Analysis of factors related to prognosis and curative effect for posterolateral fusion of lumbar low-grade isthmic spondylolisthesis

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Abstract The objective of this study was to select factors related to the prognosis and curative effect for posterolateral fusion (PLF) of lumbar low-grade isthmic spondylolisthesis (LGIS). Of 125 patients who accepted PLF treatment, 119 obtained solid union in this prospective study. Statistical analysis was used to evaluate factors related to the prognosis and curative effect. Spondylolisthetic position (L4, L5), gender and postoperative percent disc height were not significant factors for the prognosis and curative effect. Length of disease history (LDH), preoperative Japanese Orthopaedic Association (JOA) score and postoperative percentage of slipping (% slip) were significantly related to postoperative JOA score and postoperative improved JOA score. LDH and postoperative % slip were significantly related to postoperative recovery rate. LDH, preoperative JOA score and postoperative % slip were independent related factors for the prognosis and improvement of LGIS. LDH and postoperative % slip were independent related factors for the curative effect. However, age, gender, spondylolisthetic position and postoperative percent disc height were not significant factors.

Résumé L'objectif de cette étude est d'examiner les facteurs pronostic et les effets du traitement du spondylolisthésis isthmique (LGIS) de bas grade après une greffe postéro-latérale. Matériel et méthode: 119 sur 125 patients ont accepté ce traitement avec perspective d'obtention d'une bonne greffe. Une étude statistique a permis d'évaluer les facteurs pronostics

et le traitement. Résultats: la position des vertèbres, le pourcentage de hauteur discale sont des facteurs pronostics significatifs pour le traitement. La longueur de l'évolution (LDH), le score préopératoire (JOA), le pourcentage résiduel de glissement sont en relation significative avec le taux de récupération. Conclusions: la LDH, le score préopératoire de la JOA et le pourcentage de glissement postopératoire sont des facteurs indépendants du pronostic du LGIS, LDH et le pourcentage de glissement post-opératoire sont également indépendants des traitements. Cependant, l'âge, le sexe, la position vertébrale et le pourcentage de la hauteur des disques ne sont pas des facteurs significatifs.

Introduction

Isthmic spondylolisthesis with slippage involves defects in bony contacts in the pars interarticularis, resulting in loss of the posterior stabiliser. The nerve root deficits and leg pains involve foraminal stenosis caused by a combination of fibrocartilaginous mass at the isthmic defect, disc and osteophyte of the slipped body. Sufficient decompression of nerve roots is essential to obtain good surgical outcomes as is the need for stabilisation [25]. Posterolateral fusion (PLF) using a pedicle screw system (PSs) is the most popular spinal fusion technique to treat isthmic spondylolisthesis [4, 5, 15, 16]. PLF without interbody fusion has provided satisfactory long-term clinical results with high fusion rates [13, 22].

At present, the type of reduction to be done is still questioned. Lonner et al. showed that reduction benefits included a decrease in shear stresses, restoration of sagittal alignment and lumbosacral spine balance, and improvement in clinical deformity [18]; however, Poussa et al. showed that the fusion in situ group seemed to perform better in almost all clinical parameters measured. These findings

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suggest that fusion in situ should be considered as the method of choice in isthmic spondylolisthesis [21].

There is controversy about how much to restore the disc height (% disc height) in the operation. On theoretical grounds: (1) in low-grade spondylolisthesis, complete decompression with foraminotomy retrieves the normal path for nerve roots; therefore, to restore the space relieves the stress; (2) excessive loss of space results in loss of height of the intervertebral foramen, zygapophyseal joint subluxation, shrinkage and prominence of arcuate ligaments, which cause intervertebral foramen narrowing and nerve root compression [7]; and (3) there is a tendency to lose space between the fusion segments after operation. Therefore, to restore the height of the intervertebral space to a certain amount can prevent or postpone the recurrence of intervertebral space stenosis and foramen narrowing. But Lidar et al. [17] indicated that disc space does not seem to affect clinical outcome in lumbar fusion, and efforts to maintain it may be unwarranted.

In view of these different points, this study was conducted to determine whether the parameters including postoperative % disc height, postoperative percentage of slipping (% slip), age, gender, length of disease history (LDH), spondylolisthetic position and preoperative Japanese Orthopaedic Association (JOA) score [19] have any effect on postoperative JOA score, postoperative improved JOA score and postoperative recovery rate with solid fusion after operation.

Materials and methods

1. Research method: this was a prospective study. Potential factors affecting the outcome included preoperative parameters: gender, age (at time of operation), spondylolisthetic position, LDH and preoperative JOA score. Postoperative parameters at two years after operation were: postoperative % disc height, postoperative % slip, postoperative JOA score, postoperative improved JOA score (postoperative JOA score – preoperative JOA score) and postoperative recovery rate [(postoperative JOA score – preoperative JOA score)/(normal JOA score – preoperative JOA score)] [19]. Postoperative % slip and postoperative % disc height were measured on both postoperative X-ray films in the standing position, as described in a previous report [23] (Figs. 1 and 2). In order to have better comparability, postoperative statistical data were collected at two years after operation for every patient in this study, but follow-up continues.
2. Patients: between July 2002 and February 2005, 125 consecutive patients with lumbar low-grade isthmic spondylolisthesis (LGIS) underwent PLF with PSs in our department. The isthmic cleavage was confirmed

Fig. 1 Postoperative percent slip is the ratio between *a* and *b*. *a* is the distance from a line parallel to the posterior portion of the vertebral body just below the slipped vertebra to a line drawn parallel to the posterior portion of the slipped vertebral body and *b* is the anteroposterior dimension of the slipped vertebra

by X-ray for every patient. All patients had been given a trial of conservative treatment for six months before surgery with no improvement in symptoms. Five cases were excluded because of breakage of pedicle screws and pseudoarthrosis and one patient died of myocardial infarction six months after operation. A total of 119 cases of solid fusion after operation were evaluated in this study. Solid union was determined by bony trabecular continuity and immobility at the fused segments on functional stress radiographs. Of the 119 patients, signs and symptoms appeared as lower back pain with radiation to both legs in 62 cases, or to one leg in 31 cases, back pain only in 18 cases and neurological intermittent claudication in 62 cases; 82 patients had weakness of leg muscle or relaxation, two patients had an L1 compression fracture and the other two patients had a T12 compression fracture. There was no obvious external injury in any of the patients.

All patients had single segmental lumbar spondylolisthesis on X-ray films preoperatively. The diagnosis of stenosis was established by computed tomography (CT) scan or magnetic resonance imaging (MRI). Some other complications, such as articular process hyperplasia, arcuate ligament thickening, shear stress and dura mater sac compression, also existed.

3. Treatment methods: all patients were treated surgically including decompression, reduction, fixation with an instrument (transpedicular screws) and arthrodesis. Decompression was performed by removing part of the cephalad and caudad lamina of the involved vertebra, together with bilateral medial caudad and cephalad facetectomy. The techniques of spinal arthrodesis were used for single-level bilateral PLF. Pieces of corticocancellous and cancellous bone were harvested from the outer and middle tables of the iliac crest and then were

Fig. 2 Postoperative percent disc height is calculated as the ratio between *c* and *d*. *c* is the height of the posterior margin in the slipped vertebral body and *d* is the distance from a line drawn parallel to the superior aspect of the vertebral body below the slipped vertebra to the posterior portion of the slipped vertebral body

transplanted posterolaterally. Decortication of the transverse processes was performed before transplantation of bone graft. Reduction was achieved by traction and instrumentation. All operations were performed by the same group of orthopaedic surgeons. The follow-up time was from two years and five months to six years.

4. Statistical analysis: an independent sample *t*-test was used to test the effect of gender and position of spondylolisthesis on postoperative JOA score, postoperative improved JOA score and postoperative recovery rate. A multifactor stepwise correlation analysis was used to evaluate relativities between independent variables including age, LDH, preoperative JOA score, postoperative % disc height and postoperative % slip and dependent variables including postoperative JOA score, postoperative improved JOA score and postoperative recovery rate. Stepwise correlation criteria (probability of *F*): $P \leq 0.05$, entry; $P \geq 0.10$, removal. SPSS 13.0 software was used for all statistical analysis, with 95% confidence intervals.

Results

1. Effects of gender and spondylolisthetic position on prognosis and curative effect

Table 1 Statistical analysis of effect of gender and spondylolisthetic position on prognosis

Groups	Position (<i>n</i>)		<i>t</i> value	<i>P</i>	Gender (<i>n</i>)		<i>t</i> value	<i>P</i>
	L4 (51)	L5 (68)			Male (53)	Female (66)		
POJOAS	24.9±2.2	24.8±2.0	0.191	0.849	24.7±2.3	24.9±1.9	-0.582,	0.562
POIJOAS	13.3±1.1	13.2±1.0	0.472	0.638	13.3±0.9	13.2±1.2	0.573	0.588
PORR	78.0±10%	77.7±9.5%	0.208	0.836	77.9±11%	77.8±8%	0.058	0.954

POJOAS postoperative JOA score, POIJOAS postoperative improved JOA score, PORR postoperative recovery rate

An independent sample *t*-test showed in our study that there was no significant difference between L4 and L5 spondylolisthesis or gender for postoperative JOA score, postoperative improved JOA score and postoperative recovery rate ($P > 0.05$, respectively) (Table 1).

2. Multifactor stepwise correlation analysis of factors related to prognosis and curative effect

Independent variables included age (X_1), LDH (X_2), preoperative JOA score (X_3), postoperative % disc height (X_4) and postoperative % slip (X_5); dependent variables included postoperative JOA score (Y_1), postoperative improved JOA score (Y_2) and postoperative recovery rate (Y_3) (Table 2).

(1) The multifactor stepwise correlation analysis of independent variables and postoperative JOA score showed that LDH, preoperative JOA score and postoperative % slip were significantly related to postoperative JOA score ($P < 0.05$, respectively). The regression equation is $Y_1 = 23.672 - 0.506X_2 + 0.338X_3 - 0.126X_5$ (Table 3).

(2) The multifactor stepwise correlation analysis of independent variables and postoperative improved JOA score showed that LDH, preoperative JOA score and postoperative % slip were significantly related to postoperative improved JOA score ($P < 0.05$, respectively). The regression equation is $Y_2 = 22.723 - 0.452X_2 - 0.600X_3 - 0.118X_5$ (Table 4).

(3) The multifactor stepwise correlation analysis of independent variables and postoperative recovery rate showed that LDH and postoperative % slip were significantly related to postoperative recovery rate ($P < 0.05$, respectively). The regression equation is $Y_3 = 0.962 - 0.034X_2 - 0.008X_5$ (Table 5).

Discussion

Lumbar isthmic spondylolisthesis is divided into inborn and acquired spondylolisthesis. In acquired spondylolisthesis, lumbar vertebrae stress concentration and instability lead to breakage of the pedicle of the vertebral arch, resulting in degeneration of the intervertebral disc, narrowing of the intervertebral space, looseness of the annulus fibrosus,

Table 2 Statistical analysis of the postoperative curative effect and the related factors

Groups	Age (years) (X ₁)	LDH (years) (X ₂)	PRJOAS (X ₃)	PODH (%) (X ₄)	POS (%) (X ₅)	POJOAS (Y ₁)	POIJOAS (Y ₂)	PORR (%) (Y ₃)
Mean ± SD	56.30±8.87	4.00±1.64	11.68±2.25	26.21±7.59	5.97±2.77	24.84±2.07	13.20±1.06	77.87±9.65

LDH length of disease history, PRJOAS preoperative JOA score, PODH postoperative % disc height, POS postoperative % slip, POJOAS postoperative JOA score, POIJOAS postoperative improved JOA score, PORR postoperative recovery rate

instability of lumbar vertebrae, spinal stenosis and degeneration of the ligament and zygapophyseal joint, which induce the shear stress and back and leg symptoms. All patients in this study underwent complete decompression, reduction and fixation, and obtained solid fusion, which are essential for a successful operation.

Significance of complete decompression, reduction, fixation and solid fusion

Complete decompression of the nerve root is necessary to obtain a better prognosis and curative effect. Images should be examined carefully before surgical treatment. Features including arcuate ligament thickening, intervertebral foramen stenosis and nerve root compression can be identified by CT scan or MRI. In all patients who undergo a posterior decompressive laminectomy, the superior and inferior articular processes that form the lateral wall of the vertebral canal and posterior wall of the nerve root should all be addressed, because they induce the nerve root compression. Intraoperative reduction is not only a key step to remove spinal stenosis and the pressure on the nerve root but also a prerequisite to reconstruct the normal spinal architecture and restore the function physiological. Moreover, reduction brings the internal fixation instrument into full play to improve bone graft fusion. Reduction of slip is beneficial to relieve lumbosacral deformity, to restore normal vertebral canal shape and sagittal balance, and to reconstruct stability of the lumbar spine. Isthmic spondylolisthesis causes additional segmental instability and requires further stabilisation. Further evidence was found that PLF is superior to exercise alone for adult isthmic spondylolisthesis [20]. The advantages of

supplementary pedicle screw fixation are the ability to correct the deformity and to reduce the listhesis. The rigid fixation is expected to give better fusion rates and to increase the chance of a long-term clinical success [6]. Single-segment solid fusion is the final objective of surgical treatment for spondylolisthesis. Bridwell et al. confirmed that decompression of the nerve root without internal fixation can aggravate the displacement and that decompression with pedicle screw fixation and bone graft fusion could obtain a better curative effect than that of other surgical treatments [2]. A prospective, randomised study on patients who underwent posterior lumbar decompression with bilateral posterolateral arthrodesis indicated that a solid fusion improves the long-term clinical result for patients undergoing single-level decompression and posterolateral arthrodesis for spinal stenosis and concurrent spondylolisthesis [14]. Butt et al.'s study [3] showed that satisfactory clinical outcome is closely associated with the rate of successful fusion. The results suggest that clinical outcome is closely related to the attainment of solid fusion. Inamdar et al. [8] studied 20 patients treated by posterior lumbar interbody fusion (PLIF) versus intertransverse fusion (ITF) in the management of lumbar spondylolisthesis. They concluded that morbidity and complication rate are much higher following PLIF than ITF. ITF is recommended because of the simplicity of the procedure, lower complication rate and good clinical and radiological results. Jacobs et al. [10] considered that PLF appears to be the general gold standard for the treatment of adult isthmic low-grade lumbar spondylolisthesis. Kim and Lee [13] followed up 40 isthmic spondylolisthesis patients who underwent operative treatment and indicated that there was no significant difference in

Table 3 Multifactor stepwise correlation analysis between independent variables and postoperative JOA score

Independent variable	Unstandardised coefficients		Unstandardised coefficients	<i>t</i>	Sig.
	B	SE	Beta		
Constant	23.672	1.562		15.157	0.000
X ₂	-0.506	0.128	-0.401	-3.955	0.000
X ₃	0.338	0.093	0.367	3.649	0.000
X ₅	-0.126	0.058	-0.170	-2.189	0.031

Dependent variable: postoperative JOA score

Table 4 Multifactor stepwise correlation analysis between independent variables and postoperative improved JOA score

Independent variable	Unstandardised coefficients		Unstandardised coefficients	<i>t</i>	Sig.
	B	SE	Beta		
Constant	22.723	1.513		15.022	0.000
X ₂	-0.452	0.124	-0.697	-3.646	0.000
X ₃	-0.600	0.090	-1.270	-6.697	0.000
X ₅	-0.118	0.056	-0.308	-2.109	0.037

Dependent variable: postoperative improved JOA score

Table 5 Multifactor stepwise correlation analysis between independent variables and postoperative recovery rate

Independent variable	Unstandardised coefficients		Unstandardised coefficients	<i>t</i>	Sig.
	B	SE	Beta		
Constant	0.962	0.015		64.385	0.000
X ₂	-0.034	0.006	-0.573	-5.507	0.000
X ₅	-0.008	0.004	-0.232	-2.230	0.028

Dependent variable: postoperative JOA score recovery rate

curative effect between anterior intervertebral body fusion and PLF. Takahashi et al.'s results [24] were in agreement with those of Kim and Lee's study. We found that PLF gives rise to less blood loss and the manipulation is simpler. Therefore, PLF with complete decompression and pedicle screw fixation can obtain a satisfactory therapeutic effect for low-grade isthmic spondylolisthesis.

In our operation, the bone graft was harvested from the outer and middle tables of the iliac crest and a satisfactory fusion rate (119/125) was obtained. Kho and Chen [11] used laminectomy bone chips as bone graft; the outcome of spinal fusion was good with 129 of 136 patients attaining solid fusion. They think that the fusion rate obtained with this type of autogenous bone graft is comparable to that of the iliac bone crest autogenous graft; hence, they suggest laminectomy bone chips as a good substitute for iliac crest bone autogenous graft.

Japanese Orthopaedic Association scoring system

Clinical evaluation was done using the JOA assessment of treatment for low back pain (JOA score). This system comprises subjective symptoms, clinical signs, restriction of activities of daily living and urinary bladder function [17]. Its full score is 29 points. It reflects the patient's condition completely and objectively and numerous scholars have confirmed its value. Many authors and editors use this system to evaluate a patient's condition for isthmic spondylolisthesis [1, 19, 24].

Postoperative JOA score, postoperative improved JOA score, postoperative recovery rate

The postoperative JOA score reflects the degree of disease severity and prognosis for the patient with low back disorder. The postoperative improved JOA score is the difference in preoperative and postoperative scores, indicating improvement in the patient's condition; however, it does not involve the lost score. The postoperative recovery rate is a ratio between postoperative improved JOA score and preoperative lost JOA score. It is a parameter that can

reflect curative effect. There is a different clinical and statistical significance for each definition.

Curative effect and prognosis-related factors for low-grade lumbar spondylolisthesis

Lumbar spondylolisthesis mainly includes isthmic and degenerative spondylolisthesis. Isthmic spondylolisthesis is divided into inborn and acquired spondylolisthesis. In the latter, lumbar vertebrae stress concentration and instability lead to breakage of the pedicle of the vertebral arch. Lumbar spondylolisthesis occurs frequently at L4 and L5, and can happen in men and women.

In this study, statistical analysis indicated that gender, spondylolisthetic position (L4, L5), age and postoperative % disc height are not significant factors in relation to postoperative JOA score, postoperative improved JOA score and postoperative recovery rate. Iwamoto and Takeda's findings suggested that surgical treatment appears to alleviate the clinical symptoms and increase physical activity in older patients with degenerative lumbar spondylolisthesis, potentially resulting in the suppression of bone resorption. Surgical treatment may contribute to the prevention of physical inactivity-induced osteoporosis in elderly patients with neurogenic intermittent claudication caused by degenerative lumbar disease [9]. In Kilincer et al.'s retrospective study comprising 129 patients (age range: 25–91 years) with spondylolisthesis, the patients were stratified by age: those younger than 65 years of age (85 patients) and those at least 65 years of age (44 patients). The results showed that older patients did not have increased complications, estimated blood loss or operative time. Longer hospitalisation was observed in the older patient group (7 ± 3.5 days) compared with the younger patient group (5.5 ± 1.9 days) ($P=0.022$). They concluded that complications and perioperative events following posterior lumbar decompression and fusion in the elderly are comparable with those observed in younger patients. Withholding lumbar spine fusion solely based on advanced age is not warranted [12].

There is still controversy regarding how much of the intervertebral space should be restored postoperatively. This study showed that postoperative % disc height is not significantly related to postoperative JOA score, postoperative improved JOA score and postoperative recovery rate. Our results are consistent with those of Lidar et al. [17] who indicated that disc space does not seem to affect clinical outcome in lumbar fusion, and efforts to maintain it may be unwarranted. Suda et al.'s study showed that preserved disc height was a risk factor for pseudoarthrosis and/or instrument breakage in PLF [23].

This study indicated that LDH has a significant negative correlation to postoperative JOA score, postoperative im-

proved JOA score and postoperative recovery rate. A longer disease history leads to a worse prognosis and curative effect. Lumbar vertebrae degeneration is associated with LDH of low back pain. The longer LDH of spondylolisthesis readily induces arcuate ligament thickening and hyperplasia of superior and inferior articular processes. Long-term spinal instability harms the spinal internal environment; meanwhile, long-term nerve root and dura mater sac compression lead to a worse outcome of surgical treatment, which suggests that if a patient has undergone short-term nonoperative treatment and whose pathogenetic condition has not been improved obviously, surgical treatment should be recommended.

The preoperative JOA score is significantly related to postoperative JOA score and postoperative improved JOA score, positive to the former and negative to the latter, which indicates that the preoperative JOA score has a significant effect on prognosis, the slighter the preoperative condition, the better the prognosis. However, if the preoperative JOA score is higher, the postoperative improved JOA score will be lower, which shows that patients with a preoperative JOA score that is not so low will not have evident improvement. This is also an important theoretical foundation to understand the indications for operation. The postoperative recovery rate is a ratio of postoperative improved JOA score to preoperative lost JOA score, which can reflect the curative effect more accurately. Statistical analysis shows that the preoperative JOA score has no significant correlation to postoperative recovery rate.

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