months and later. Therefore, the comparability of the endoscopic approach with microsurgical in the treatment of central and lateral stenosis to targeted decompression has been established. Moreover, several advantages of endoscopy have been identified, including reduced postoperative back pain and a higher recovery rate.

In a prospective randomized controlled study, Ruetten et al. [53] compared interlaminar endoscopic decompression with microsurgical decompression in 161 patients with lateral stenosis. Leg pain completely disappeared in 74.5 % of patients. 20.5 % of patients experienced only occasional pain. However, the clinical outcomes were the same in

both groups. Nevertheless, the frequency of complications and operative explorations was significantly lower in the group of endoscopic surgeries.

Therefore, most patients with lumbar spinal stenosis after endoscopic decompression with both transforaminal and interlaminar approaches noted satisfaction with clinical outcomes. This is reflected in the significant positive trend in the indicators of back and leg pain according to VAS and the dynamics of quality of life according to Oswestry.

Discussion

Lumbosacral spinal canal stenosis is a degenerative disease associated with aging of the spine. The effectiveness of the combination of surgical decompression of the spinal canal with posterior fusion in this pathology is controversial. Microsurgical decompression of the spinal canal with transcutaneous transpedicular fixation and transforaminal intervertebral fusion to widen the disc space can protect the paravertebral muscles and facet joints. Nevertheless, the problems of degeneration of intervertebral discs of adjacent segments remain [54]. According to the meta-analysis, additional spinal fusion in the treatment of lumbar spinal canal stenosis did not result in clinical improvements compared to decompression alone [4].

Due to contradictory research results, it is hard to conclude the optimal surgical tactics for the treatment of patients with lumbar spinal canal stenosis and spinal instability. The performance of decompression alone cannot effectively solve the problem arising from the instability of the spinal motion segment. Thus, a small percentage of patients with preoperative lumbar instability, as a rule, have unsatisfactory clinical postoperative outcomes. Wen et al. [55] provided examples where patients with lumbar spinal stenosis and segment instability who underwent percutaneous transforaminal endoscopic decompression may immediately experience pain relief. However, the pain returned 3 months after surgery, unlike patients with lumbar stenosis without instability. Similar outcomes were obtained with reoperations on the same spinal motion segment.

Meanwhile, it is necessary to evaluate the frequency of complications in such operations. In open laminectomy in patients with lumbar spinal canal stenosis, it turned out to be quite high, ranging from 4.8 to 8.8 % [53, 56]. In this regard, it is preferable to perform endoscopic decompression and reconstruction of the spinal canal in elderly patients with a variety of comorbidities.

Today, the favorable clinical outcome has been proven in patients with lumbar spinal stenosis who underwent transforaminal endoscopic decompression according to certain indications [57]. The results indicate that percutaneous transforaminal endoscopic decompression may be efficient in elderly patients with lumbar spondylosis, and central and lateral spinal canal stenosis. Following surgery, patients at different times showed a persistent improvement in back and leg pain according to VAS and the dynamics of the Oswestry index.

Endoscopic techniques are also widely used in elderly patients with mild herniated intervertebral discs and lumbar spinal stenosis. Li et al. [58] showed good clinical outcomes of percutaneous lumbar foraminoplasty and percutaneous lumbar endoscopic discectomy in 90.6 % of a series of 85 patients with lateral recess stenosis in combination with or without intervertebral disc herniation.

Less invasive technologies have long been the main strategy for the development of spinal surgery. The goal of this direction is to minimize surgical injury and provide a good therapeutic outcome. As a result, the patient can return to an ordinary life earlier, with fewer complications, and maintain a high quality of life. Nevertheless, endoscopic reconstructive surgery requires a certain experience from the surgeon. This is due to the possible incomplete removal of the herniated disc sequester and more frequent relapses of hernias. It is no coincidence that the learning curve in spinal endoscopy is quite long [59].

Conclusions

Nowadays it is difficult to say unequivocally about a certain amount of surgical treatment for lumbar spinal stenosis. However, general patterns are noted. Firstly, the complication rate of open decompressive and stabilizing operations is higher than that of endoscopic ones. The decompression in any volume without stabilization does not give a significant clinical outcome in case of a combination of stenosis and instability of the spinal motion segment.

Even though the endoscopic reconstruction of the spinal canal is a fairly new approach, the first outcomes were favorable, and the number of complications decreased. It is no coincidence that the evolution of surgical techniques for the treatment of lumbar spinal stenosis was in the direction of minimizing the surgical impact. This is due not only to technical progress and improvement of endoscopic viewing systems but also to the search by spinal surgeons for the causes of unsatisfactory outcomes of open surgeries.

However, it is vital to carry out a large number of randomized studies to compare open decompression and stabilization, and endoscopic reconstructive surgeries in patients with various manifestations of lumbosacral spinal canal stenosis. This is important for determining more selective indications and evaluating the outcomes of these operations.

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