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Predictors of outcomes after posterior decompression and fusion in degenerative spondylolisthesis

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Abstract No consensus has been reached regarding surgical management of degenerative spondylolisthesis. The optimal type of surgical procedure and surgical indications have not been precisely defined. In order to screen for predictors of outcome, we retrospectively studied patient outcomes after posterior decompression and fusion for isolated lumbar degenerative spondylolisthesis. Twenty-four consecutive patients (age range 50–78 years) underwent primary surgery for isolated lumbar degenerative spondylolisthesis. The surgical procedure consisted of posterior decompression and pedicle screw instrumented fusion using autogenous bone graft, with or without interbody fusion. Clinical and radiologic status were assessed using the Beaujon functional score and plain AP and lateral radiographs. A multivariate analysis was used to correlate the functional score increase with surgical procedure modifications and preoperative clinical

and radiologic features in order to determine which of them led to better results. Eighteen patients completed the evaluation. Six others were lost to follow-up after a minimum of 0.87 years. Combining all the results, the mean follow-up was 2.87 years. The Beaujon score was improved in the 24 patients ($P<0.001$), and fusion was successful in all cases. Additional interbody fusion and preoperative leg pain were significantly correlated with larger score increase ($P=0.016$ and $P=0.003$). Posterior decompression and fusion is successful in treating lumbar degenerative spondylolisthesis. From this study, circumferential fusion improves the outcomes and leg pain is a fair indication for surgery.

Keywords Degenerative spondylolisthesis · Postero-lateral fusion · Interbody fusion · Decompression · Surgical indication · Multivariate analysis

Introduction

Lumbar degenerative spondylolisthesis is a segmental spinal destabilization related to degenerative discopathy. Described for the first time by Junghans in 1930 [22], it was reported in the English literature by McNab in 1950 [32]. Degenerative spondylolisthesis is a unique disease. Its origin is multifactorial; factors include intervertebral disc degeneration [9,49], facet joint anatomic orientation [7, 15], iliolumbar configuration [12], gender [45,48], liga-

ment hyperlaxity [31], and physical overactivity [46]. Over time, degenerative spondylolisthesis can lead to either further degenerative destabilization or arthritic restabilization [4,31,47]. Patients can present with back pain, leg pain or both [39], and symptomatology does not correlate with the amount of slippage observed on radiographic examination [5]. When conservative treatment fails, surgical procedures may include decompression, posterior, anterior or circumferential arthrodesis, and rigid or semi-rigid instrumentation [1,13,14,20,21,23,25,28,35,40, 49,51]. Comparative studies have been published [3,10,

Table 1 Beaujon functional score

Items/points	0	1	2	3	4	Total
Walking distance	<100 m	100–500 m	>500 m	Unlimited	–	3
Resting leg pain	Constant	Major crises	Mild and rare crises	Absent	–	3
Ambulatory leg pain	Upon first steps	Rare and late	Absent	–	–	2
Back pain	Constant	Major crises	Mild and rare crises	Absent	–	3
Neurologic deficit	Major	–	Mild	–	Absent	4
Painkiller use	Strong medication required	Mild medication or occasional use	No medication use	–	–	2
Quality of life	Poor	Fair	Good	Excellent	–	3
						20

11,19,24,26,28,35], but no consensus has been reached concerning the choice of procedure or indications for surgery.

The goal of this study was to present the results of surgical management of degenerative spondylolisthesis at our institution and to determine which perioperative features led to better results. This may allow us to refine our technique and our indications for treating patients with degenerative spondylolisthesis in the future.

Material and methods

Patients

Twenty-four patients who underwent primary spine surgery for isolated lumbar degenerative spondylolisthesis from 1 April, 1995 through 14 March 2000 at our institution were identified. They were invited to come in to undergo a physical and radiographic examination.

Nineteen women (average weight 65.5 kg; height 1.59 m) and five men (average weight 84.5 kg; height 1.73 m) who had not had previous spine surgery were included in the study. Mean age at surgery was 67.9 years (standard deviation 8.17, range 50.1–78.7 years). The level of spondylolisthesis was located at L4–L5 in 16 cases, at L5–S1 in five cases, at L3–L4 in two cases and at both L3–L4 and at L4–L5 in one case. The American Society of Anesthesiology (ASA) Score [42] was 2 in 18 cases, 1 in five cases, and 3 in one case.

Surgical procedure

Patients underwent posterior decompression (laminectomy of the spondylolisthetic vertebra and of the cranial adjacent level, keeping the facet joints intact), and posterior spinal fusion with plate and pedicle screw semi-rigid instrumentation (Domino; Stryker Spine, Allendale, N.J., USA). Pedicle screws were placed under direct visualization. Autogenous iliac crest bone grafting was performed in all patients. No active reduction procedure was performed. In 18 cases, the instrumented arthrodesis was single level (only the spondylolisthetic level). The fusion was extended to the cranial adjacent level in two cases or to the caudal adjacent level in four cases because of preoperative evidence of hypermobility. In addition to the posterior fusion, eight patients also underwent an inter-body fusion with inter-somatic cage (Stryker Spine) on the same operative day (seven posterior and one anterior approaches). Patients began ambulating on postoperative day 2. A custom brace was used for 3 months after surgery.

Fig. 1 Lateral radiograph of the lumbar spine in standing position : L4–L5 degenerative spondylolisthesis. **A** Computerized measurement of percentage of spondylolisthesis (a/b). **B** Computerized measurement of percentage of disc height $[(c+d)/2e]$

Evaluation

Retrospective evaluations were performed, and charts and radiographs were reviewed, by an independent orthopaedic surgeon observer (M.A.R.). The Beaujon functional score [27] was assessed for each patient before surgery and at last follow-up. The Beaujon functional score correlates well with the SF 36 [17], but is specific to spine disorders (Table 1).

Standing AP and lateral (both flexion and extension) radiographs were taken before surgery, in the postoperative period, and at last follow-up. The following measurements were performed on digitized radiographs at the spondylolisthetic level and at the level cranial to the instrumented arthrodesis (Fig. 1).

Percentage of spondylolisthesis

Percentage of spondylolisthesis was defined as slippage in extension. Slippage was measured as the distance between the anterior borders of the two vertebral bodies divided by the length of the inferior endplate of the cranial vertebra. This method, which was based on that of Morgan and King [36], allowed us to normalize for differences in X-ray magnification and patient size.

Percentage of disc height

Disc height was calculated from the extension radiograph as the sum of the anterior and posterior disc heights divided by twice the cranial vertebra height. This method was described by Farfan [44] and modified by Guigui [16].

We also calculated anteroposterior mobility as the difference in slippage in flexion minus extension. Radiographic fusion was defined as the presence of bridging bone on standard radiographs, and classified according to Brantigan grading system [2].

Statistics

Data were analyzed using statistical software (SPSS 11.5; SPSS Inc., USA). Significance was set at $P < 0.05$. Results are given with 95% confidence interval. In order to determine which perioperative features led to better results, a multiple linear regression analysis was performed with the increase in Beaujon functional score as the dependent variable. Eight independent variables were chosen for the regression analysis: addition of an intersomatic cage to the surgical procedure (presence or absence), extent of the arthrodesis (one or more than one level), combination of resting and ambulating leg pain scores (addition), back pain item score, body mass index, percentage of spondylolisthesis, anteroposterior mobility, and percentage of disc height. The variables were separated into three blocks (surgical technique modifications, preoperative clinical characteristics, and preoperative radiologic characteristics) and were added in a hierarchical fashion to the regression. The significance of the increase in the multiple r -squared was calculated for each block. Variables were standardized to decrease colinearity as recommended [38].

Results

Clinical data

Eighteen of the 24 identified patients came to the practice between 18 February, 2002 and 24 April, 2002. The mean follow-up period was 3.4 years (95% confidence interval 3.1–3.7). Their overall functional score increased from 11.7 (10.7–12.8) to 17.5 (15.9–19.1) between the preoperative period and the last follow-up. The six patients who

could not be reached were lost to follow-up after 1.2 years (0.9–1.6). Their last known Beaujon functional score was 18.5 (17.1–19.9) with uneventful outcomes reported in their charts.

Combining the results for all patients, the mean follow-up was 2.9 years (2.5–3.3), while the Beaujon functional score increased from 11.3 (10.4–12.1) to 17.8 (16.6–18.9). The global increase was significant ($P < 0.001$, paired Student t -test); each item increase was also significant (pain-killer use, ambulating leg pain, resting leg pain, quality of life, back pain, neurological deficit, and maximum walking distance).

Two successful revisions were performed: one at postoperative day 15 for superficial staphylococcal infection (irrigation), and one at postoperative day 21 for postoperative leg pain (pedicle screw replacement).

Radiologic data

All the patients were Meyerding [33] grade I or II with an average preoperative percentage of spondylolisthesis of 20.7% (17.7–23.5). Postoperatively, the value decreased significantly [mean 16.1% (12.7–19.5), $P = 0.001$, Student paired t -test]. The average anteroposterior mobility at the spondylolisthetic level before surgery was 2.9% (1.4–4.3).

At last follow-up, fusion was successful in all patients, (Brantigan grade 4 in four cases and 5 in 20 cases). Cranial adjacent disc height at last follow-up was not significantly different from its preoperative value [21.1% (18.4–23.8) versus 21.4% (18.1–24.6), $P = 0.68$, paired Student t -test]. There were two cases of asymptomatic secondary spondylolisthesis cranial to the arthrodesis at last follow-up. The final Beaujon functional score for these two women was 19/20 and 18/20 at 2.9 and 2.6 years after surgery, respectively. In these two cases, the preoperative percentage of L4–L5 spondylolisthesis was 25.6% and 23.7%, respectively. Another similar point in these cases

Table 2 Blockwise hierarchical regression ($R^2 = 0.859$, $P = 0.003$). The Beaujon functional score increase at follow-up is significantly influenced by the addition of an intersomatic cage during posterior decompression and fusion, and by the degree of preoperative leg pain

	Significance of adding each block to the model	Significance of the individual variables in the two block model
<i>Block 1: surgical technique</i>		
Use of intersomatic cage	0.036	0.026
Multi-level arthrodesis		0.137
<i>Block 2: clinical variables</i>		
Leg pain	0.010	0.003
Back pain		0.500
Body mass index		0.108
<i>Block 3: radiologic variables</i>		
Percentage of spondylolisthesis	0.584	–
Anteroposterior mobility		–
Percentage of disc height		–
Constant	–	0.533
Two block model	–	0.003

was the peroperative decision to extend the arthrodesis to L3–L4 because of evidence of hypermobility.

Multivariate analysis

The mean Beaujon functional score increase was 7.17 ± 2.49 at last follow-up. The results of the blockwise multivariate linear regression demonstrated that surgical technique modifications and clinical characteristics contributed significantly to the increase in Beaujon score but radiologic characteristics did not ($R^2=0.859$ for the two block model, $P=0.003$). Within the clinical characteristics block, we found that leg pain history was significantly correlated with the observed increase in functional score ($P<0.003$). Significance in the surgical technique block arose from the use of circumferential fusion through the addition of an intersomatic cage ($P<0.016$, Table 2). The Beaujon functional score increased from 11.8 (10.3–13.3) to 18.0 (17.0–19.0) in the posterior fusion group ($n=16$), and from 10.0 (8.3–10.7) to 19.0 (17.5–20.5) in the circumferential fusion group ($n=8$).

Discussion

Using multivariate analysis to screen retrospectively for predictors of outcomes in degenerative spondylolisthesis surgery, this study demonstrated that leg pain and the addition of an intersomatic cage were associated with better results after posterior decompression and fusion.

Even though each item of the Beaujon functional score, when examined separately, increased significantly after surgery, the multivariate analysis demonstrated that leg pain contributed significantly to the overall Beaujon functional score increase, and back pain did not. These results suggest that decompression-fusion surgery will be more successful in treating leg pain than back pain in the spondylolisthetic patient. This finding is consistent with the experience of several investigators [8,14,20,25,26] who reported larger decreases in leg pain than in back pain after different types of surgery for degenerative spondylolisthesis.

The complementary use of inter-somatic cages in eight cases was an important optional modification of the surgical technique. It significantly influenced the outcome independently of the other variables examined at the same time. This procedure is meant to improve fusion rate in degenerative spondylolisthesis [23]. Since fusion itself is not automatically related to improved clinical outcomes in degenerative lumbar spondylolisthesis [11], the use of intersomatic cages in addition to posterior fusion may have improved the outcome by another mechanism such as better decompression of the foramen, better rigidity in the arthrodesis [6], or removal of the pain generator by performing discectomy [41]. The utility of circumferential

fusion versus posterior fusion alone is controversial in the treatment of spondylolytic spondylolisthesis [30,50] but has not been directly and prospectively investigated in the degenerative spondylolisthesis. It was striking that the outcome after surgery was not statistically influenced by either the static or the dynamic preoperative radiologic characteristics of spondylolisthesis. This emphasizes the absence of correlation between radiologic characteristics and clinical presentation in spondylolisthesis [5]. For those with Meyerding grade I or II with no neurological deficit, the preoperative radiologic aspects of disc destabilization should not be part of the indications for surgery.

This study assessed predictors of outcomes based on clinical and radiologic data which are consistent with improvements in clinical status and high fusion rates reported in the literature examining posterior instrumented arthrodesis in degenerative spondylolisthesis [1,3,11,13,23,24,34,40,49]. We also observed a small but significant passive reduction, which has already been reported to be associated with the posterior procedure [40]. We found no radiographic signs of degeneration at the level above the arthrodesis except two cases of secondary spondylolisthesis, which were still asymptomatic after 2.78 years. In particular, there was no significant decrease in the cranial adjacent intervertebral space height at last follow-up. Since Booth et al. [1] have reported that revision surgery for transition syndrome following lumbar fusion for degenerative spondylolisthesis was required in 10% of cases after an average of 7 years, signs of degeneration in our cohort may also increase over time.

Multivariate analysis is recommended [18] for identifying predictors of outcomes among confounding factors, since the use of univariate statistical methods to test multiple variables separately may be misleading. Using univariate statistics, Nork et al. [40] did not find any correlation between overall clinical outcome and patient age, preoperative leg pain, preoperative back pain, percentage of slippage, and number of fused levels even though they reported significant improvements in back pain, painkiller use, walking tolerance, and quality of life 1 year after posterior decompression and fusion for degenerative spondylolisthesis. Possible unbalanced distributions of factors in the population, statistical issues due to correlated variables of interest, or the statistical irrelevance of performing too many univariate tests on the same population are biases avoided through the use of multivariate analysis.

The low incidence of pure degenerative spondylolisthesis limited the number of patients in our study. Specifically, those with any kind of previous lumbar surgery or any associated lumbar anomalies (for example, multilevel spinal stenosis, which is commonly seen with degenerative spondylolisthesis) were not selected. The population size limited the number of independent variables in the regression analysis. The variables utilized in the model were selected either because they were thought to be the most interesting or because their inclusion was necessary

to account for potential confounding factors. Extended arthrodesis was one of these potential confounding factors, since multiple level fusion increases mechanical stresses in adjacent levels more than single level fusion [37]. However, a higher rate of radiologic disc degeneration in adjacent discs has not been proven [16,29,43].

In conclusion, posterior semi-rigid instrumented arthrodesis with local and cranial adjacent decompression is a satisfactory procedure for treating degenerative lumbar spondy-

lolisthesis. Our study indicates that circumferential fusion improves patient outcome and that leg pain is an important indication for decompression fusion surgery. Multivariate regression is a complex statistical method and its limitations must be taken into account in the interpretation of the results. However, this approach is an important tool for determining predictors of outcomes and should therefore be utilized more often in orthopaedic clinical research.

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