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ORIGINAL ARTICLE

Observational Study

Factors that influence the results of indirect decompression employing oblique lumbar interbody fusion

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Abstract

BACKGROUND

Indirect decompression is one of the potential benefits of anterior reconstruction in patients with spinal stenosis. On the other hand, the reported rate of revision surgery after indirect decompression highlights the necessity of working out prediction models for the radiographic results of indirect decompression with assessing their clinical relevance.

AIM

To assess factors that influence radiographic and clinical results of the indirect decompression in patients with stenosis of the lumbar spine.

METHODS

This study is a single-center cross-sectional evaluation of 80 consecutive patients (17 males and 63 females) with lumbar spinal stenosis combined with the instability of the lumbar spinal segment. Patients underwent single level or bisegmental spinal instrumentation employing oblique lumbar interbody fusion (OLIF) with percutaneous pedicle screw fixation. Radiographic results of the indirect decompression were assessed using computerized tomography, while MacNab scale was used to assess clinical results.

RESULTS

After indirect decompression employing anterior reconstruction using OLIF, the statistically significant increase in the disc space height, vertebral canal square, right and left lateral canal depth were detected ($P < 0.0001$). The median (M) relative vertebral canal square increase came to $M = 24.5\%$ with 25%-75% quartile border (16.3%; 33.3%) if indirect decompression was achieved by restoration of the segment height. In patients with the reduction of the upper vertebrae slip, the median of the relative increase in vertebral canal square accounted for 49.5% with 25%-75% quartile border (2.35; 99.75). Six out of 80 patients (7.5%) presented with unsatisfactory results because of residual nerve root compression. The critical values for lateral recess depth and vertebral canal square that were associated with indirect decompression failure were 3 mm and 80 mm² respectively.

CONCLUSION

Indirect decompression employing anterior reconstruction is achieved by the increase in disc height along the posterior boarder and reduction of the slipped vertebrae in patients with degenerative spondylolisthesis. Vertebral canal square below 80 mm² and lateral recess depth less than 3 mm are associated with indirect decompression failures that require direct microsurgical decompression.

Key Words: Indirect decompression; Anterior reconstruction; Central lumbar spinal stenosis; Degenerative spondylolisthesis; Lateral recess stenosis; Spinal instability; Oblique lateral interbody fusion

Core Tip: This is a cross-sectional study of 80 patients who underwent oblique lateral interbody fusion. The radiographic results were measured using computed tomography while clinical results were assessed using MacNab Scale and cases with unresolved nerve root compression were registered. Indirect decompression is achieved by segment height restoration and the reduction of slipped vertebra. Using multivariate regression modeling it has been evaluated that postoperative spinal canal square is more predictable than the lateral recess depth. Marginal values of the lateral recess depth that can be used for the prediction of unsatisfactory results according to MacNab scale were estimated.

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INTRODUCTION

Spinal stenosis is one of the most frequent causes of pain syndromes and neurologic deficits in elderly adult patients, with the prevalence range of 11%-38%[1]. Lumbar stenosis combined with spinal instability requires both decompression and fusion to achieve long-term clinically significant results, and spinal fusion employing anterior reconstruction is becoming more popular with spinal surgeons because of its capability to restore alignment and the superior stability achieved because of bigger cage footprint[2-5].

An additional benefit of the anterior reconstruction in patients with the degenerative pathology of the lumbar spine is indirect decompression that can be achieved without manipulations on the nerve root and spinal cord[6-8]. It has been demonstrated that direct decompression is associated with a certain risk of nerve root damage because of its traction and intractable postoperative pain because of epidural adhesions and scar formation that favor the application of indirect decompression[3,9-11]. On the other hand, the latter may have certain limitations that require careful patient selection to avoid the necessity of revision surgery in a short-term period.

A certain amount of knowledge was gained concerning the mechanisms and rational application of indirect decompression. It has been demonstrated that the effect of the indirect decompression may sometimes even exceed that one achieved employing transforaminal lumbar interbody fusion, while the results of the indirect decompression in patients with central stenosis remain controversial[7,11-14]. The most frequently spoken limitations concerning the application of indirect decompression were considered lateral stenosis, ankylosis of the facet joints and osteoporosis, and severe central stenosis, corresponding to the Schizas D stage[6,15-17]. Even though limitations for indirect decompression are acknowledged the rate of the reported failure remains considerable, ranging from 9% to 43%[18-20]. The reported rate of revision surgery after indirect decompression highlights the necessity of working out prediction models for the radiographic results of indirect decompression with assessing their clinical relevance.

The study aim was to assess factors that influence radiographic and clinical results of the indirect decompression in patients with stenosis of the lumbar spine.

MATERIALS AND METHODS

Study population and data collection

This study is a single-center cross-sectional evaluation of 80 consecutive patients with lumbar spinal stenosis combined with the instability of the lumbar spinal segment including 17 males and 63 females. The age at the time of surgery was median (*M*) = 59 year [25%-75% (54, 65), range 32-72 years]. Patients with either neurogenic claudication or radiculopathy associated with spinal stenosis including that one associated with degenerative spinal spondylolisthesis with spinal segment instability confirmed by dynamic X-Ray were enrolled. All patients underwent single level or bisegmental spinal instrumentation employing oblique lateral interbody fusion (OLIF) supplemented with percutaneous pedicle screw fixation. Radiographic results of the indirect decompression were assessed using computed tomography (CT) while MacNab scale was used to assess clinical results. Patients with clinical signs of residual nerve root compression underwent magnetic resonance imaging (MRI) imaging. Cases with confirmed nerve root compression underwent direct microsurgical nerve root decompression. The study was reviewed and approved by the local institutional review board, given that no risks associated with current study were anticipated.

Inclusion and exclusion criteria

The inclusion criterion was presence of either neurogenic claudication or radiculopathy associated with stenosis or degenerative spondylolisthesis on L3-L4, L4-L5 Levels or both, with instability of the affected segments confirmed by dynamic radiograms. The criterion for spinal instability was the difference in anterior translation on flexion-extension images > 3 mm.

Indications for spinal instrumentation were: (1) Axial and radicular pain syndromes with a visual analog scale score of over 4 (0-10), resistant to repeated conservative treatment for 3 months; (2) Neurogenic claudication; (3) Evidence of spinal segment instability; and (4) An Oswestry Disability Index score of over 40%.

The exclusion criteria were: (1) High-grade spondylolisthesis (grades 3 and 4); (2) Degenerative pathology that required fixation of more than two segments; (3) Tumor-related lesions of the lumbar spine; (4) Sagittal and frontal imbalance and spinopelvic parameter mismatches that required correction; (5) Revision surgery; (6) Implant malposition detected on postoperative CT images; (7) Different types of fusion applied on different levels; (8) Evidence of disc extrusion that require direct nerve root decompression; neurologic deficit, sensory or motor; or (9) Evidence of disc extrusion that require direct nerve root decompression; neurologic deficit, sensory and motor.

Preoperative assessment: Before the procedure, all patients underwent dynamic X-ray imaging, MRI and CT evaluation. The criteria for spinal instability were anterior translation greater than 3 mm or rotation more than 10°[21]. CT and MRI were used as a part of the preoperative work-up. MRI was used for qualitative assessment of degenerative pathology, while the CT scans were used to measure preoperative and postoperative parameters of the spinal canal. The scans used a slice thickness of 0.5 mm and covered a scan area of 50 cm. The scan parameters included tube voltage 120 kV, tube current 300 mA, auto mAs range 180 to 400; 1.0 second/3.0 mm/0.5 × 32, helical pitch 21.0. Figure 1A demonstrates sufficient contrast to provide the required measurements.

During CT evaluations, measurements of vertebral canal square, right and left lateral recess depth were measured at the level of maximal constriction. Disc space height was measured at the anterior and posterior border of the vertebral bodies along the midline in the sagittal plane; those measurements were taken by two independent radiologists. Cases with facet joints degeneration corresponding to Weishaupt 4 stage were registered because advanced stage of facet joints degeneration might affect the results of the indirect decompression. Difference in radiodensity provided a sufficient contrast to differentiate bone, ligaments, disc and neural structures.

Operative techniques

Prepsoas OLIF approach with the anterior longitudinal ligament transection and segment height restoration was used to perform fusion. Cages with allogenic bone with a footprint of 1000 mm square, height 13-15 mm were utilized. Percutaneous pedicle screw fixation with polyaxial screws was used, the applied technique was a standard strait trajectory. Pedicle screws were introduced at least to the anterior third of a vertebral body. In patients with spondylolisthesis the reduction of a slipped vertebra was performed. No posterior structures resection was performed during surgery. The surgeon qualification accounted for at least of 10 years' experience.

Postoperative assessment

All patients underwent CT evaluation; postoperative measurements of spinal canal square, left and lateral recess depths were taken at the same level as during preoperative assessment. Postoperative disc space height was taken in sagittal plane at the midline along anterior and posterior boarder of the vertebral bodies. Changes in the anterior slip of the upper vertebrae were assessed if reduction was applied in cases with degenerative spondylolisthesis. Clinical results of the applied treatment options were assessed employing MacNab scale.

Statistical analysis

The relationships between preoperative, postoperative CT parameters and potential contributing factors were assessed employing either multiply linear regression model in case of continuous independent or general regression ANCOVA analysis in case of continuous and categorical independent variables. Logistic regression analysis was used to assess the relationship between dichotomized dependent variable and continuous predictive variable. The analysis employing

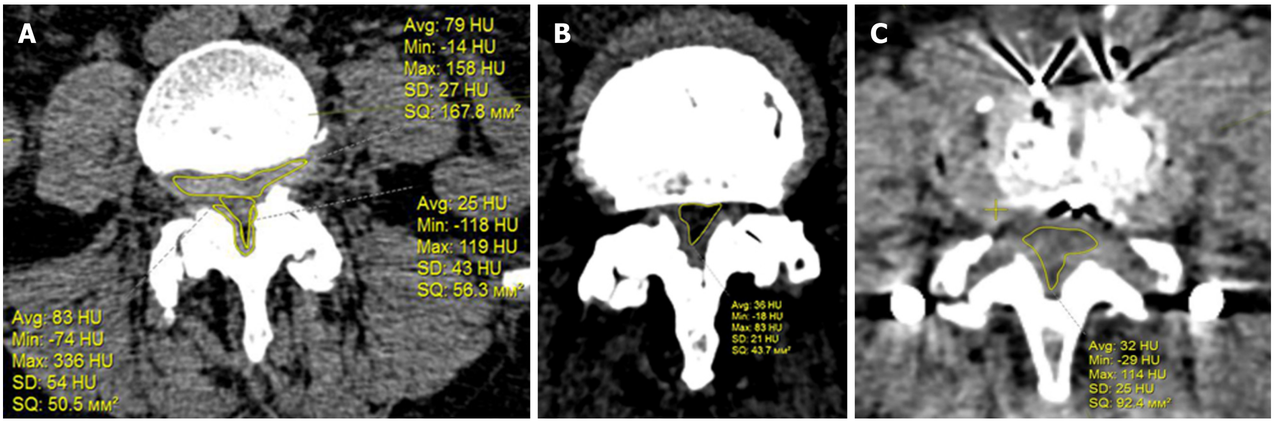

Figure 1 Computed tomography image. A: Computed tomography scan in axial plane, contrast in HU provides differentiation of disc material, ligamentum flavum and spinal canal content including dura and epidural fat; B: Computed tomography image in axial plane taken at the level L4-L5, evidence of the absolute spinal stenosis with vertebral canal square 473 mm^2; C: Postoperative computed tomography image in axial plane taken at the level L4-L5 demonstrate an increase in spinal canal square up to 92.4 mm^2.

receiver operating characteristic (ROC) curves was used for optimal dichotomization of continuous predictor to detect optimal cutoff criteria. Kernel-Fisher discriminant analysis was used to detect variables associated with poor results according MacNab scale.

RESULTS

Radiographic results

After indirect decompression employing anterior reconstruction using OLIF, the statistically significant increase in the disc space height, vertebral canal square, right and left lateral canal depth were detected; preoperative and postoperative radiographic parameters are present in Table 1.

In patients with the reduction of the upper vertebrae slip, the median of the relative increase in vertebral canal square accounted for 49.5%, 25.0%-75.0% (22.35, 99.75), range 0.5%-99.7%. The median for the increase in depth for the left and right lateral recess equaled 0.9 mm, with 25%-75% quartile boarders (0.3, 1.7) and (0.4, 1.5), respectively. In this subgroup, postoperative spinal canal square depended on the preoperative size, and its increase was correlated with the amount of reduction achieved. The parameters of the linear regression model for postoperative vertebral canal square in patients who were treated with anterior reconstruction and reduction are presented in Table 2. Goodness-of-fit of the estimated linear regression model: R = 0.8980 (r = 0.8064), P < 0.0001.

To assess the relationship between lateral recess depth and potential predictors, an ANCOVA analysis was performed. The results of the ANCOVA analysis estimating model with the best explanatory value for the right lateral recess depth are presented in Table 3, while those for the left lateral recess depth are presented in Table 4. Goodness-of-fit of models for the right and left lateral recess depth were r = 0.7068, r = 0.4996, P < 0.0001 and r = 0.7871, r = 0.6195, P < 0.0001 respectively. The estimated proportion of the explained variability (R) for the vertebral canal square and lateral recess depth demonstrates that postoperatively, the former is more predictable than the latter.

The effect of the indirect decompression would be smaller if it were achieved only by employing segment height restoration. The median relative vertebral canal square increase came to M = 24.5% with 25%-75% quartile border (16.3%, 33.3%). The postoperative vertebral canal square depended on the initial dimension, with the increase correlated to the difference in the disc space height along the midline of the posterior border. The parameter of the linear regression model for the cases with indirect decompression by disc height space restoration is presented in Table 5. Goodness-of-fit of the estimated linear regression model: R = 0.9508 (r = 0.9041), P < 0.0001.

In terms of postoperative lateral recess depth, no statistically significant correlations between postoperative parameters and potential predictors were detected. The results of the analysis support the conclusion that the vertebral canal square can be better predicted than lateral recess depth if indirect decompression is applied to treat patients with spinal stenosis. An example of the results of indirect decompression employing anterior reconstruction is presented in Figure 1B and C.

Clinical relevance of the observed radiographic findings

Clinical results of the indirect decompression were classified according to the MacNab scale; 6 out of 80 patients (7.5%) presented with unsatisfactory results because of unresolved radiculopathy associated with residual nerve root compression. Those patients underwent direct neurosurgical nerve root decompression. Logistic regression with consequent ROC curve analysis was used to find critical values for lateral canal depth and vertebral canal square that can be used to predict the failure of the indirect decompression. The estimated best predictive critical values were for the lateral recess depth of 3 mm (regardless of level and side) and the spinal canal square of 80 mm^2 (regardless of level). The parameters of the logistic regression for those critical values were the following. For the lateral recess depth below 2 mm: B0 = -2.9957, P

Table 1 Preoperative and postoperative radiographic parameters of the enrolled group according to the results of computed tomography examination

	Preoperative value	Postoperative value	Statistical	*P* value
Vertebral canal square in axial plane mm^2	*m* = 102.4468 ± 8.6091 SD = 67.7880 95%CI: 85.2319, 119.6617	*m* = 150.3774 ± 8.9059 SD = 70.1252 95%CI: 132.5689, 168.1859	*t*-test for matched samples	< 0.0001
Left lateral recess depth in axial plane mm	*M* = 3.90 25%-75%: (2.8, 4.8)	*M* = 4.95 25%-75%: (3.7, 6.2)	Wilcoxon test	< 0.0001
Left lateral recess depth in axial plane mm	*M* = 3.45 25%-75%: (2.7, 5.0)	*M* = 4.95 25%-75%: (3.8, 6.2)	Wilcoxon test	< 0.0001
Disc height along the midline of anterior boarders of vertebral bodies	*m* = 6.6677 ± 0.3016 SD = 2.3751 95%CI: 6.0646, 7.2709	*m* = 12.0161 ± 0.2734 SD = 2.1531 95%CI: 11.8693, 12.963	*t*-test for matched samples	< 0.0001
Disc height along the midline of posterior boarders of vertebral bodies	*m* = 4.4500 ± 0.2496 SD = 1.9656 95%CI: 3.9508, 4.949	*m* = 7.1871 ± 0.2749 SD = 2.1649 95%CI: 6.6373, 7.736	*t*-test for matched samples	< 0.0001

M: Median; m: Mean.

Table 2 The parameters of linear regression model for postoperative vertebral canal square in patients who were treated with anterior column reconstruction and reduction

Component of linear regression equation	Beta coefficient	Regression coefficient	*P* value
Intercept		39.2163	0.0001
Preoperative vertebral canal square	0.8486	0.8893	< 0.0001
Difference in the upper vertebral body anterior slip	0.1782	6.2508	0.0029
Difference in the disc space height along the anterior boarder, midline	-0.0302	-0.7912	0.6087
Difference in the disc space height along the posterior boarder, midline	-0.0460	-1.3984	0.4312

Table 3 The results of covariance analysis for the postoperative right lateral recess depth

Component of ANCOVA regression	Beta coefficient	Regression coefficient	*P* value
Intercept		1.8432	< 0.0001
Preoperative lateral recess depth	0.7401	0.8139	< 0.0001
Weishaupt 4 degenerative changes in the facet joints	0.1746	0.4954	0.0041

< 0.0001; B1 = 2.6391, P = 0.0009, odds ratio (OR) = 14; 95%CI: (3.0226, 64.8444), χ^2 = 13.126; P = 0.0003. Surface under ROC curve accounts for 0.682. For the vertebral canal square below 80% B0 = -3.0910, P < 0.0001; B1 = 3.6507, P < 0.0001, OR = 38.5; 95%CI: (6.9336, 213.778), χ^2 = 21.182; P < 0.0001. Surface under ROC curve came to 0.796. The chosen critical values for the lateral canal depth and vertebral canal square provided the maximal achievable surface square under the ROC curve.

Using kernel-Fisher general discriminant analysis, a model for the failure of the indirect decompression was estimated. The previously mentioned critical values for lateral recess depth and vertebral canal square, together with continuous data on those parameters, were used to estimate the general discriminant model. Overall goodness-of-fit was F = 14.6210; P < 0.0001; Wilks λ = 0.5030; χ^2 = 51.8745; P < 0.0001; canonical correlation r = 0.7050. The parameters of the regression model are presented in Table 6. The sensitivity and specificity of the estimated model account for 70.0% and 92.5% respectively with overall classification accuracy reaching 92.5%. The results of the analysis support the conclusion that vertebral

Table 4 The results of covariance analysis for the postoperative right lateral recess depth

Component of ANCOVA regression	Beta coefficient	Regression coefficient	*P* value
Intercept		1.3199	0.0384
Preoperative lateral recess depth	0.6515	0.8145	< 0.0001
Weishaupt 4 degenerative changes in the facet joints	0.1746	0.4954	0.0041
Difference in the disc space height along the anterior boarder, midline	0.1886	0.1477	0.0384

Table 5 The parameters of linear regression model for postoperative vertebral canal square in patients who were treated with anterior reconstruction without reduction applied

Component of linear regression equation	Beta coefficient	Regression coefficient	*P* value
Intercept		6.4119	0.5567
Preoperative vertebral canal square, mm^2	0.9527	0.9968	< 0.0001
Difference in the disc space height along the anterior boarder, midline	0.11073	1.8073	0.1181
Difference in the disc space height along the posterior boarder, midline	0.1689	4.2827	0.0287

Table 6 The parameters for the discriminant regression function for the failure of the indirect decompression prediction

Component of the regression equation	Regression coefficient	*P* value	Beta coefficient
Intercept	0.5591	< 0.0001	-
Postoperative square of the vertebral canal below 80 mm^2	0.2777	0.0001	0.5783
Lateral recess depth below 3 mm	0.1008	0.0088	0.2671
Vertebral canal square mm^2	-0.0005	0.3351	-0.1013
Right lateral recess depth, mm	0.0221	0.2670	0.1426
Left lateral recess depth, mm	-0.0037	0.8763	0.0207

canal square less than 80 mm^2 and lateral recess depth less than 3 mm are predictors of indirect decompression failure associated with the residual nerve root compression.

DISCUSSION

Being one of the most frequent causes of disability, spinal stenosis is a frequently encountered morbid condition in the elderly - adult population. Cases with nerve root compression and neurogenic claudication resistant to multidisciplinary therapy require surgical decompression; those presented with segment instability also require spinal instrumentation employing various types of fusion and fixation[22,23]. It has been defined that vertebral canal square below 100 mm^2 and 75 mm^2 are criteria for relative and absolute spinal stenosis, while lateral recess depth below 3 mm is considered lateral stenosis[24-27].

Different studies were performed to define critical values of the spinal canal that are associated with the manifestation of neurological symptoms; however, the estimation of the relationships between the results of the radiological examination and spinal canal parameters remains problematic. The main difficulties of research on this topic are associated with the fact that the dimensions of the spinal canal are not static and tend to change bending, extending, and under load, while only a few clinics can provide CT or MRI examinations in standing positions[28-31]. Under vertical load and posture, bending backwards may cause spinal canal shrinkage because of posterior longitudinal ligament prolapse and thickening of the ligamentum flavum. Capability either to prevent those changes under load in vertical posture and during movements or to provide an increase in spinal canal square because of posterior longitudinal ligament tension and ligament flavum thinning are the main principles of the indirect decompression that can be achieved employing anterior reconstruction[6-8]. The latter is getting more and more popular because of its effectiveness in terms of spinal lordosis restoration and the additional stability that can be achieved because of favorable load distribution[2-4,32]. An additional strong point is that indirect decompression may have certain advantages compared to direct decompression. During direct decompression, manipulations on nerve structures are required, and finally, those are associated with an increased risk of nerve structure injury or epidural scar formation that may cause neuropathic pain or a permanent neurologic deficit[3,9,33].

Even though the option of indirect decompression seems attractive, the discussed technique may have certain limitations because the reported rate of revision surgery remains considerable. Several studies were performed to detect factors that may impact the results of the indirect decompression. It has been detected that the unfavorable factors are osteoporosis and high-grade facet joint degeneration with ankyloses that may prevent segment height restoration[34]. On the other hand, the research by Navarro-Ramirez (2017) supports the conclusion that locked facet joints with the Weishaupt 4 stage of degeneration are not a counterindication for the indirect decompression application. Additional unfavorable factors that can affect the results of indirect decompression are disc extrusion, osteophytes, ligament calcification, and Schizas D degree of spinal stenosis[35]. The negative impact of those listed is associated with an insufficient spinal canal size increase in patients with Schizas D spinal stenosis and the necessity of microsurgical removal of the extruded disc fragments or osteophytes[6,15-17]. Even though the unfavorable factors are known, the information is insufficient to work out valid patient selection criteria because the rate of revision surgery after indirect decompression remains considerable and varies between 9.5% and 43.0%[18-20].

Until now, certain knowledge has been gained concerning the radiographic results of the indirect decompression. It has been reported that indirect decompression has a high efficacy in patients with foraminal stenosis, sometimes exceeding the results of indirect decompression. According to the reported results, indirect decompression employing segment height restoration is capable of increasing foraminal square by 8.0%-60% of the initial and height by 60%-65% of the initial [7]. The range of influence on the postoperative square of the spinal canal has a higher variability, ranging from 7% to 143% from the initial value[7,11,13,14]. On the other hand, the clinical result of the indirect decompression does not have a linear correlation with the increase in the dimensions of the spinal canal, inasmuch as sometimes even an increase of 14% of the initial spinal canal square is capable of providing a clinically significant result[36]. Those reported results support the assumption that the clinical effect of indirect decompression is achieved only by transcending marginal values that are required to provide neural structures with decompression under the condition of static fused segments; on the other hand, those figures remain uncertain. The weak point of papers published on relevant topics is that they only support the statement that indirect decompression provides an increase in spinal canal and foraminal size with the relevant improvement in relevant pain and disability scores without detailed analysis of preoperative and postoperative parameter's relationships and their clinical significance[37-39]. A viable suggestion for patient selection was given by Lim *et al*[21], in 2019, that is based on the assumption that if neurological presentation depends on posture with pain relief in a horizontal or sitting position, a clinically significant effect is expected after indirect decompression[21]. The weak point of the proposed patient selection criterion is that reduction cannot be taken into account.

The current study was performed to estimate the marginal values of spinal canal parameters that can be used as a criterion for indirect decompression failure prediction. CT was selected for preoperative and postoperative data collection to estimate regression models for postoperative spinal canal dimension prediction. The reason to choose CT for patient examination is supported by evidence that even though MRI has better sensitivity for spinal stenosis detection, CT may provide better differentiation of bone, osteophytes, ligament flavum, and cerebrospinal liquid under degenerative conditions[40,41]. The results of the current study are in agreement with previously reported data that support the conclusion that the increase in spinal canal square correlates with the restoration of disc space height[42]. The goodness of fit of the linear regression assessing the relationships between preoperative and postoperative spinal canal square supports the conclusion that the given parameter is predictable if indirect decompression is achieved by disc height restoration. The results of the analysis also point out the effect of slipped vertebra reduction in patients with spondylolisthesis on the results of the indirect decompression. According to the multiple linear regression analysis, the impact of the reduction can be greater than that provided by only disc height restoration since the significance of disc height increase turned insignificant in the presence of a change in the anterior translation variable. Taking into account the results of the regression analysis, the regression equations should be estimated separately for the discussed subgroups. The most controversial results employing indirect decompression were achieved in patients with lateral recess stenosis. It has been reported that one of the most frequent reasons for revision surgery employing direct decompression was inadequate lateral recess depth; furthermore, bony lateral recess stenosis is considered an unfavorable predictor for the result of indirect decompression[42-45]. The result of the data analysis provides an additional explanation for the observed discrepancies in indirect decompression application in patients with lateral recess stenosis. Even though 11h indirect decompression provides an additional increase in lateral recess depth with a median of 0.9 mm, the estimated regression models lack sufficient explanation for the variability of its postoperative value. In other words, the results of indirect decompression are unpredictable in patients with lateral recess stenosis.

Even though a considerable amount of research was performed to evaluate the efficacy of indirect decompression, the cutoff criteria that are capable of predicting clinically significant results remain uncertain. As a consequence, no valid algorithm is provided for patient selection to perform indirect decompression using anterior reconstruction. In the majority of published studies, the results of indirect decompression are matched to the results of pain-related scores; however, this kind of study design may have a certain vulnerability in terms of bias[38,39,44]. The latter statement is supported by the fact that, in a significant proportion of cases, the residual pain could be irrelevant to the applied surgery [43,46-48]. To address the previously mentioned potential bias, the radiographic results were matched to the risk of unsatisfactory results according to the Macnub scale that are associated with unresolved nerve root compression. According to the results of the logistic regression analysis, vertebral canal square below 80 mm^2 and lateral recess depth below 3 mm are associated with a considerable risk of indirect decompression failure. The estimated general discriminant model for unsatisfactory results prediction based on those cutoff values provides 92.5% classification accuracy. The estimated critical values are close to those used as the criteria to define absolute lumbar spinal stenosis. Those values have additional meaning: Values below those estimated are insufficient to resolve nerve root compression even on a stable fused segment.

Limitation

This is an observational study performed on a small group; a greater number of patients is required to estimate prognostic models with higher accuracy. The results assessment is based on CT measurements while MRI can provide better visualization of soft tissues. On the other hand, the obtained gradient in radiodensity provides appropriate contrasting to perform the required measurements.

CONCLUSION

Indirect decompression employing anterior reconstruction is achieved by the increase in disc height along the posterior boarder and reduction of the slipped vertebrae in patients with degenerative spondylolisthesis. Vertebral canal square below 80 mm^2 and lateral recess depth less than 3 mm are associated with indirect decompression failures that require direct microsurgical decompression.

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