Review article
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Direct lateral interbody fusion with indirect decompression of the spinal roots in patients with degenerative lumbar spinal stenosis

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Abstract

Introduction Degenerative spine conditions involve the gradual loss of normal structure of the spine among the population and remain a common form of work-limiting health condition in 80 % of the population. The demand for surgical interventions will remain high in an aging population to improve quality of life. Lumbar spinal decompression and stabilization are produced using ventral, posterior and lateral approaches. Lateral lumbar interbody fusion (LLIF) is used for treatment of degenerative lumbar stenosis having advantages over surgical interventions from other approaches.

The **objective** was to determine the prospects of LLIF as an independent decompressive and stabilizing surgical intervention using literature data.

Material and methods This article presents generalized information from Russian and foreign publications on LLIF with indirect decompression of the lumbar nerve roots. The original literature search was conducted on key resources including Scientific Electronic Library (www.elibrary.ru), the National Library of Medicine (www.pubmed.org) and Scopus using keywords: direct lateral interbody fusion, indirect decompression of the spinal nerve roots, predictors, lateral lumbar interbody fusion, direct lumbar interbody fusion, extreme lumbar interbody fusion, indirect decompression. The review included 60 articles published between 1998 and 2023 inclusive.

Results and discussion After performing LLIF, some patients experience indirect decompression of the spinal nerve roots to prevent epidural fibrosis, injury to the dura mater and spinal nerve roots. Identifying a model of patients with degenerative spinal stenosis who can undergo LLIF as an independent decompressive-stabilizing surgical intervention without additional instrumentation can improve the effectiveness of surgical treatment.

Conclusion LLIF was shown to be an effective method for indirect decompression of spinal nerve roots at the intervertebral foramina. Indirect decompression of the spinal nerve roots in the spinal canal may fail and the choice of a LLIF candidate (a single surgical intervention) remains open.

Keywords: degenerative spinal stenosis, direct lateral fusion, indirect decompression, predictors of indirect decompression

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INTRODUCTION

Spinal degenerative diseases are associated with morbidity, pain and disability in the population of developed countries affecting 80 % of the working population according to the World Health Organization (WHO). About 266 million individuals (3.63 %) worldwide are diagnosed with lumbar degenerative diseases yearly [1].

The increase in the average age of the population and high requirements for quality of life are cause for development of surgical treatments of patients with degenerative spine diseases [2]. Modern diagnostic equipment, innovative technical solutions in the field of minimally invasive spine surgery, anesthesia options facilitate surgical care to patients for whom spinal surgery was previously unavailable due to high risks of complications [3]. Reducing the morbidity of surgical interventions is essential for surgical communities [4].

Decompressive minimally invasive interventions with preservation of the supporting spinal structures are less traumatic in comparison with decompressive-stabilizing operations, and some cases require fixation of the spinal motion segment. Decompressive and stabilizing surgical interventions can be performed using ventral (ALIF\OLIF), posterior (PLIF\TLIF) and lateral (LLIF) approaches. Each of the accesses can be performed using MIS technology. With LLIF, some complications encountered with PLIF\TLIF and OLIF\ALIF can be eliminated, and LLIF can be considered a minimally invasive standalone decompressive-stabilizing surgical intervention if indirect decompression can be produced in some cohorts of patients with interbody implant placed and no need for additional fixation of the SMS. The objective was to determine, based on literature data, the prospects for performing LLIF as an independent decompressive and stabilizing surgical intervention.

The **objective** was to determine the prospects of LLIF as a standalone decompressive and stabilizing surgical intervention using literature data.

MATERIAL AND METHODS

The article presents generalized information from Russian and foreign publications on direct lateral spinal fusion with indirect decompression of the spinal cord roots in the lumbar spine, the history of the development of the method, its capabilities in the treatment of patients with degenerative spinal diseases, and differences from other approaches to the lumbar spine.

The original literature search was conducted on key resources including Scientific Electronic Library (www.elibrary.ru), the National Library of Medicine (www.pubmed.org) and Scopus using keywords and phrases: direct lateral spinal fusion (direct lumbar interbody fusion, lateral lumbar interbody fusion, extreme lumbar interbody fusion), indirect spinal decompression, predictors of indirect decompression. The review included 60 articles published between 1998 and 2023 inclusive.

Inclusion criteria:

— full-text scientific articles, abstracts of scientific conferences and dissertations reporting surgical treatments of patients with degenerative spinal stenosis;

— full-text scientific papers on direct lateral fusion and its capabilities in achieving indirect decompression of the spinal cord roots, comparison of direct lateral fusion with other methods of fusion;

— full-text scientific papers reporting the nature and rate of complications after LLIF including comparison with other methods of spinal fusion.

Exclusion criteria included scientific articles that had no information on the treatment of patients with degenerative spinal diseases. Overall, 60 scientific papers were selected for the literature review, of which 6 (10 %) reported by Russian authors and 54 (90 %) by foreign contributors.

RESULTS AND DISCUSSION

Degenerative spinal stenosis

Degenerative spinal stenosis is associated with progressive pathological changes in the spine leading to a decrease in reserve spaces for neurovascular formations in the spinal canal and intervertebral foramina, and can cause compression of the spinal cord root with neurogenic intermittent claudication and/or radicular syndrome [5]. Pathomorphological substrates for compression of the spinal cord roots include hypertrophied facet joints, hypertrophied ligamentum flavum, osteophytes and intracanal synovial cysts of the facet joints. Degenerative spinal stenosis can be localized to the spinal canal, lateral recesses and intervertebral foramina.

Surgical treatment of degenerative spinal stenosis

Degenerative diseases account for 59.9–71.4 % of surgical interventions in spine surgery [6]. Decompressive, decompressive-stabilizing, decompressive-corrective and decompressive-plastic surgical interventions are used to treat patients with degenerative spinal stenosis using open surgical techniques and minimally invasive procedures. Today, the surgeon has the opportunity to perform surgical interventions on the lumbar spine using different approaches: LLIF, ALIF, OLIF, PLIF, TLIF. Technical solutions in the field of surgical visualization and power equipment allow maximum preservation of the supporting structures of the spine during decompression of the spinal cord roots and can eliminate the need for spinal fusion in some cases [4].

There is a group of patients with unstable spinal motion segment of the spine who require spinal fusion, and decompression of the spinal cord roots if combined with degenerative spinal stenosis. Indirect decompression of the spinal cord roots may occur if spinal fusion is produced using ventral approaches for the patients especially in cases of the dynamic compression [7]. The surgical interventions are minimally invasive and can ensure long-term preservation of treatment results.

There are no strict standards in fixation of the spinal motion segment, surgical access and decompression of the spinal cord roots and the selection of the surgical method would depend on the decision of the surgeon [8].

Direct lateral fusion

In 2006, Ozgur et al. reported a spinal fusion technique with an access to the intervertebral discs of the lumbar spine without endoscopic equipment and posterior traction of the psoas [9]. The method was a modernized retroperitoneal approach to the lumbar spine anterior to the psoas, described by McAfee et al. in 1998, and access through the psoas with use of endoscopic equipment reported by Pimenta in 2001 [10, 11]. Direct lateral spinal fusion is termed in modern literature as LLIF (lateral lumbar interbody fusion), DLIF (direct lumbar interbody fusion), XLIF\ELIF (extreme lateral lumbar interbody fusion). Direct lateral spinal fusion is more common, and there is an increase in scientific publications on the topic over time [12]. Direct lateral fusion is normally performed at the levels L2–L3, L3–L4 and occasionally at L1–L2, L4–L5 levels. The L4–L5 segment may be inaccessible due to the high position of the iliac crests, and the lower ribs may make access to the L1–L2 intervertebral disc difficult.

Such complications as retrograde ejaculation, injury to major vessels, ureter, peritoneum, intestines, venous or arterial thromboembolism are not common with LLIF compared to ALIF\OLIF, and the preserved anterior and posterior longitudinal ligaments do not allow the implant to migrate anteriorly and posteriorly [13, 14, 15].

LLIF can be the most practical surgical intervention for patients with excess body weight, does not increase the risk of complications with direct lateral fusion [16] and allows easier performance. Previous surgical interventions in the lumbar spine with use of ventral or posterior approaches faclitate LLIF for treatment at the adjacent level [17, 18] to avoid scars and a long transpedicular system [19]. Indirect decompression of the spinal cord roots helps to avoid microsurgical decompression of the spinal cord roots providing shorter operation time and reducing the risk of injury to the dura mater and spinal cord roots. The advantages of ventral approaches include the parameters of interbody implants with a larger supporting surface area than implants for PLIF\TLIF [20]. Implants for LLIF are wider than those used for OLIF\ALIF with the cortical edges of the vertebral endplates being most resistant to subsidence of interbody implants [21–24], thereby the risk of implant subsidence in LLIF is not greater without additional transpedicular fixation [25, 26].

Indirect decompression

Indirect decompression of the spinal cord roots with spinal fusions produced using ventral approaches is often described in the scientific literature. Indirect decompression can be interpreted as a clinical result in the form of regression of compression syndromes of the spinal cord roots after surgery, and secondarily as an increased size of the intervertebral foramina, lateral recess or spinal canal seen with neuroimaging. Indirect decompression of the spinal cord roots in the intervertebral foramina after ventral spinal fusion is reported [9, 10, 11, 19, 27, 28], and indirect decompression of the spinal cord roots in the spinal canal is less predictable, with severe stenosis, in particular.

An increased size of the intervertebral foramina can be identified with intraoperative radiographs. An increased reserve space for the spinal roots is difficult to visualize intraoperatively in case of degenerative spinal canal stenosis and a successful LLIF as a decompression surgical intervention can be identified with ambulation. LLIF as the only surgical intervention can be unreliable for decompression of the spinal roots in the spinal canal and stabilization of SMS. LLIF is commonly used as the first stage of surgery to stabilize and/or correct the spinal balance. The second stage involves microsurgical decompression of the spinal cord roots and transpedicular fixation of the SMS. Neurosurgeons are interested in indirect decompression of the spinal cord roots with the effect being similar to microsurgical decompression with no contact with the dura mater during repeated surgical intervetions [29].

The mechanism of indirect decompression of the spinal cord roots relies on the restored height of the intervertebral disc, increasing the height of the intervertebral foramina and stretching the posterior longitudinal and flaval ligaments [30–41]. An increased reserve space for the spinal cord roots in the spinal canal can be observed at two years of LLIF due to hypotrophied ligamentum flavum and rigid fixation of the SMS [42–44].

Maximum preservation of the anatomical integrity of the SMS with LLIF, in comparison with ALIF\OLIF, preservation of the anterior and posterior longitudinal ligaments, a greater portion of the fibrous ring contribute to the stability of the segment creating conditions to avoid anterior and posterior migration of the cage [45]. This is the main reason for strict selection of patients for indirect decompression of the spinal cord roots in the spinal canal after LLIF in comparison with ALIF\OLIF, because the limited possibility of a higher interbody implantation can lead to an insufficient increase in the volume of the spinal canal.

With possibilities of indirect decompression of the spinal cord roots in the spinal canal it should be noted that Schizas grade D spinal canal stenosis has less potential for indirect decompression with direct lateral spinal fusion, however, there are results of surgical interventions with no need of direct decompression [46] reducing the volume of surgical intervention.

Modern scientific publications focus on indirect decompression of the spinal cord roots in the intervertebral foramina [12, 47, 48]. Studies that focus on indirect decompression of the spinal cord roots in the spinal canal and identification of the predictors have low reliability [49, 50, 51]. Other series do not report a particular group of patients with degenerative spinal stenosis and the effectiveness of indirect decompression of the spinal cord roots [52–54]. There are publications reporting patients with Schizas grade C and D spinal stenosis being excluded from the study [55]. There are publications reporting the effectiveness of indirect decompression using different surgical approaches (LLIF, OLIF, ALIF) [29]. It is difficult to identify a model of a patient with degenerative spinal stenosis in whom clinically effective indirect decompression can be predicted after LLIF.

Patients with Roussouly type 3 sagittal profile of the spine can be treated with indirect decompression [56], and spinal canal stenosis caused by ossified posterior longitudinal and flaval ligaments cannot be treated with LLIF for the purpose of indirect decompression of the spinal cord roots [45].

Indirect decompression of the spinal cord roots using ALIF and OLIF can be predicted in most cases preoperatively due to the knowledge of the capabilities with the methods. If direct decompression is necessary, the approaches allow microsurgical decompression of the spinal cord roots through the interbody space after total discectomy, and the surgical procedure can be produced in one stage.

Indirect decompression failure (IDF) after lateral lumbar interbody fusion is reported as absence of indirect decompression scheduled preoperatively, mainly in the spinal canal after direct lateral interbody fusion [57]. This outcome of surgical intervention results from insufficient knowledge of indirect decompression of the spinal cord roots in the spinal canal performing direct lateral spinal fusion.

MIS LLIF allows for indirect decompression of the spinal cord roots at the intervertebral foramina being equivalent to MIS TLIF and ALIF [46]. In the absence of a bone fusion with the involved SMS, there is a high probability of increased disc height due to interbody implantation, which leads to an increase in the height and area of the intervertebral foramina on both sides, regardless of the side for the surgical approach [45]. The effectiveness of indirect decompression of the spinal cord roots in the intervertebral foramina after LLIF does not depend on the position of the interbody implant, whereas the likelihood of indirect decompression of the spinal cord roots is higher in the spinal canal with the dorsal position of the implant [46]. This is a complicating factor in planning indirect decompression of the spinal cord roots in the spinal canal with correction of the sagittal balance with the sagittal profile, position of the interbody implant to be restored in the anterior third of the interbody space. Subsidence of the interbody implant has a lesser effect on the loss of indirect decompression in the intervertebral foramina than in the spinal canal [12].

With the formation of severe spinal canal stenosis, compensatory capabilities allow many patients manage without medical help for a long time due to the absence of clinical manifestations of the disease [58]. Indirect decompression of the spinal cord roots with a slight increase in the volume of the spinal canal at the level of degenerative stenosis evidenced with neuroimaging can be effective in relief of clinical manifestations of compression of the spinal cord roots.

Complications associated with LLIF

Iatrogenic lumbar plexus injury is a common complication early postop after LLIF [59]. The manifestations include weakness of the hip flexors in 24 % of cases, decreased sensitivity along the anterior surface of the femur in 38 % and paresis of the abdominal muscles in 1.8 %. Other complications associated with LLIF include vascular injury (0.1 %), intestinal injury (0.08 %) and interbody implant subsidence (14 %) [60].

Common events associated with surgical access through the psoas include weakness of the psoas, pain or decreased sensitivity along the anterior femur resulting from the surgical approach that can be resolved within two weeks to one year with conservative treatment [12].

Treatment of degenerative spinal stenosis and stabilization of the SMS can be produced with LLIF and indirect decompression of the spinal roots and transcutaneous transpedicular fixation (or without it) in some cases.

Confidence is required for LLIF as the only decompressive-stabilizing surgical procedure bringing an effect in relieving spinal root compression in the spinal canal. Predictors of indirect decompression of the spinal cord roots in the spinal canal with degenerative stenosis are to be identified for LLIF. Patients with Schizas grade D spinal stenosis cannot be excluded from studies in search for predictors of indirect decompression and the ability of LLIF to achieve it. A slight increase in the volume of the spinal canal will be sufficient to relieve clinical manifestations of compression of the spinal cord roots.

With rigid fixation of the SMS, the thickness of the hypertrophied ligamentum flavum decreases. Therefore, LLIF can be considered as the only decompressive-stabilizing surgical intervention with indirect decompression of the spinal cord roots and volume of the spinal canal can be followed up using MRI and MSCT of the lumbar spine.

The approach can improve the effectiveness of surgical treatment of patients with degenerative spinal stenosis in the lumbar spine, and more often use the LLIF can be employed as the only decompressive-stabilizing minimally invasive surgical intervention for particular cohort of patients to reduce surgical stages of treatment, operation time, blood loss and the morbidity with overall surgical treatment.

CONCLUSION

LLIF is a method of surgical intervention on the lumbar spine, which appeared as an effective minimally invasive surgical intervention for stabilization, correction of deformity in the SMS providing indirect decompression of the spinal roots in the intervertebral foramina.

Direct lateral fusion is not commonly used as the only surgical intervention on the SMS for decompression and stabilization due to little knowledge in indirect decompression of the spinal roots in the spinal canal with degenerative stenosis.

Identification of predictors of indirect decompression of the spinal cord roots in the spinal canal will improve the efficiency of surgical treatment of patients using the LLIF.

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