Risk Factors for Reoperation in Patients Treated Surgically for Intervertebral Disc Herniation

A Subanalysis of Eight-Year SPORT Data

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Background: Lumbar discectomy and laminectomy in patients with intervertebral disc herniation (IDH) is common, with variable reported reoperation rates. Our study examined which baseline characteristics might be risk factors for reoperation and compared outcomes between patients who underwent reoperation and those who did not.

Methods: We performed a retrospective subgroup analysis of patients from the IDH arm of the Spine Patient Outcomes Research Trial (SPORT) randomized and observational cohorts. We analyzed baseline characteristics and outcomes of patients who underwent reoperation and those who did not with use of data collected from enrollment through eight-years of follow-up after surgery. Follow-up times were measured from the time of surgery, and baseline covariates were updated to the follow-up immediately preceding the time of surgery for outcomes analyses.

Results: At eight years, the reoperation rate was 15% (691 no reoperation; 119 reoperation). Sixty-two percent of these patients underwent reoperation because of a recurrent disc herniation; 25%, because of a complication or other factor; and 11%, because of a new condition. The proportion of reoperations that were performed for a recurrent disc herniation ranged from 58% to 62% in the individual years. Older patients were less likely to have reoperation ($p = 0.015$), as were patients presenting with asymmetric motor weakness at baseline ($p = 0.0003$). Smoking, diabetes, obesity, Workers' Compensation, and clinical depression were not associated with a greater risk of reoperation. Scores on the Short Form (SF)-36 for bodily pain and physical functioning, the Oswestry Disability Index (ODI), and the Sciatica Bothersomeness Index as well as satisfaction with symptoms had improved less at the time of follow-up in the reoperation group ($p < 0.001$).

Conclusions: In patients who underwent surgery for IDH, the overall reoperation rate was 15% at the eight-year follow-up. Patients of older age and patients presenting with asymmetric motor weakness were less likely to undergo a reoperation. Less improvement in patient-reported outcomes was noted in the reoperation group.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

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Surgery for patients with intervertebral disc herniation (IDH) has been supported by several long-term outcome studies¹⁻⁶. Despite these findings, the reoperation rate remains

relatively high, with some reports as high as 26%^{1,7-9}. There have been few large, prospective studies that have identified consistent risk factors for reoperation^{7,8,10-13}. Additionally, a fifteenfold variance in

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TABLE I Patient Baseline Demographic Characteristics, Comorbidities, and Health Status Measures by Group (Reoperation or No Reoperation within Eight Years of Index Surgery)

	Reoperation, N = 118*	No Reoperation, N = 685	P Value†
Age‡ (yr)	38.4 ± 9.9	41.1 ± 10.9	0.013
Female	57 (48%)	289 (42%)	0.25
Ethnicity: non-Hispanic§	116 (98%)	650 (95%)	0.16
Race: white§	107 (91%)	600 (88%)	0.42
Education: at least some college	78 (66%)	505 (74%)	0.11
Income: <\$50,000	65 (55%)	308 (45%)	0.053
Married	86 (73%)	476 (69%)	0.53
Work status			0.52
Full or part time	70 (59%)	397 (58%)	
Disabled	14 (12%)	108 (16%)	
Other	34 (29%)	179 (26%)	
Compensation: any#	22 (19%)	140 (20%)	0.75
Mean body mass index‡ (kg/m ²)	28.8 ± 5.7	28.1 ± 5.7	0.18
Smoker	31 (26%)	170 (25%)	0.82
Comorbidities			
Hypertension	17 (14%)	82 (12%)	0.55
Diabetes	5 (4%)	23 (3%)	0.83
Osteoporosis	0 (0%)	9 (1%)	0.44
Heart problem	4 (3%)	33 (5%)	0.66
Stomach problem	16 (14%)	73 (11%)	0.44
Bowel or intestinal problem	10 (8%)	40 (6%)	0.37
Depression	16 (14%)	78 (11%)	0.60
Joint problem	19 (16%)	111 (16%)	0.91
Other**	44 (37%)	290 (42%)	0.35
<6 months since most recent episode	91 (77%)	528 (77%)	0.91
Outcome measures‡			
Short Form-36††			
Bodily pain	20.7 ± 15.3	23.9 ± 18.4	0.075
Physical functioning	30.7 ± 24.9	32.9 ± 23.2	0.34
Mental component summary	44.2 ± 11.5	44.8 ± 11.4	0.65
Oswestry Disability Index‡‡	57.2 ± 18.5	54.3 ± 19.8	0.13
Sciatica Frequency Index§§	17.3 ± 4.7	16.6 ± 5.2	0.21
Sciatica Bothersome Index##	16.7 ± 4.7	16.4 ± 5.0	0.45
Low Back Pain Bothersomeness Scale***	4.4 ± 1.6	4 ± 1.9	0.067
Leg Pain Bothersomeness Scale†††	5 ± 1.4	5 ± 1.4	0.95
Satisfaction with symptoms: very dissatisfied	103 (87%)	602 (88%)	0.98
Self-assessed health trend			0.55
Getting better	8 (7%)	58 (8%)	
Staying about the same	47 (40%)	301 (44%)	
Getting worse	61 (52%)	322 (47%)	
Treatment preference			0.24
No surgery	19 (16%)	111 (16%)	
Not sure	11 (9%)	103 (15%)	
Surgery	88 (75%)	468 (68%)	
Pain radiation	116 (98%)	671 (98%)	0.92

continued

TABLE I (continued)

	Reoperation, N = 118*	No Reoperation, N = 685	P Value†
Straight-leg raise test			
Ipsilateral	73 (62%)	447 (65%)	0.54
Contralateral/both	25 (21%)	128 (19%)	0.61
Any neurological deficit	84 (71%)	541 (79%)	0.078
Reflexes: asymmetric depression	42 (36%)	288 (42%)	0.22
Sensory: asymmetric decrease	57 (48%)	376 (55%)	0.22
Motor: asymmetric weakness	35 (30%)	324 (47%)	<0.001
Herniation level			0.74
L2-L3 and/or L3-L4	5 (4%)	37 (5%)	
L4-L5	44 (37%)	270 (39%)	
L5-S1	69 (58%)	377 (55%)	
Herniation type			0.42
Protruding	27 (23%)	183 (27%)	
Extruded	85 (72%)	452 (66%)	
Sequestered	6 (5%)	49 (7%)	
Posterolateral herniation	92 (78%)	544 (79%)	0.81
Taking antidepressants	7 (6%)	30 (4%)	0.61

*One hundred and nineteen patients underwent reoperation within eight years of the index surgery; 118 had at least one follow-up through eight years and were included in the current study along with 685 patients who did not undergo reoperation. In the no-reoperation group, data unavailable for one patient regarding work status; for four patients, self-assessed health trend; for three patients, treatment preference; and for one patient, herniation level. In the reoperation group, data unavailable for two patients regarding self-assessed health trend. †Chi-square test for categorical variables and t test for continuous variables. ‡Except for satisfaction, values are presented as the mean and the standard deviation. §Race and ethnic group were self-assessed. Whites and blacks could identify as either Hispanic or non-Hispanic. #Includes patients who were receiving or had applications pending for Workers' Compensation, Social Security compensation, or other compensation. **Other = problems related to stroke, diabetes, osteoporosis, cancer, fibromyalgia, chronic fatigue syndrome (CFS), posttraumatic stress disorder (PTSD), alcohol, drug dependency, heart, lung, liver, kidney, blood vessel, nervous system, hypertension, migraine, anxiety, stomach, or bowel. ††The SF-36 scores range from 0 to 100, with a higher score indicating less severe symptoms. †††The Oswestry Disability Index ranges from 0 to 100, with a lower score indicating less severe symptoms. §§The Sciatica Frequency Index ranges from 0 to 24, with a lower score indicating less severe symptoms. §§§The Sciatica Bothersomeness Index ranges from 0 to 24, with a lower score indicating less severe symptoms. §§§§The Low Back Pain Bothersomeness Scale ranges from 0 to 6, with a lower score indicating less severe symptoms. ††††The Leg Pain Bothersomeness Scale ranges from 0 to 6, with a lower score indicating less severe symptoms.

rates of discectomy is seen across the United States, supporting the need for further studies to better guide decision-making strategies^{3-6,14-17}.

The advent of new technology has helped with improving outcomes and decreasing complications, and, as we now have the tools to better analyze outcome data and treatment effects, a better understanding of predictors of reoperation will enhance our ability to indicate treatment in and manage patients with IDH. Prior studies have investigated risk factors, such as age, comorbidities, type of discectomy, and disc morphology, that may be predictive of reoperation^{9,11,12,18-21}. However, most of these reports are from single institutions or surgeons, or were limited in background and clinical data.

The purpose of our study was to perform a subanalysis of the eight-year Spine Patient Outcomes Research Trial (SPORT) data to determine which patient baseline characteristics would emerge as risk factors for reoperation in patients treated surgically for IDH and compare outcomes among patients who underwent reoperation with patients who did not. We hypothesized that patient and clinical characteristics would be

risk factors for reoperation and that patient outcomes would be more favorable among patients who did not undergo reoperation.

Materials and Methods

This investigation was a retrospective subanalysis of data from the SPORT study that were prospectively collected from enrollment through eight years of follow-up.

Study Design

Patient Population

The SPORT study is a multicenter investigation carried out among thirteen institutions in eleven states across the United States. The study included both randomized and observational cohorts and used validated primary and secondary outcome measures (the Short Form [SF]-36, AAOS/MODEMS [American Academy of Orthopaedic Surgeons/Musculoskeletal Outcomes Data Evaluation and Management System] version of the Oswestry Disability Index [ODI], patient-reported improvement, satisfaction with current symptoms and care, Sciatica Bothersomeness Index, and Low Back Pain Bothersomeness Scale). Further details of the original IDH arm of the SPORT study have been reported elsewhere^{4,6}.

TABLE II Operative Treatments, Complications, and Events

	Reoperation, N = 118*	No Reoperation, N = 678	P Value†
Discectomy level			
L2-L3	2 (2%)	12 (2%)	0.76
L3-L4	3 (3%)	24 (4%)	0.76
L4-L5	43 (36%)	270 (40%)	0.48
L5-S1	72 (61%)	379 (57%)	0.43
Operative time‡ (min)	78.5 ± 44.3	76.5 ± 36.1	0.59
Blood loss‡ (mL)	68.6 ± 83.5	66.8 ± 109.8	0.87
Blood replacement			
Intraoperative replacement	0 (0%)	6 (1%)	0.66
Postoperative transfusion	0 (0%)	0 (0%)	—
Length of stay‡ (days)	1.2 ± 1.2	0.9 ± 0.9	0.015
Intraoperative complications§			
Dural tear/spinal fluid leak	3 (3%)	23 (3%)	0.84
Nerve root injury	1 (1%)	1 (0%)	0.69
Other	0 (0%)	3 (0%)	0.93
None	114 (97%)	652 (96%)	0.98
Postoperative complications/events#			
Nerve root injury	0 (0%)	1 (0%)	0.32
Wound hematoma	2 (2%)	2 (0%)	0.20
Wound infection	10 (9%)	8 (1%)	<0.001
Other	3 (3%)	24 (4%)	0.79
None	104 (89%)	640 (95%)	0.019

*Two hundred and seventy patients in the randomized cohort and 550 patients in the observational cohort had surgery; surgical information was available for 118 patients who underwent reoperation and 678 patients who did not undergo reoperation. Data regarding the “None” category of postoperative complications unavailable for three patients in the no-reoperation group. †Chi-square test for categorical variables and t test for continuous variables. ‡Values are presented as the mean and the standard deviation. §None of the following were reported: aspiration, operation at wrong level, or vascular injury. #Any reported complications up to eight weeks postoperatively. None of the following were reported: bone-graft complication, cerebrospinal fluid leak, paralysis, cauda equina injury, wound dehiscence, or pseudarthrosis.

Inclusion Criteria

Inclusion criteria were radicular pain (of greater than six weeks) distal to the knee for lower-lumbar herniations or into the anterior part of the thigh for upper-lumbar herniations and a positive nerve-root tension sign (positive straight-leg raise or positive femoral-tension sign) or a corresponding neurological deficit. All patients had imaging (97%, magnetic resonance imaging [MRI], and 3%, computed tomography [CT]) showing disc herniation at a level and side corresponding with their symptoms. Exclusion criteria were prior lumbar spine surgery, cauda equina syndrome, substantial deformity, vertebral fractures, inflammatory spondyloarthropathy, pregnancy, and other contraindications for elective surgery.

A research nurse at each site identified participants and verified eligibility with use of a shared decision-making video. Enrollment took place from March 2000 to November 2004. Follow-up was at six weeks, three months, one year, two years, four years, six years, and eight years post-enrollment.

Study Intervention

Surgery consisted of a standard open discectomy with examination and decompression of the involved nerve root. “Standard” nonsurgical intervention involved physical therapy, education with home instruction, and nonsteroidal anti-inflammatory drugs (NSAIDs), if not contraindicated.

Study Measures

Primary end points were the SF-36 bodily pain and physical functioning scores as well as ODI scores. Secondary outcomes included patient-reported improvement, the Sciatica Bothersomeness Index score, satisfaction with current symptoms, and work status.

Patient characteristics included age, sex, race, body mass index (BMI), education, income, marital status, work status, work lift demand, compensation, smoking status, comorbidities (hypertension, diabetes, osteoporosis, clinical depression, heart problem, joint problem, or other), duration of time since the most recent episode, expectation of being free of pain with surgery, expectation of being free of pain with nonoperative treatment, opioid use, use of injections, physical therapy, use of antidepressants, use of NSAIDs, missed work, predominantly back pain, and low back pain.

Operative outcomes included discectomy level, operative time, blood loss, use of blood replacement, length of stay, intraoperative complications (dural tear, nerve root injury, or other), and postoperative complications (nerve root injury, wound complication, infection, or other).

Statistical Considerations

We performed a subgroup analysis of surgically treated patients, including both randomized and observational cohorts. Patients were further stratified into two groups: no reoperation or reoperation.

TABLE III Reoperation Rates by Time Period for Combined Randomized and Observational Cohort*

Time Period	Total, N = 810† (no. [%])	Recurrent Disc Herniation (no. [%])	Complication or Other (no. [%])	New Condition (no. [%])
3 mo	24 (3%)	14 (2%)	11 (1%)	0 (0%)
1 yr	48 (6%)	28 (4%)	17 (2%)	3 (0%)
2 yr	66 (8%)	40 (5%)	19 (2%)	4 (1%)
3 yr	73 (9%)	44 (6%)	20 (3%)	7 (1%)
4 yr	85 (10%)	50 (6%)	21 (3%)	10 (1%)
5 yr	90 (11%)	54 (7%)	22 (3%)	10 (1%)
6 yr	102 (12%)	60 (8%)	26 (3%)	12 (2%)
7 yr	112 (14%)	67 (8%)	30 (4%)	12 (2%)
8 yr	119 (15%)	74 (9%)	30 (4%)	13 (2%)

*Kaplan-Meier estimates. Numbers and percentages are based on the first additional surgery if there was more than one additional surgery. Surgical procedures include any additional spine surgery, not just reoperation at the same level. †Two hundred and seventy patients in the randomized cohort and 550 in the observational cohort had surgery; data were available for 262 patients in the randomized cohort and 548 patients in the observational cohort. One hundred and nineteen patients underwent reoperation within eight years of the index surgery. Of these, 118 had at least one follow-up through eight years and were included in the current study along with 685 of the 691 patients who did not undergo reoperation.

Baseline characteristics, operative factors, complications, and medical events were compared between the two groups using chi-square tests for categorical variables and t tests for continuous variables. To analyze the risk factors for reoperation, a Cox proportional hazards model was used to explore which variables maintained significance after adjusting for other variables. Variables that were significant at the $p < 0.10$ level were candidates for inclusion in the final multivariable regression model. Final selection for the model was done using the stepwise method as implemented in SAS software (version 9.2 for Windows XP Pro; SAS Institute, Cary, North Carolina), which sequentially enters the most significant variable and then, after each entered variable, removes variables that do not maintain significance at $p < 0.05$. Age and sex were forced to be in the model. Primary outcome analyses compared the reoperation and no-reoperation groups using changes from baseline at each follow-up point, with a mixed-effects longitudinal regression model including a random individual effect to account for correlation between repeated measurements within individuals. The analyses were adjusted for age, sex, race, marital status, com-

pensation, smoking status, herniation location, work status, stomach comorbidity, depression, diabetes, other comorbidity, self-rated health trend, duration of the most recent episode, treatment preference, baseline score (for SF-36, ODI, and Sciatica Bothersomeness Index), and treatment center. Across the eight years of follow-up, overall comparisons of the “area under the curve” between groups were made using a Wald test. Computations were performed using the SAS procedure PROC MIXED for continuous data and PROC GENMOD for binary outcome. Significance was defined as $p < 0.05$ based on a two-sided hypothesis test with no adjustments made for multiple comparisons.

Source of Funding

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TABLE IV Mean Change in Scores Over Eight Years and Satisfaction Rate*

	Reoperation, N = 118	No Reoperation, N = 685	Difference (95% Confidence Interval)†	P Value
SF-36 bodily pain‡	35.2 (1.7)	47.6 (0.7)	-12.4 (-16.0 to -8.8)	<0.001
SF-36 physical functioning‡	35.2 (1.6)	46.6 (0.7)	-11.4 (-14.8 to -8.0)	<0.001
ODI‡	-30.8 (1.4)	-40 (0.6)	9.2 (6.3 to 12.1)	<0.001
Sciatica Bothersomeness Index‡	-8.4 (0.4)	-11.3 (0.2)	2.8 (1.9 to 3.7)	<0.001
Very or somewhat satisfied with symptoms (%)	56.4	73.8	-17.4 (-24.1 to -10.7)	<0.001

*Scores are adjusted for age, sex, race, marital status, compensation, smoking status, herniation location, work status, stomach comorbidity, depression, diabetes, other comorbidity, self-rated health trend, duration of most recent episode, treatment preference, baseline score (for SF-36, ODI, and Sciatica Bothersomeness Index), and center. Other comorbidities include stroke, osteoporosis, cancer, fibromyalgia, chronic fatigue syndrome, posttraumatic stress disorder, or problem related to alcohol, drug dependency, heart, lung, liver, kidney, blood vessel, nervous system, hypertension, migraine, anxiety, or bowel. †Difference between reoperation and no reoperation. ‡Values are presented as the mean change from baseline, with the standard error in parentheses. The SF-36 scores range from 0 to 100, with a higher score indicating less severe symptoms. The ODI ranges from 0 to 100, with a lower score indicating less severe symptoms. The Sciatica Bothersomeness Index ranges from 0 to 24, with a lower score indicating less severe symptoms.

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Results

Index Patient Population

Overall, 1244 patients with lumbar IDH were enrolled in SPORT; 501 were enrolled in the randomized cohort and 743, in the observational cohort (Fig. 1). Eight hundred and twenty patients underwent surgery during the first eight years, and 424 patients remained nonoperative. Data were available at the eight-year follow-up for 810 of the patients who had undergone surgery: 262 patients in the randomized cohort and 548 patients in the observational cohort. Of the 810 patients, 803 patients had at least one follow-up through eight years and were included in the analyses. Those lost to follow-up dropped out of the study, missed visits, or died.

The overall mean age was 40.7 years, with slightly more male patients than female patients (Table I). In the combined

randomized and observational groups, the index lumbar discectomy was performed at L5-S1 in 57%, L4-L5 in 39%, L3-L4 in 3%, and L2-L3 in 2% of the 796 patients in the data set for whom surgical information was available; some patients had discectomy at more than one level (Table II).

Surgical Treatment

At eight years post-enrollment, the rate of reoperation was 15%, with 119 patients having had a reoperation and 691 patients, no reoperation (Table III). Forty-eight (6%) of the cohort of 810 underwent reoperation by one year; sixty-six (8%), within two years; eighty-five (10%), within four years; and 102 (13%), within six years.

Of the 119 patients who had a reoperation, forty-eight (40%) underwent a reoperation within the first year; sixty-six (55%), by two years; eighty-five (71%), by four years; and 102 (86%), by six years. The reasons for reoperation were a recurrent disc herniation (62%), complication or other factor (25%), or

Fig. 1

Flow diagram of the SPORT IDH study randomized and observational cohorts. Numbers reported at the follow-up time points are cumulative, and percentages are calculated from the number of patients in each respective arm.

new condition (11%). The proportion of reoperations that were attributed to recurrent disc herniations was fairly consistent over the eight-year study period (Table III).

Of the patients who underwent reoperation, 104 had complete information for an analysis of operative levels. In seventy-four (71%) of these patients, reoperation was performed at the same level as the index surgery. In twenty (19%) of the 104 patients, reoperation included at least one different level. For ten (10%) of the patients, the level was unspecified. In the seventy-four patients who had a recurrent disc herniation, sixty-four underwent reoperation at the same level as in the index surgery; eight, at a different level; and two, at an unspecified level.

Patient Characteristics

The reoperation group was younger (38.4 versus 41.1 years; $p = 0.013$). The prevalence of asymmetric motor weakness at enrollment was lower in the reoperation group (30% versus 47%; $p < 0.001$). No other factors, such as neurological deficit, disc herniation level (L2 to L3, etc.), or type of herniation (protruding, extruded, sequestered, or posterolateral), reached statistical significance. There were no significant differences in other demographic variables or the prevalence of comorbidities, health-related quality of life, or baseline clinical information (Table I).

Operative Outcomes

The analysis of operative treatments, complications, and events revealed that patients in the reoperation group had a slightly longer length of hospital stay (1.2 versus 0.9 days; $p = 0.015$) (Table II). Patients in the reoperation group had a higher prevalence of postoperative wound infection (9% versus 1%; $p < 0.001$) and a higher prevalence of total postoperative complications (13% versus 5%; $p = 0.019$). No significant differences between the two groups were found in discectomy level, operative time, blood loss, use of blood replacement, and rate of intraoperative complications.

Patient-Reported Outcomes

Patient-reported outcomes at follow-up, measured by scores on the SF-36 for bodily pain and physical functioning, the ODI, and the Sciatica Bothersomeness Index as well as satisfaction with symptoms and care, were better in the group that did not undergo reoperation (Table IV and Fig. 2). Patients who underwent a reoperation thus had less improvement from baseline to the eight-year follow-up than those who did not undergo a reoperation.

Risk Factors for Reoperation

The Cox proportional hazards model revealed that patients who assessed their health as getting worse showed a higher risk

Fig. 2

Primary outcomes over time. Each p value is for the comparison of the areas under the two curves (i.e., for the effect of reoperation status on the change from baseline during the eight years of follow-up).

TABLE V Results of Cox Proportional Hazards Model for Variables Predicting Time to Reoperation*

Variable	Estimate	Standard Error	Chi-Square	P Value	Hazard Ratio	95% Confidence Interval
Age	-0.022	0.009	5.910	0.0151	0.98	0.96-1.00
Sex						
Female vs. male	0.128	0.187	0.468	0.4941	1.14	0.79-1.64
Patient self-assessment of health trend						
Getting worse vs. getting better or same	0.378	0.186	4.113	0.0426	1.46	1.01-2.10
Asymmetric motor weakness						
Any vs. none	-0.725	0.201	13.000	0.0003	0.48	0.33-0.72

*Cox proportional hazards modeling was used to explore which variables maintained significance after adjusting for other variables. Variables that were significant at $p < 0.10$ were candidates for inclusion in the final multivariable regression model. Final selection for the model was done using the stepwise method as implemented in SAS software (version 9.2), which sequentially enters the most significant variable, and then, after each entered variable, removes variables that do not maintain significance at $p < 0.05$. Age and sex were forced to be in the model. Candidate predictor variables were age; sex; race; education; marital status; work status; body mass index; smoking status; income; work lift demand; hypertension; diabetes; depression; heart problem; joint problem; duration of time since most recent episode; patient self-assessment of health trend; patient dissatisfaction with symptoms; expectation of being free of pain with surgery; expectation of being free of pain with nonoperative treatment; opioid use; use of injections; having had physical therapy; taking antidepressants; taking NSAIDs; predominantly back pain; Low Back Pain Bothersomeness Index; Leg Pain Bothersomeness Scale; Sciatica Bothersomeness Index; Oswestry Disability Index; Short Form-36 bodily pain, physical functioning, mental component summary, and physical component summary; pain on straight-leg raising or femoral-nerve tension sign; any neurological deficit; asymmetric reflexes; asymmetric sensory decrease; asymmetric motor weakness; herniation level; herniation type; and herniation location.

for reoperation (hazard ratio [HR] = 1.46; $p = 0.0426$) compared with patients who rated themselves as getting better or staying about the same. Older age and the presence of motor weakness were associated with a decreased risk of reoperation (HR = 0.98 per year; $p = 0.0151$, and HR = 0.48; $p < 0.001$, respectively). None of the other variables were significantly associated with reoperation when the type-I error level was set at 0.05, including, smoking, diabetes, obesity, Workers' Compensation, depression, work lift demand, the Low Back Pain Bothersomeness Scale, and the Sciatica Bothersomeness Index (Table V).

Discussion

We analyzed eight-year data from the SPORT study to determine risk factors and reasons for reoperation among patients who underwent index surgery for IDH, and to compare outcomes among patients who underwent reoperation with those who did not. High reoperation rates have been reported in the literature, and several studies have shown inferior outcomes for patients who undergo reoperation^{7,12,18,21,22}. This investigation focused on improving clinicians' understanding of risks and outcomes when indicating IDH patients for surgery, thus improving long-term outcomes and minimizing unnecessary costs and morbidity associated with multiple operations.

In this investigation, patients who underwent surgery for IDH had an overall reoperation rate of 15% at the eight-year follow-up. Of the patients who underwent reoperation, greater than half (55%) underwent reoperation within the first two years, and the most common cause overall was a recurrent disc herniation (62%), which is consistent with prior studies⁷⁻¹¹. In all surgically treated patients, the risk of a recurrent disc herniation at the same level as the index operation was 9%

(seventy-four of 810). Our study also demonstrated a fairly consistent proportion of reoperations attributed to recurrent disc herniation over the eight-year study period, accounting for 58% to 62% of reoperations each year.

Patients who thought at enrollment that their symptoms were getting worse were more likely to undergo a reoperation (HR = 1.46; $p = 0.0426$). This patient group may have had inferior outcomes according to these data, and the underlying cause needs to be studied further. It is unclear whether this reflects anxiety experienced by the patient with severe or worsening symptoms or a preference toward surgery among surgeons caring for these patients. Further randomized studies analyzing patients' symptoms and preferences will help guide surgeons and patients during the shared decision-making process.

Older age was associated with a lower risk of reoperation (HR = 0.98 per year; $p = 0.0151$), which is consistent with prior reports^{21,23}. This patient group is more likely to have other medical comorbidities precluding them from having multiple operations, and because of this, surgeons may be less likely to indicate reoperation for older patients. It is unclear whether these patients are less likely to develop a recurrent disc reherniation or other symptomatic pathology that may warrant reoperation. Conversely, higher risk in the younger population may reflect greater physical demands or higher expectations of physical function on their part. Regardless, patients should be counseled appropriately when making the decision to undergo surgery for IDH.

Patients with asymmetric motor weakness had a lower risk for reoperation, which favors the use of strict inclusion criteria when indicating patients for surgery. Prior reports have shown an inverse relationship between a higher severity of motor weakness and specific muscle groups with chances of motor recovery^{8,24,25}.

However, similar correlations with reoperation rates have not been reported, to our knowledge. It is unclear why other neurological deficits did not correlate with a decreased risk for reoperation; perhaps when a disc herniation is large enough to cause motor deficits (ventral compression of the spinal cord or nerve roots), adequate decompression is more likely to resolve these symptoms. This may also suggest that motor weakness is less likely to reoccur when the discectomy is thoroughly performed, although other factors may contribute. We know of no prior studies that have documented this specific finding.

Contrary to prior studies, a history of depression, smoking, obesity, diabetes, Workers' Compensation, and higher scores on the Low Back Pain Bothersomeness Scale did not correlate with a higher risk for reoperation. These patient factors are often associated with inferior outcomes^{3,7,8,10,21,26-28}, although they were not found to be associated with a higher reoperation rate in our study. As patient comorbidities did not correlate with a higher reoperation rate, the underlying reason for the reoperation may be more likely an organic cause, such as a disc reherniation or incomplete decompression, although additional studies are needed.

The findings from this SPORT subanalysis showed a lower reoperation rate compared with the Maine Lumbar Spine Study (MLSS) (15% versus 25%); however, the MLSS study was from a homogenous sample and did not include imaging confirmation^{7,10}. Martin et al. analyzed reoperation rates following lumbar discectomy and found reoperation rates similar to those in our investigation (a one-year rate of 6% in both studies; 13% versus our four-year rate of 10%). Martin et al. also noted female sex, comorbidities, and Workers' Compensation and public insurance to be associated with a higher risk of reoperation. Older age was associated with higher short-term reoperation risk and lower long-term risk²⁰.

Our subanalysis showed lower reoperation rates than in a large study from Finland that found a reoperation rate at nine years of 18.9%²¹. Similar to our study, patients under fifty years of age had a slightly higher risk of reoperation than patients older than fifty: relative risk (RR) = 1.07 (95% confidence interval [CI] = 0.93 to 1.23) versus RR = 0.77 (95% CI = 0.64 to 0.93). However, the Finnish study was limited by a homogeneous cohort (patient population restricted to Finland, which has a universal health care system).

The strengths of our study include the large number of patients and multicenter design as well as the extensive amount of data recorded and analyzed in the SPORT study. However, there are also various limitations of our study. There is subjectivity involved and inherent bias when studying the outcomes of an elective procedure. Individual surgeon experience may impact the rate of reoperation, although the multicenter design captured a fairly accurate nationwide sample. As with any long-term study, the drop-out rate may confound the findings of the study; 63% of the patients enrolled into SPORT were available for follow-up eight years post-enrollment³. It is possible that the reoperation rate among those lost to follow-up was higher or lower than among those who remained in the study, although

the reoperation rate in this study was comparable with rates previously reported. Our study also did not analyze predictors of reoperation on the basis of radiographic parameters (e.g., disc morphology).

As expected, the patient-reported pain and functional outcomes at eight years were more favorable for patients who did not require a reoperation. Patients going on to have a reoperation had less improvement in patient outcome scores. They also had slightly longer lengths of stay and were more likely to have had a wound or "any" complication from the index operation. Other studies have shown similar findings, with worse outcome scores reported for patients who required multiple lumbar spine operations^{20,24,27}. In this time of a changing health-care climate and a focus on clinical and cost effectiveness, decreasing reoperation rates through a better understanding of risk factors and surgical indications will improve long-term patient outcomes.

In conclusion, this study highlights the relatively low reoperation rate (15%) among patients treated surgically for IDH at an eight-year follow-up. Reoperations were most commonly due to a recurrent disc herniation, and greater than half occurred within the first two years. Our investigation demonstrated that patients who felt that they were getting worse upon enrollment had significantly higher reoperation rates. Additionally, patients with asymmetric motor weakness on enrollment and patients of older age had a lower risk of reoperation. The patient-reported outcomes at eight years were more favorable for patients who did not undergo a reoperation, supporting the importance of proper indications for surgery, performing a thorough decompression, and understanding risk factors for reoperation. These data address the high success with surgery for these patients and further outline patient factors most predictive of reoperation. ■

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