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Outcome analysis for adults with spondylolisthesis treated with posterolateral fusion and transpedicular screw fixation

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The outcomes of 52 adult patients with symptomatic low-grade spondylolisthesis treated with autologous posterolateral arthrodesis and pedicle screw fixation were retrospectively reviewed.

Although a 90% rate of successful fusion was obtained using this technique, only 60% of patients were considered to have good outcomes. Treatment failures consisted mostly of back pain and were not predicted by preoperative symptoms. Compensation claims and smoking had very significant adverse impacts on both employment and pain results despite high fusion rates, particularly in patients under the age of 55 years. Overall, patients who required more than one operation demonstrated poor outcomes compared to those who only needed one. However, patients with at least two prior operations or preoperative pseudoarthrosis fared particularly poorly, whereas those who had undergone only one prior surgery and had no attendant compensation issue reported good results. A trend toward poor outcome was observed in patients with postlaminectomy spondylolisthesis, versus those with isthmic or degenerative etiologies. Gender did not exert an impact on outcome.

The authors conclude that autologous posterolateral arthrodesis combined with pedicle screw fixation resulted in a high fusion rate, and contributed to successful outcomes in the treatment of certain subgroups of adults with spondylolisthesis. In the absence of other risk factors, patients may obtain significant benefit from surgery despite older age and a single failed operation. Careful patient selection appears critical in predicting the maximum benefit from this technique.

KEY WORDS • **spondylolisthesis** • **spinal fusion** • **spinal instrumentation** • **pedicle screw** • **outcome**

OPERATIVE management for adults with nontraumatic spondylolisthesis is usually reserved for treating intractable radiculopathy, claudication, or symptomatic instability.[2,3,39] When an operation is indicated, fusion is generally advocated for isthmic,[2,3,15,21,23,35,39] degenerative,[2,3,17,20,25,27,29,37–39] and iatrogenic[2,10,17,27,29,39,41] spondylolisthesis, especially when wide decompression is performed, to avoid symptomatic slip progression. However, fusion rates for adults with spondylolisthesis are often suboptimal.[15,17,23,27,29,31,38,44]

Increasingly, internal fixation using transpedicular fixation has been advocated to improve fusion rates and thereby clinical results for spondylolisthesis.[1,2,5,10,12,15,20–23,29,35,39–44] However, these devices are not yet approved by the U.S. Food and Drug Administration for general use in the lumbar spine and may be a source of medicolegal concern for spinal surgeons.

Given this controversy, it is crucial to develop patient selection criteria for this technique. For this purpose, we present a retrospective analysis of adult patients with symptomatic spondylolisthesis treated with intertransverse fusion and transpedicular fixation, using carefully defined indications for operation. Our goal is to identify those patients who appear likely to benefit from surgery.

Clinical Material and Methods

Patient Demographics and Selection

A total of 52 patients with spondylolisthesis who underwent posterolateral lumbar fusion and transpedicular screw fixation performed by the senior author (L.V.A.) between 1992 and 1995 were included. The mean age of the patients was 53.4 years (range 24–77 years); there were 30 women and 22 men. Spondylolisthesis was classified as isthmic in 14 patients, degenerative in 12, and postlaminectomy in 26. These last 26 patients accounted for 53 previous operations: 32 discectomies, 11 decompressions, nine fusions, and one hardware removal. An additional eight patients had undergone one previous surgery at an unrelated lumbar level, including four decompressions, three discectomies, and one fusion. Twenty patients had preoperative secondary gain issues, including claims for worker's compensation and long-term disability or litigation following motor vehicle accidents.

All patients had radiographic evidence of spondylolisthesis or translational motion of 4 mm or greater. Spondylolisthesis was Meyerding Grade I in 46 patients and Grade II in six. All patients selected for surgery had failed conservative treatment, which included bed rest,

TABLE 1

Prolo economic and functional rating scale

Economic (activity) Status		Functional (pain) Status	
Grade	Description	Grade	Description
E1	complete invalid (worse)	F1	total incapacity (worse)
E2	no gainful occupation (including housework or retirement activities)	F2	moderate-to-severe daily pain (no change)
E3	working/active but not at premorbid level	F3	low level of daily pain (improved)
E4	working/active at previous level w/ limitation	F4	occasional or episodic pain
E5	working/active at previous level w/o restriction	F5	no pain

a course of antiinflammatory medication, physiotherapy, and in some instances, a trial of external bracing. Symptoms consisted of back, buttock, and posterior thigh claudication pain or lumbosacral radiculopathy. Examination revealed reproducible neurological deficits that correlated with radiographic pathology in 46 patients (88%). Deficits consisted of dermatomal sensory loss in 46 patients (88%), diminished or absent reflex in 24 (46%), and weakness in eight (15%). No patient had incontinence. Informed consent identifying the pedicle screws as experimental devices was obtained prior to the operation.

Clinical Studies and Statistical Analysis

Patient records were reviewed and the patients or their family members were interviewed. Mean clinical follow up was 18.6 months (range 6–36.7 months).

Economic (activity) and functional (pain) grades, based on a published grading system for lumbar fusion outcome (Table 1),[33] were assigned preoperatively (defined as E0 and F0) and at follow-up review (defined as Ef and Ff). Improvement after surgery, based on a change in grade, was calculated (designated as ΔE and ΔF). Statistical methods used in this study included analysis of variance (ANOVA) for perioperative variables and the Kruskal–Wallis one-way analysis of variance and the Mann–Whitney test to assess outcome by patient subgroups. Significant probability values were established at less than 0.05. Analysis was performed using computer statistical software (BMDP Statistical Software, Inc., Los Angeles, CA).

Perioperative variables, including estimated blood loss (EBL), length of surgery, length of hospital stay, and duration of postoperative bracing were assessed with respect to the number of fused segments and history of lumbar operations. The patients were grouped by gender, age, cause of spondylolisthesis, secondary gain, and smoking history for outcome analysis. Data for patients with previous surgery were compared to those for patients without prior operation and then subdivided to evaluate those with a history of multiple operations, pseudoarthrosis, and compensation issues.

Radiographic Studies

All patients obtained preoperative radiographs with flexion–extension views and imaging studies to evaluate both neural compression and pedicle anatomy.[3,4] Radiographs were obtained postoperatively and at regular intervals until fusion was demonstrated. The mean radiographic follow-up period was 10.4 months (median 10 months, range 3–36.5 months). Fusion was defined strictly as the presence of bilateral continuous trabecular bone between fixed segments (Fig. 1). When visualization was indeterminate due to osteoporosis or obscured by hardware, the construct was considered solid, but not fused, if stable radiographic parameters (degree of slippage or angulation) and no hardware breakage or motion were observed in patients more than 1 year postoperatively.

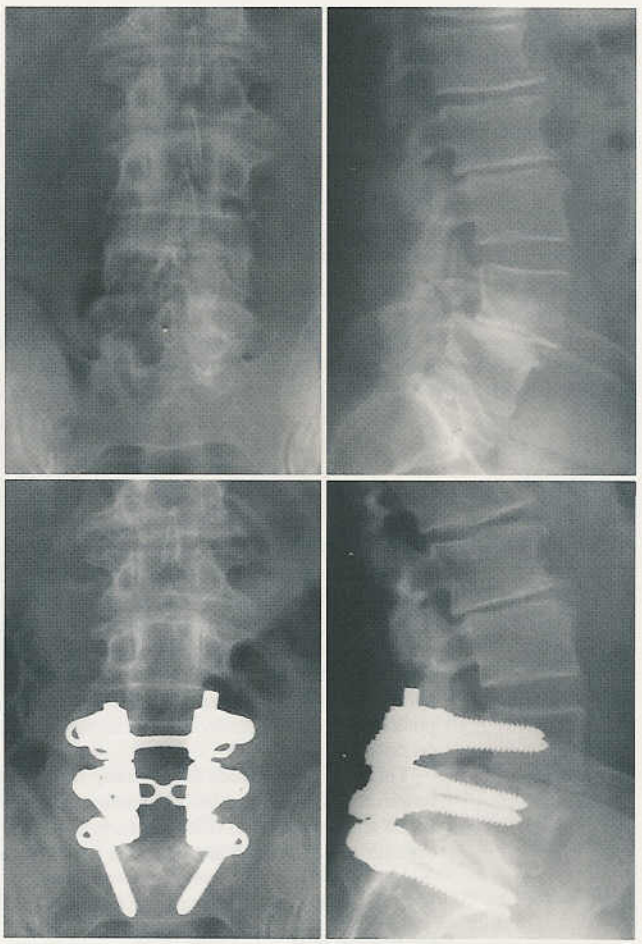

FIG. 1. Radiographs obtained in a 53-year-old man with Grade I spondylolisthesis and pars defect who had undergone a previous hemilaminectomy. *Upper Left* and *Right:* Preoperative views. *Lower Left* and *Right:* Postoperative views demonstrating decompression, solid posterolateral fusion, and transpedicular screw fixation.

Operative Technique

Laminectomy was performed in all cases of isthmic and degenerative spondylolisthesis. Following decompression, graft harvest, decortication and packing of the facet joints, pedicle screws (Isola System; Acromed Corp., Cleveland, OH) were sized to occupy 70% of pedicle diameter. The L-5 and S-1 pedicles typically accepted 7-mm screws; L1–4 variably accommodated 5.5-, 6.25-,

TABLE 2

Perioperative variables in 52 patients undergoing surgery for symptomatic low-grade spondylolisthesis

Variable	No. of Patients	Mean Values			
		EBL* (ml)	Duration of Surgery (min)	Duration of Stay (days)	Duration of Bracing (wks)
all patients' fusion	52	934	417	8.0	8.6
1 level	37	849	294	7.5	9.4
2 levels†	11	802	446	10.8	8.5
>2 levels†	4	1778	603	6.8	8.5
surgery					
no prior surgery	18	920	403	6.7	8.7
prior surgery	32	940	425	8.8	9.5
pseudoarthrosis	7	1450	547	9.4	8.3

* Estimated blood loss after replacement of recycled blood.
† Considered together for statistical analysis.

TABLE 3

*Economic/activity outcome in 52 patients undergoing surgery for symptomatic low-grade spondylolisthesis**

Group	No. of Patients	Duration of Follow Up (mos)	Percentage of Patients at Follow Up With Grades		
			E1–2	E3†	E4–5
all patients	52	18.6	31	10	60
sex					
M	22	19.7	23	9	68
F	30	17.2	37	10	53
age					
<55 yrs	33	19.2	39	9	52
≥55 yrs	19	16.6	16	11	74
cause of spondylolisthesis					
isthmic	14	17.7	21	7	72
degenerative	12	15.5	23	0	77
postlaminectomy	26	18.2	40	16	44
other considerations					
compensation	20	21.0	65	15	20
no compensation	32	17.7	9	6	84
smoker	17	19.6	59	6	35
nonsmoker	35	17.7	17	11	72
no prior surgery	18	17.8	28	5	67
1 prior surgery, no compensation‡	17	17.7	6	12	82
≥2 prior surgeries‡	13	21.3	62	15	23
pseudoarthrosis‡	7	18.9	57	29	14

* Grading is based on modified Prolo scale. See Table 1 for description of grades.
† For statistical analysis, E3 scores were grouped with E1–2 as poor outcomes.
‡ For statistical analysis, these subgroups were considered together as patients who had undergone previous surgeries.

or 7-mm screws.[4] Screw placement was accomplished using anatomical landmarks with an intracanalicular probe identifying the medial wall of the pedicle. Screw hole preparation was performed using the drill to penetrate the cortex, followed by using a blunt curved bone dissector, sized taps, and a probe to assure pedicle integrity. Pedicle and screw stimulation were performed in most patients. Polymethylmethacrylate was used to supplement screw purchase in osteoporotic bone in 11 patients (21%).[10,25,46] Satisfactory screw position was confirmed with radiographs.

Reduction was generally not attempted. Intertransverse bone graft was packed and cross links were applied at each instrumented level. Demineralized bone matrix polymer (Grafton; Osteotech, Shrewsbury, NJ) and allograft cancellous chips were used to supplement autologous graft in some cases of osteoporosis or pseudoarthrosis. Subfascial and donor site drains were placed before multilayer wound closure. A blood product recycling unit was used in all instances and supplemented by autologous and donor-directed transfusion. Perioperative transfusion of crossmatched donor blood was performed in 18 cases (35%). Patients were observed overnight in the intensive care unit and mobilized with a rigid orthosis within 2 days in most instances. Rehabilitation therapy was initiated.

Results

A total of 248 screws were placed. Instrumented fusion was performed at one level in 37 patients, two levels in 11, and more than two levels in four patients. Most (nine of 11) two-level fixations were performed for single-level spondylolisthesis with an adjacent pars defect, large disc herniation, or intraoperative evidence of instability. One patient had two-level spondylolisthesis and five had multilevel laminectomies and pseudoarthrosis. Operated segments included L5–S1 in 33 patients, L4–5 in 22, L3–4 in 11, L2–3 in four, L1–2 in one, and T12–L1 in one patient.

Perioperative Variables

Data for net EBL, length of operation, duration of hospital stay, and external bracing are presented in Table 2. There were no statistically significant differences when comparing patients with and without prior surgery or patients with one and more than one operated levels. Increased blood loss and longer operating time occurred in cases with more than two fixed segments or pseudoarthrosis.

Economic (Employment) Outcome

Employment outcomes and duration of follow up by subgroup are listed in Table 3. The mean E0 and Ef grades for all patients were 2.4 and 3.7, respectively. Overall, 31 patients (60%) returned to their premorbid level of employment, housework, or retirement activities and were considered good outcomes (Grades E4–5). Twenty-one patients were classified as poor outcomes: five patients (10%) were considered active at a suboptimal but improved level or were retraining (E3) and 16 (31%) did not return to their premorbid level of activity (E1–2).

Predictors of poor E0 were patient age under 55 years ($p = 0.007$) and secondary gain ($p = 0.011$). Patients with prior surgery showed a trend toward a lower E0, which was not significant ($p = 0.06$). There were no significant differences for E0 based on gender ($p = 0.6$) or etiology ($p = 0.3$).

Evaluation of ΔE revealed a highly adverse effect of secondary gain ($p = 0.0005$) and smoking ($p = 0.019$) on resuming employment. Patients who underwent more than one surgery also had a significant risk of poor outcome

TABLE 4

*Pain and fusion outcome in 52 patients undergoing surgery for symptomatic low-grade spondylolisthesis**

Group	No. of Patients	Percentage of Patients at Follow Up With Grades F1–2	F3†	F4–5	Percent Fused‡
all patients	52	23	21	56	90
sex					
M	22	23	23	54	100
F	30	37	10	53	84
Age					
<55 yrs	33	33	24	42	100
≥55 yrs	19	5	21	74	74
etiology of spondylolisthesis					
isthmic	14	14	14	72	100
degenerative	12	17	0	83	92
postlaminectomy	26	30	35	35	88
other considerations					
compensation	20	50	35	15	95
no compensation	32	6	13	81	88
smoker	17	47	35	18	94
nonsmoker	35	11	15	74	89
no prior surgery	18	22	11	67	94
1 prior surgery, no compensation§	17	0	24	76	88
≥2 prior surgeries§	13	46	31	23	85
pseudoarthrosis§	7	43	43	14	57

* Grading is based on modified Prolo scale. See Table 1 for description of grades.

† For statistical analysis, F3 scores were grouped with F1–2 as poor outcomes.

‡ Based on 50 patients fulfilling radiographic outcome criteria.

§ For statistical analysis, these subgroups were considered together as patients who had undergone previous surgeries.

($p = 0.043$) due to the particularly poor results of those with two or more prior operations (23% returned to work) or pseudoarthrosis (14% returned). However, 82% of patients with only one prior operation and no compensation issue resumed preoperative activity. Return to work was also achieved in 84% of all noncompensation cases, 72% of nonsmokers, and 67% of patients without prior surgery. Although only 44% of patients with postlaminectomy spondylolisthesis resumed employment, compared to 77% and 72% of patients with degenerative and isthmic etiologies, respectively, this difference was not statistically significant ($p = 0.4$). There were no significant differences in employment outcome by age ($p = 0.9$) or gender ($p = 0.3$).

Pain Outcome

Pain results by subgroup are listed in Table 4. The mean F0 and Ff grades for all patients were 1.8 and 3.7, respectively. At follow-up review, 29 patients (56%) reported absent or occasional back and leg pain and were considered good outcomes (Grades F4–5). Poor outcomes in 23 patients (44%) consisted of 11 patients (21%) who improved, but still reported daily pain (Grade F3), and 12 (23%) whose pain did not improve or worsened (Grades F1–2).

Preoperatively, 23 patients had back and unilateral leg pain, 16 complained of back and bilateral leg symptoms, and 13 had mechanical or claudication syndromes involving the back, buttocks, or proximal thighs. Postoperatively, pain failures occurred in eight of 23 patients from the unilateral leg symptom group, eight of 16 patients from the bilateral leg symptoms group, and seven of 13 patients with back and proximal extremity symptoms. In the 23 pain treatment failures, 17 patients complained of persistent back and/or proximal extremity symptoms, five patients had continuing back and leg pain, and one had increased pain in a previously less symptomatic leg.

No significant differences for F0 were found with respect to age ($p = 0.1$), gender ($p = 0.2$), etiology ($p = 0.8$), smoking ($p = 1.0$), compensation ($p = 0.4$), or previous surgery ($p = 0.1$).

Evaluation of ΔF revealed highly significant adverse effects of compensation ($p = 0.0001$), smoking ($p = 0.0001$), and age under 55 years ($p = 0.014$) on pain relief. Reoperated patients also had a significant risk of poor pain outcome ($p = 0.045$), due to those with either two or more prior operations (only 23% had good pain relief) or pseudoarthrosis (14% had relief). However, 76% of patients with only one prior operation and no compensation issue reported good pain results. Good pain results were seen in 81% of patients with no compensation issues, 74% of nonsmokers, 74% of patients over 55 years of age, and 67% of those without prior surgery. Although only 35% of patients with postlaminectomy spondylolisthesis obtained good pain relief, compared to 83% and 72% of patients with degenerative and isthmic etiologies, respectively, this difference was not statistically significant ($p = 0.1$). There were no significant differences in pain outcome based on gender ($p = 0.7$).

Neurological Outcome

Subjective improvement in sensory examination was reported by 12 (26%) of 46 patients and motor radiculopathy improved in five (63%) of eight patients after operation. Reflexes did not change appreciably after surgery. No patient developed incontinence.

Radiographic Outcome

Fusion results by subgroup are presented in Table 4. Fifty patients had sufficient radiographic follow up; 45 attained fusion (90%). The other five patients did not fulfill fusion criteria but had solid constructs as described in *Clinical Material and Methods*. These five patients were all osteoporotic women more than 55 years of age; three had preoperative pseudoarthrosis and had poor clinical results, but the other two had good pain relief. Two unilateral screw fractures (0.8% of all screws) were detected in asymptomatic patients who had achieved fusion. Asymptomatic scoliosis developed in one case.

Complications and Reoperation

Major complications occurred in nine patients (17%). There were six wound infections that required debridement and a course of intravenous antibiotic medications, whereas one febrile patient underwent reexploration that yielded negative results. One patient developed a foot drop postoperatively with incomplete recovery. There was one case of gastrointestinal bleeding requiring transfusion. There were no dural tears or vascular injuries from screw placement. No patient died.

Minor complications were reported in seven patients (13%). These included superficial infections treated with a course of oral antibiotic medications in two patients and prolonged graft site pain (> 6 months) in five patients.

The reoperation rate, excluding the seven patients surgically explored for possible infection, was 5.8%. Two patients underwent elective hardware removal after fusion. One patient developed degeneration and instability at an adjacent level requiring reoperation and extension of her fusion–fixation 20 months postoperatively.

Discussion

Nontraumatic spondylolisthesis in adults is classified according to its etiology, and includes isthmic, degenerative, pathological, and iatrogenic subtypes. Although isthmic spondylolisthesis is most common, symptomatic isthmic defects are infrequent in adults.[2,3] Degenerative spondylolisthesis may develop in the setting of disc and facet degeneration.[2,3,20,27,29,30,39] Pathological spondylolisthesis may result from tumor, infection, or systemic bone disease.[2,3,39] Iatrogenic spondylolisthesis may follow laminectomy when the facet joints are incompetent or removed.

It is estimated that 10 to 20% of adults with symptomatic spondylolisthesis will have persistent pain despite conservative measures.[3,39] Factors such as age, lifestyle, bone quality, degree of facet arthropathy, response to bracing, and medical condition may influence operative indications.[3,39] The goals of surgery are to prevent deficit, enhance maximum recovery of any existing deficit, relieve pain, stabilize abnormal motion, and prevent slippage progression.[2,3,10,17,20,21,39]

Fusion in Spondylolisthesis

Most authors advocate fusion for spondylolisthesis, especially following wide decompression.[2,3,10,15,17,20,21,23,25,27,29,35,37–39,41] Herkowitz and Kurz[17] reported prospective data for fusion following decompression for degenerative spondylolisthesis and found a significant improvement in outcome after concomitant fusion. However, fusion rates in adults are variable, and suboptimal results have been associated with heavier weight, osteoporosis, smoking, and systemic illness.[3,6,10,15,28,31,37,45] Fusion rates for adults with isthmic spondylolisthesis lag behind those of children and adolescents; fusion rates for children in whom instrumentation is not placed approach 100%,[16] whereas those for adults are 60 to 72%.[15,23] Fusion was attained in all patients with isthmic spondylolisthesis in this study. Published noninstrumented fusion rates for degenerative spondylolisthesis range from 64 to 86%,[17,29,31,38,44] whereas fusion was attained by 92% of our patients with degenerative spondylolisthesis.

Pedicle Screw Fixation

Instrumentation is advocated as a temporary measure to attain rigid fixation while bone is incorporating, thereby enhancing the likelihood of union.[22] Fixation may also reduce the risk of deformity progression despite wide decompression and reduce postoperative back pain, thereby encouraging immediate ambulation.[1,2,5,10,12,20,21,29,41] Transpedicular screw systems have become a preferred technique of internal fixation for lumbar spondylolisthesis.[2,10,12,22,29,36,39,41,44] Biomechanically, pedicle screws achieve three-column stabilization with a stronger grip force than other posterior fixation systems.[7,11,14,25] In comparison to hook–rod and wire systems, transpedicular technique requires fixation of fewer motion segments, thus preserving normal adjacent segments. This may reduce the risk of postoperative mechanical pain syndromes.[2,10,25,29,36,39,46] Moreover, pedicle screws do not require intact posterior elements or canal intrusion for placement.[10,25,29,36,39,46] Despite the potential risks of neural damage, cerebrospinal fluid fistula, vascular injury, and possibly increased infection associated with these devices, larger series have demonstrated their safety in experienced hands.[9,10,12,28,29,34,37,40–46]

In 1993, McGuire and Amundson[31] published the only prospective, randomized study evaluating pedicle screw fixation for adult spondylolisthesis. Twenty-seven patients were included; the fusion rate was greater in patients with fixation but was not statistically significant. In 1994, Yuan and colleagues[44] published a historical cohort study of pedicle screw fixation for degenerative spondylolisthesis in 2684 patients. This revealed a statistically significant increased rate of fusion in patients treated with pedicle screws (83% vs. 75% in patients in whom instrumentation had not been placed). Fusion also occurred more rapidly with fixation. Adding pedicle screw fixation to fusion, Ricciardi and coworkers[35] reported an increased rate of arthrodesis (94%) for low-grade isthmic slippages. Pedicle screw fixation also increases the likelihood of stabilization in high-grade slippages;[1,5] fusion alone may have a high failure rate.[4,39]

Defining Fusion

The establishment of fusion was strictly derived from radiographic confirmation of continuous bone traversing the grafted segments, which showed no evidence of motion on flexion–extension radiographs.[31,38] However, the difficulty of assessing solid fusion, in the presence of fixation, is acknowledged.[35,45] Pseudoarthrosis is typically defined as a discontinuous or fibrous interface,[10,19,22,25,31,34] but may also refer to translational motion (typically ≥ 4 mm) in an apparently fused segment.[10,13,24,27,31,34,41,45] Pseudoarthrosis may be painful or asymptomatic.[13,24,26]

Correlation of Fusion and Outcome

There is disagreement in the literature as to whether fusion correlates with clinical outcome in the treatment of lumbar spinal disorders. In series specific for spondylolisthesis, a direct relationship between failure to achieve arthrodesis and unsatisfactory pain outcome was reported in both prospective[31] and retrospective[15,20,21,23,29,32,35,40] studies. However, satisfactory fusion and pain outcomes do not correlate in all series,[10] and even when outcome is satisfactory, return to premorbid employment is not assured.[15,35,40,42] Correlation of good clinical outcome to successful arthrodesis in pseudoarthrosis repair is reported in some series[24,40,47] and appears unreliable in others.[26,38] Finally, despite increased fusion rates with the addition of pedicle screw fixation, evidence suggests that factors other than solid fusion markedly influence clinical outcome in patients undergoing operation for degenerative disc disease.[13,28,32,37,38,40,42,45]

Despite a 90% fusion rate, good clinical results were seen in only 60% of our patients. Back pain accounted for persistent symptoms in 74% of our treatment failures. A comparable number of pain failures occurred among patients with different preoperative complaints. Furthermore, patients not fulfilling the fusion criteria in this study, but reaching what appeared to be a radiographic endpoint, also had mixed results. These findings suggest that factors other than preoperative symptoms and radiographic fusion significantly influenced clinical results.

Preoperative Secondary Gain

Compensation issues represented a highly significant risk factor for disabled preoperative employment status, failure to return to work, and poor pain result. Only 20% of these patients returned to previous employment and 15% had good pain relief, despite a 95% fusion rate. In the absence of compensation claims, the fusion rate was lower at 88%, yet 84% of these patients resumed premorbid activity and 74% had good pain relief. Previous fusion series for spondylolisthesis,[15,35,38,40] degenerative conditions,[13,33,42] and pseudoarthrosis repair[26] have also reported an adverse impact of compensation issues on clinical outcome. Consideration of surgery in these patients should be approached with caution, and only in the absence of other apparent risk factors for poor outcome.

Cigarette Smoking

Cigarette smoking also represented a highly significant risk of failure for both return to premorbid activity and pain relief. Numerous fusion series reveal a higher pseudoarthrosis and poor outcome rate in smokers.[6,10,15,28,31,34,37,45] Moreover, Daftari and coworkers[8] reported experimental evidence that nicotine was associated with delayed vascularization, smaller areas of revascularization, and larger areas of necrosis in autologous cancellous grafts. This effect was not dose related or absolute. The authors postulated that smoking delayed early graft revascularization, leading to impaired osteogenesis and reduced cell counts. It is thus possible that smoking results in a hypocellular fusion mass, which could adversely impact clinical outcome.

We found that although smokers had a 94% fusion rate, only 35% returned to work and 18% had good pain relief. Similar findings were published by Ransom and colleagues,[34] who reported that although pseudoarthrosis was not statistically correlated with smoking in patients treated with pedicle screws, smokers were still more likely to be clinical failures. In our study, a crossover effect from compensation status may also be present because 14 smokers also had secondary gain issues. We recommend that patients discontinue smoking once they have decided to undergo operation.

Age at Operation

Previous studies generally have not found an association between age and fusion outcome in degenerative spondylolisthesis.[10,17,27,29] This is somewhat surprising, given the association of osteoporosis, which would be more prominent in an older population, and nonunion.[10] The oldest patient operated on in this study with a degenerative slippage was 74 years of age; patients up to age 84 years are included in other published series.[29]

Isthmic disease typically presents in younger patients.[15,23,35] Kim and coworkers[23] found that increasing age adversely affected fusion rate in isthmic spondylolisthesis. However, age was not identified as a risk factor for nonunion after fusion for isthmic spondylolisthesis by either Hanley and Levy[15] or Ricciardi and colleagues.[35]

We found that patients under the age of 55 years had significantly increased risks of poor employment and pain outcomes. Only 52% returned to premorbid activity and 42% had good pain relief, compared to 74% in both categories for patients over 55 years. This result was striking given that the fusion rate in younger patients was 100%, including three patients with preoperative pseudoarthrosis, whereas fusion was attained in only 74% of older patients. Thus, clinical result was clearly influenced by factors other than fusion in younger patients. Because all but two of the compensation and smoking patients were under 55 of age, these may be critical factors. Our results suggest that older patients, up to age 75 years, may obtain an excellent surgical result and should be considered for operation if indicated.

Prior Surgery and Pseudoarthrosis

Patients undergoing repeated operations had significant risks of poor employment and pain outcomes. However, these findings were heavily weighted by the extremely poor outcomes of those with secondary gain, pseudoarthrosis, and two or more previous operations. Our data indicate that patients with one previous operation may achieve excellent results in the absence of compensation claims. We found that 82% of these patients returned to work and 76% reported good pain relief. Thus, our results suggest that a subgroup of patients with a failed discectomy or laminectomy obtained benefit from surgery and should not be excluded from consideration on this basis alone.

Patients with a history of failed fusion are notoriously difficult to treat and carry a substantial risk of persistent pseudoarthrosis, even when pedicle screws are added.[10,24,26,38,40] Published noninstrumented and instrumented fusion rates in this population are 49 to 77%, but clinical improvement is seen in only 42 to 53%.[24,26,38,40] Internal fixation is generally advised, given the reported correlation of good clinical outcome to successful arthrodesis in pseudoarthrosis repair.[24,40,46,47] The rate of reoperative fusion in this series was 57%; however, good clinical outcomes were only seen in 14%. Further attempts at arthrodesis in this population should only be considered when symptomatology strongly correlates with pathological and radiographic findings. When other risk factors are present, the risk of treatment failure may be prohibitive.

Perioperative Variables

We did not find statistically significant risks for blood loss based on history of prior operation or comparing the incorporation of one or more than one level. The increased blood loss seen in pseudoarthrosis patients and patients with at least two operated levels suggested a more arduous procedure and higher transfusion risk. Our overall mean EBL of 934 ml compares favorably with previous re-

ports.[18,28,42] Johnson, et al.,[18] reported prospective data for blood loss in lumbar fusion. They found that increased EBL was associated with the use of instrumentation, male gender, younger age, and operation on multiple levels. The use of a blood product recycling unit has become standard for lumbar fusions[9,10,18] and is effective when EBL exceeds 700 ml.[18]

Length of operation, hospital stay, and bracing were also not significantly different when evaluated with respect to history of prior operation or fixation of one or more than one level. Again, the results for pseudoarthrosis patients and patients with multiple (≥ two) operated levels were not considered separately, and their increased length of operation and hospital stay suggest a potentially longer recovery. Overall, our mean length of surgery (417 minutes) is longer, but our mean hospital stay of 8 days and bracing period of 8.6 weeks are comparable to other reports.[19,28,42,45]

Complications and Reoperation

Our major infection rate of 11% for pedicle screw fixation is considerably higher than the 0 to 6% incidence reported elsewhere.[9,10,28,36,37,44] Most (five of six) cases occurred in patients who had undergone previous surgery, which may be due in part to the increased mean length of surgery in this group. We had one new neurological deficit (2%), which was consistent with or lower than the published risk in large series.[9,37,40,44,45]

Our reoperation rate of 5.8% was considerably lower than the 15 to 17% reported in the cohort study.[44] Hardware removal has been reported in up to 14% of patients, although the outcome from this is not defined in the literature.[42,44] Reported indications include development of painful and tender bursa, back pain, screw prominence, implant failure, and elective removal.[42,44] Another indication for reoperation was unstable disc and facet degeneration of an adjacent segment in one of our patients, presumably resulting from new stresses on vertebral motion created by the fusion.[41,45] Involvement of an adjacent segment required operation in 2.4% of the cohort study.[44] Extension of the fusion and transpedicular fixation of the affected segment are suggested for this problem.[41]

Pedicle screw failure may occur in patients who are asymptomatic or have pseudoarthrosis.[10,46] Asymptomatic screw breakage was noted in 4% of our patients, which is comparable to or less than screw failure results in the other series.[9,40,43,44]

Conclusions

A retrospective review of 52 adult patients with spondylolisthesis treated with autologous posterolateral arthrodesis and pedicle screw fixation was performed. A high rate (90%) of successful fusion was obtained with this technique, but this did not correlate with good clinical outcome in all patients. Treatment failures consisted mostly of back pain and could not be predicted by preoperative symptoms. Compensation claims and smoking exerted significant adverse effects on both return to work and relief of pain. These two factors were especially prevalent in patients under the age of 55 years, who had significantly worse outcomes than those over 55 years. Although a history of surgery was also associated with poor outcome, this reflected the very poor results of patients with secondary gain, two or more prior operations, or preoperative pseudoarthrosis. Patients who had undergone only one prior operation and had no attendant compensation issue reported excellent results. Also, patients with postlaminectomy spondylolisthesis demonstrated a trend toward poor outcome, although those with isthmic and degenerative listhesis obtained more favorable results; nevertheless, the difference was not statistically significant. Gender did not impact on outcome.

We conclude that autologous posterolateral arthrodesis combined with pedicle screw fixation results in a high fusion rate, but careful patient selection appears critical to the correlation of this result to benefit from operation. Older patients and those with a single failed operation may obtain satisfying results, but patients with compensation issues, smokers, and those with multiple failed operations or pseudoarthrosis should be carefully evaluated for other risk factors before surgery is considered.

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