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### **Supplementary material**

Commentary and Perspective, data tables, additional images, video clips and/or translated abstracts are available for this article. This information can be accessed at <http://www.ejbjs.org/cgi/content/full/90/9/1811/DC1>

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# Lumbar Discectomy Outcomes Vary by Herniation Level in the Spine Patient Outcomes Research Trial

By J.D. Lurie, MD, MS, S.C. Faucett, MD, MS, B. Hanscom, MS, T.D. Tosteson, ScD, P.A. Ball, MD, W.A. Abdu, MD, MS, J.W. Frymoyer, MD, and J.N. Weinstein, DO, MSc

*Investigation performed at the Multidisciplinary Clinical Research Center, Dartmouth Medical School, Lebanon, New Hampshire*

**Background:** The Spine Patient Outcomes Research Trial showed an overall advantage for operative compared with nonoperative treatment of lumbar disc herniations. Because a recent randomized trial showed no benefit for operative treatment of a disc at the lumbosacral junction (L5-S1), we reviewed subgroups within the Spine Patient Outcomes Research Trial to assess the effect of herniation level on outcomes of operative and nonoperative care.

**Methods:** The combined randomized and observation cohorts of the Spine Patient Outcomes Research Trial were analyzed by actual treatment received stratified by level of disc herniation. Overall, 646 L5-S1 herniations, 456 L4-L5 herniations, and eighty-eight upper lumbar (L2-L3 or L3-L4) herniations were evaluated. Primary outcome measures were the Short Form-36 bodily pain and physical functioning scales and the modified Oswestry Disability Index assessed at six weeks, three months, six months, one year, and two years. Treatment effects (the improvement in the operative group minus the improvement in the nonoperative group) were estimated with use of longitudinal regression models, adjusting for important covariates.

**Results:** At two years, patients with upper lumbar herniations (L2-L3 or L3-L4) showed a significantly greater treatment effect from surgery than did patients with L5-S1 herniations for all outcome measures: 24.6 and 7.1, respectively, for bodily pain ( $p = 0.002$ ); 23.4 and 9.9 for Short Form-36 physical functioning ( $p = 0.014$ ); and  $-19$  and  $-10.3$  for Oswestry Disability Index ( $p = 0.033$ ). There was a trend toward greater treatment effect for surgery at L4-L5 compared with L5-S1, but this was significant only for the Short Form-36 physical functioning subscale ( $p = 0.006$ ). Differences in treatment effects between the upper lumbar levels and L4-L5 were significant for Short Form-36 bodily pain only ( $p = 0.018$ ).

**Conclusions:** The advantage of operative compared with nonoperative treatment varied by herniation level, with the smallest treatment effects at L5-S1, intermediate effects at L4-L5, and the largest effects at L2-L3 and L3-L4. This difference in effect was mainly a result of less improvement in patients with upper lumbar herniations after nonoperative treatment.

**Level of Evidence:** Prognostic Level I. See Instructions to Authors for a complete description of levels of evidence.

Lumbar disc herniations are the most common cause of lumbar radiculopathy, and elective discectomy provides the most immediate relief of the symptoms<sup>1-5</sup>. The majority of lumbar herniations occur at the L4-L5 and L5-S1 intervertebral disc levels, affect the L5 and S1 roots, and result in sciatica<sup>6-9</sup>. Upper level herniations (levels L2-L3 or L3-L4)

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**TABLE 1** Baseline Characteristics by Herniation Level in the Spine Patient Outcomes Research Trial (SPORT) Intervertebral Disc Herniation Randomized Cohort and Observation Cohort Combined\*

	L2-L3 and L3-L4 (N = 88)	L4-L5 (N = 456)	L5-S1 (N = 646)	Overall P Value†
<b>Demographics and health status</b>				
Male patients	54 (61%)	275 (60%)	354 (55%)	0.14
Age‡ (yr)	50.9 ± 10.9	41.8 ± 12.1	40.4 ± 10.3	<0.001
Body mass index‡	28.4 ± 6.2	28.2 ± 5.3	27.8 ± 5.6	0.35
Height‡ (ft [m])	5.7 ± 0.3 (1.7 ± 0.09)	5.7 ± 0.3 (1.7 ± 0.09)	5.7 ± 0.3 (1.7 ± 0.09)	0.56
Patients who were smokers	20 (23%)	112 (25%)	149 (23%)	0.85
Patients who worked	40 (45%)	288 (63%)	417 (65%)	0.002
Workers' Compensation status				0.66
None	75 (85%)	371 (81%)	534 (83%)	
Receiving or pending	13 (15%)	84 (18%)	110 (17%)	
Cohort				0.093
Randomized	32 (36%)	165 (36%)	274 (42%)	
Observation	56 (64%)	291 (64%)	372 (58%)	
Duration of symptoms				0.20
≤6 wk	14 (16%)	68 (15%)	83 (13%)	
1.5 to 6 mo	55 (63%)	275 (60%)	434 (67%)	
>6 mo	19 (22%)	113 (25%)	129 (20%)	
Days to surgery‡	50.4 ± 194	84 ± 260.2	62.5 ± 161.9	0.31
SF-36 bodily pain score‡	29.3 ± 18.5	25.6 ± 19.4	25.6 ± 17.2	0.20
SF-36 physical functioning score‡	35.1 ± 22.8	38 ± 26.4	37.9 ± 25.3	0.59
Oswestry Disability Index score‡	46.8 ± 20.1	50 ± 21.8	49.5 ± 21.1	0.42
Leg symptom severity score‡	13.9 ± 5.3	15.4 ± 5.3	15.9 ± 5.2	0.003
<b>Clinical findings (no. of patients)</b>				
Pain radiation	87 (99%)	444 (97%)	629 (97%)	0.69
Straight leg-raising test—ipsilateral	22 (25%)	262 (57%)	465 (72%)	<0.001
Straight leg-raising test—contralateral or both	2 (2%)	92 (20%)	94 (15%)	<0.001
Any femoral tension sign	38 (43%)	34 (7%)	17 (3%)	<0.001
Any neurological deficit	67 (76%)	338 (74%)	496 (77%)	0.58
Asymmetric depressed reflexes	34 (39%)	95 (21%)	351 (54%)	<0.001
Asymmetric decreased sensory changes	42 (48%)	241 (53%)	320 (50%)	0.50
Asymmetric motor weakness	39 (44%)	219 (48%)	243 (38%)	0.002
Herniation type				<0.001
Protruding	15 (17%)	119 (26%)	188 (29%)	
Extruded	54 (61%)	309 (68%)	419 (65%)	
Sequestered	19 (22%)	28 (6%)	39 (6%)	
Posterolateral herniation	39 (44%)	345 (76%)	534 (83%)	<0.001

\*Includes only patients who had follow-up data available for the two-year outcomes analysis. †P values are based on chi-square tests for categorical variables and on analysis of variance for continuous variables. ‡The values are given as the mean and the standard deviation.

are less common, may affect the L2, L3, and L4 nerve roots, and may cause a femoral radiculopathy. Patients with upper lumbar disc herniations classically present with back and thigh pain, a negative straight leg-raising test, a positive femoral stretch test, a unilaterally depressed or absent patellar reflex, sensory changes in the thigh, and often quadriceps weakness<sup>7,8,10,11</sup>.

Few clinical studies have detailed the characteristics or outcomes of patients with upper level lumbar herniations<sup>7,8,10,11</sup>. The largest prior study of which we are aware was

a review by Spangfort of 2504 lumbar disc herniations that included forty-five patients with upper level herniations<sup>9</sup>. He found a greater improvement following surgery for L1-L2 and L2-L3 herniations than for L3-L4, L4-L5, and L5-S1 herniations. In a randomized trial by Osterman et al., operative outcomes were better than nonoperative treatment for patients with L4-L5 herniations but not for those with L5-S1 herniations<sup>2</sup>. Other, older retrospective studies found that the level of herniation had no significant effect on the outcomes of discectomy<sup>12-14</sup>.

TABLE II Operative Treatments, Complications, and Events

	L2-L3 and L3-L4 (N = 42)	L4-L5 (N = 299)	L5-S1 (N = 432)	P Value*
Operation time† (min)	81.7 ± 36.2	82 ± 40.2	71.4 ± 32.1	<0.001
Blood loss† (mL)	78.7 ± 76.1	72.6 ± 113.1	56 ± 90.9	0.053
Intraoperative complications‡ (no. of patients)				
Dural tear and/or spinal fluid leak	1 (2%)	12 (4%)	10 (2%)	0.40
Nerve root injury	0 (0%)	1 (0%)	0 (0%)	0.45
Vascular injury	0 (0%)	0 (0%)	1 (0%)	0.68
Other	0 (0%)	1 (0%)	2 (0%)	0.89
None	40 (98%)	285 (96%)	419 (97%)	0.58
Postoperative complications or events§ (no. of patients)				
Nerve root injury	0 (0%)	0 (0%)	1 (0%)	0.68
Wound hematoma	1 (2%)	2 (1%)	1 (0%)	0.15
Superficial wound infection	1 (2%)	3 (1%)	9 (2%)	0.51
Deep wound infection	0 (0%)	2 (1%)	3 (1%)	0.87
Other	3 (7%)	7 (2%)	17 (4%)	0.21
None	37 (90%)	282 (96%)	401 (93%)	0.23

\*The p value is for the comparison across all three groups with use of analysis of variance for continuous variables and chi-square tests for categorical variables. †The values are given as the mean and the standard deviation. ‡Data were not available for one patient with upper level herniation and for three patients with L4-L5 herniation. No instances of aspiration or operation at the wrong level were reported. §Any reported complications up to eight weeks postoperatively. No instances of blood transfusion, cerebrospinal fluid leak, paralysis, cauda equina injury, or wound dehiscence were reported.

The Spine Patient Outcomes Research Trial (SPORT) provides a unique opportunity to analyze the effect of lumbar disc herniation level on clinical outcomes. The purposes of this study were to describe the characteristics of patients with lumbar disc herniations at different levels and to evaluate the association between disc herniation level and treatment outcomes.

### Materials and Methods

SPORT was conducted at thirteen multidisciplinary spine practices in eleven states across the United States. The human subject committees at each center approved the standardized protocol. Patients considered for inclusion in the study were over eighteen years old, had radicular pain for at least six weeks with a positive nerve root tension sign and/or neurological deficit, and had a confirmatory cross-sectional imaging study demonstrating intervertebral disc herniation at a level and side corresponding to their symptoms. Exclusion criteria included cauda equina syndrome, a progressive neurological deficit, malignancy, scoliosis of  $>15^\circ$ , herniation cephalad to L2, prior back surgery, and other established contraindications to elective surgery.

Patients were offered participation in either a randomized or a concurrent observational cohort. Participants in the randomized cohort received computer-generated random treatment assignments blocked by center; those in the observational cohort chose their treatment with their physician. Additional details regarding the methods of randomization are available in the original articles<sup>4,5</sup>. Because of extensive cross-

over in the randomized cohort (that is, some patients randomized to nonoperative care received operative care and vice versa) and similar baseline characteristics and outcomes between randomized and observational patients when analyzed by treatment, the two groups were combined in this “as-treated” analysis.

The treating physician at each participating institution reviewed the imaging studies and classified the herniation by level, morphology, and location. The herniation location was classified as central, posterolateral, foraminal, or far lateral as defined by Fardon and Milette<sup>15</sup>. The herniation morphology was classified as protrusion, extrusion, or sequestered fragment<sup>15</sup>.

To maintain adequately sized groups for analysis, level L2-L3 and L3-L4 herniations were grouped as upper disc levels and level L4-L5 and L5-S1 herniations were each analyzed individually. After stratification by herniation level, patients were analyzed by the actual treatment received, either nonoperative therapy or operative discectomy. In these as-treated analyses, the treatment indicator was a time-varying covariate, allowing for variable times of surgery. Prior to the time of surgery, all changes from baseline were included in the estimates of the nonoperative treatment effect. Following surgery, subsequent changes in outcomes were assigned to the operative group with follow-up measured from the date of surgery. Treatment effects (defined as the change in the operative group minus the change in the nonoperative group) were evaluated by level, adjusting for important covariates (age, sex, race, marital status, work status, disability compensation status, body mass index, smoking status, joint problems, migraine

**TABLE III Adjusted Change Scores and Treatment Effects for the Intervertebral Disc Herniation Randomized and Observational Cohorts According to Treatment Received and Herniation Level\***

Group According to Herniation Level	Baseline			3-Mo Evaluation		
	Op. Treatment	Nonop. Treatment	Overall	Op. Treatment	Nonop. Treatment	Treatment Effect† (95% Confidence Interval)
<b>L2-L3 and L3-L4</b>						
No. of patients	41	53		35	45	
SF-36 bodily pain†	27.8 (2.7)	30.1 (2.6)	29.1 (1.9)	39.8 (4)	20.5 (3.5)	19.3 (8.1, 30.4)
SF-36 physical functioning†	33.4 (3.4)	36.3 (3.2)	35.0 (2.3)	38.2 (4.1)	20.6 (3.6)	17.6 (6.4, 28.9)
Oswestry Disability Index†	51.0 (3.0)	43.5 (2.8)	46.8 (2.1)	-31.9 (3.1)	-18.3 (2.8)	-13.6 (-22.1, -5.1)
<b>L4-L5</b>						
No. of patients	300	225		272	165	
SF-36 bodily pain†	21.9 (1)	32.4 (1.3)	26.4 (0.9)	43.7 (1.4)	25.6 (1.7)	18.1 (13.9, 22.3)
SF-36 physical functioning†	31.2 (1.4)	46.6 (1.7)	37.8 (1.1)	45.1 (1.3)	25.5 (1.6)	19.6 (15.7, 23.6)
Oswestry Disability Index†	57.0 (1.2)	40.6 (1.4)	50.0 (1)	-38.3 (1.1)	-23.4 (1.4)	-14.9 (-18.1, -11.6)
<b>L5-S1</b>						
No. of patients	434	334		393	222	
SF-36 bodily pain†	23.1 (0.8)	30 (1.0)	26.1 (0.6)	39.7 (1.2)	23.4 (1.5)	16.4 (12.8, 20)
SF-36 physical functioning†	31.9 (1.1)	45.6 (1.4)	37.9 (0.9)	38.3 (1.1)	21.5 (1.4)	16.8 (13.4, 20.2)
Oswestry Disability Index†	55.3 (0.9)	41.9 (1.1)	49.5 (0.8)	-34.9 (0.9)	-18.1 (1.2)	-16.8 (-19.6, -14)

\*Adjusted for age, gender, race, marital status, work status, disability compensation status, body mass index, smoking, joint problems, migraine headaches, any neurological deficit, herniation (type and location), baseline score, baseline leg-symptom severity, baseline satisfaction with symptoms, self-rated health trend, center, and insurance. †Treatment effect is defined as the change in the operative group minus the change in the nonoperative group. A moving baseline was used, with the clock reset at the time of surgery for any patient having surgery. ‡The operative and nonoperative values are given as the mean score with the standard error of the mean in parentheses. Each scale ranged from 0 to 100. SF-36 = Short Form-36.

headaches, any neurological deficit, baseline scores, baseline leg-symptom severity, baseline satisfaction with symptoms, self-rated health trend, study center, insurance status, herniation type, and herniation location) with use of longitudinal regression models. The longitudinal regression model used was a mixed effects model with a random effect for individual intercepts. This type of regression model accounts for the fact that measurements are made within a given individual over time and therefore these measurements may contain some internal correlation with each other. Missing data due to item nonresponse were rare because of the methods used for electronic data entry. Missed visits occurred, as seen in Figure 1, and resulted in the omission of the associated data from the analysis. This method appears to be optimal if the missing data depend only on parameters included in the longitudinal regression model<sup>16</sup>.

The main outcome measures were the Short Form-36 (SF-36)<sup>17</sup> bodily pain and physical functioning scales and the American Academy of Orthopaedic Surgeons MODEMS (Musculoskeletal Outcomes Data Evaluation and Management System) version of the Oswestry Disability Index<sup>18</sup>. The patients were evaluated at six weeks, three months, six months, one year, and two years. To determine whether the treatment effect of surgery varied with herniation level at the two-year time point, pairwise z-tests were performed to compare the estimated treatment effects between each level group.

Statistical modeling was performed with use of SAS software (version 9.1; SAS Institute, Cary, North Carolina), with the procedures PROC MIXED, and S-PLUS software (version 6.2; Insightful, Seattle, Washington) was used for all other calculations. Significance was defined as a p value of 0.05 on the basis of a two-sided hypothesis test.

## Results

There were 646 L5-S1 herniations, 456 L4-L5 herniations, sixty-eight L3-L4 herniations, and twenty L2-L3 herniations evaluated (Fig. 1). Fifty-four patients were excluded because no follow-up data were available. From 81% to 93% of the subjects in each subgroup provided data at the two-year visit.

### Patient Characteristics

The baseline characteristics of all of the participants are displayed in Table I, according to the level of herniation. The majority of the study population (57%) was male and had a similar baseline health status (according to the bodily pain and physical functioning scales of the SF-36 and the Oswestry Disability Index) for each group. The level of herniation varied directly with age, as patients with upper level herniations were significantly older ( $p < 0.001$ ), the L4-L5 group was of an intermediate age, and the L5-S1 group was the youngest. Consistent with the inclusion criterion, virtually all patients had radiating leg pain consistent with a radiculopathy. The

TABLE III (continued)

1-Yr Evaluation			2-Yr Evaluation		
Op. Treatment	Nonop. Treatment	Treatment Effect† (95% Confidence Interval)	Op. Treatment	Nonop. Treatment	Treatment Effect† (95% Confidence Interval)
36	45		37	42	
48.8 (4.2)	24.3 (3.5)	24.5 (13, 36)	49 (4.0)	24.4 (3.6)	24.6 (13.2, 36)
45.7 (4.2)	21.7 (3.6)	24 (12.4, 35.7)	48 (4.1)	24.6 (3.6)	23.4 (11.9, 34.9)
-36.3 (3.2)	-16.6 (2.8)	-19.7 (-28.6, -10.8)	-38.3 (3.1)	-19.3 (2.8)	-19 (-27.7, -10.2)
254	138		254	129	
44.9 (1.4)	31.4 (1.8)	13.6 (9.1, 18)	43.1 (1.4)	31.6 (1.9)	11.6 (7, 16.1)
46.2 (1.3)	28.8 (1.7)	17.4 (13.2, 21.6)	45.7 (1.3)	28.6 (1.8)	17.1 (12.8, 21.4)
-39.6 (1.1)	-25 (1.5)	-14.6 (-18.1, -11.1)	-38.5 (1.1)	-24.7 (1.5)	-13.8 (-17.3, -10.3)
361	191		355	171	
42 (1.2)	31.5 (1.6)	10.6 (6.7, 14.4)	41.7 (1.2)	34.6 (1.7)	7.1 (3.1, 11.1)
43.7 (1.1)	29.2 (1.5)	14.5 (10.9, 18.1)	42.4 (1.1)	32.5 (1.6)	9.9 (6.2, 13.6)
-36.5 (0.9)	-23.2 (1.3)	-13.4 (-16.4, -10.4)	-36.2 (0.9)	-26 (1.3)	-10.3 (-13.4, -7.2)

mean leg-symptom severity score was lower at baseline for the patients with upper level herniations (13.9) than for those with L4-L5 herniations (15.4) and L5-S1 herniations (15.9). Smoking status, the duration of symptoms prior to enrollment, the time from enrollment to surgery, and participation in the randomized cohort were similar across the subgroups.

Seventy-two percent (465) of 646 patients with L5-S1 herniations and 57% (262) of 456 with L4-L5 herniations had a positive ipsilateral straight leg-raising test, while 43% (thirty-eight) of eighty-eight patients with upper level herniations had a positive femoral stretch test. The patients with upper level herniations and L4-L5 herniations were less likely to have asymmetric reflexes, while those with L5-S1 herniations were less likely to have motor weakness. Upper level herniations were more likely to be foraminal (24% of upper level herniations, 3% of L4-L5 herniations, 2% of L5-S1 herniations;  $p < 0.001$ ) and far lateral (25% of upper level herniations, 7% of L4-L5 herniations, and 6% of L5-S1 herniations;  $p < 0.001$ ), rather than posterolateral herniations (44% of upper level herniations, 76% of L4-L5 herniations, and 83% of L5-S1 herniations;  $p < 0.001$ ). The upper level herniation group was more likely to have a sequestered fragment.

#### Nonoperative Treatments

Nonoperative treatments used for 546 patients (415 managed nonoperatively and 131 surgical patients with data on nonoperative care at follow-up visits prior to a second operation) included education and counseling (92%; 505 patients), nonsteroidal anti-inflammatory drugs (59%; 323 patients), epidural injections (48%; 264 patients), physical therapy (43%; 237 patients), and narcotic pain medication (41%; 224 patients)<sup>4,5</sup>.

#### Operative Treatments and Complications

The mean operative time was less for the treatment of L5-S1 herniations (71.4 minutes) than for L4-L5 (82.0 minutes) and upper level herniations (81.7 minutes) ( $p < 0.001$ ). Surgical complications varied slightly between groups and are shown in Table II, but no differences were significant on the basis of the numbers. Blood loss was slightly larger in operations on upper level herniations than in operations on the lower levels. The L4-L5 group had the greatest number of durotomies (4%) among the three groups.

#### Main Treatment Effects

The main treatment outcomes analyzed with use of the adjusted change scores and treatment effects (improvement in operative group minus improvement in nonoperative group), according to the treatment received for each herniation group, are shown in Table III. At all levels, the group treated operatively had greater improvement than the group treated nonoperatively at the three-month evaluation and it persisted at the two-year evaluation. While the treatment effects at three months were similar across all levels, the groups diverged at later time points. At two years, the mean treatment effects (and 95% confidence intervals) at upper lumbar levels were significantly better than at the L5-S1 level for all outcome measures (Table IV). The treatment effect was somewhat greater for the L4-L5 herniations than for L5-S1 herniations, which was significant for physical functioning ( $p = 0.006$ ) and borderline significant for bodily pain ( $p = 0.073$ ) and Oswestry Disability Index ( $p = 0.073$ ) (Figs. 2 and 3). Treatment effects for the upper lumbar levels were greater than at L4-L5 for all measures, but were significant only for bodily pain ( $p = 0.018$ ). The differences in treatment effect appeared to result from

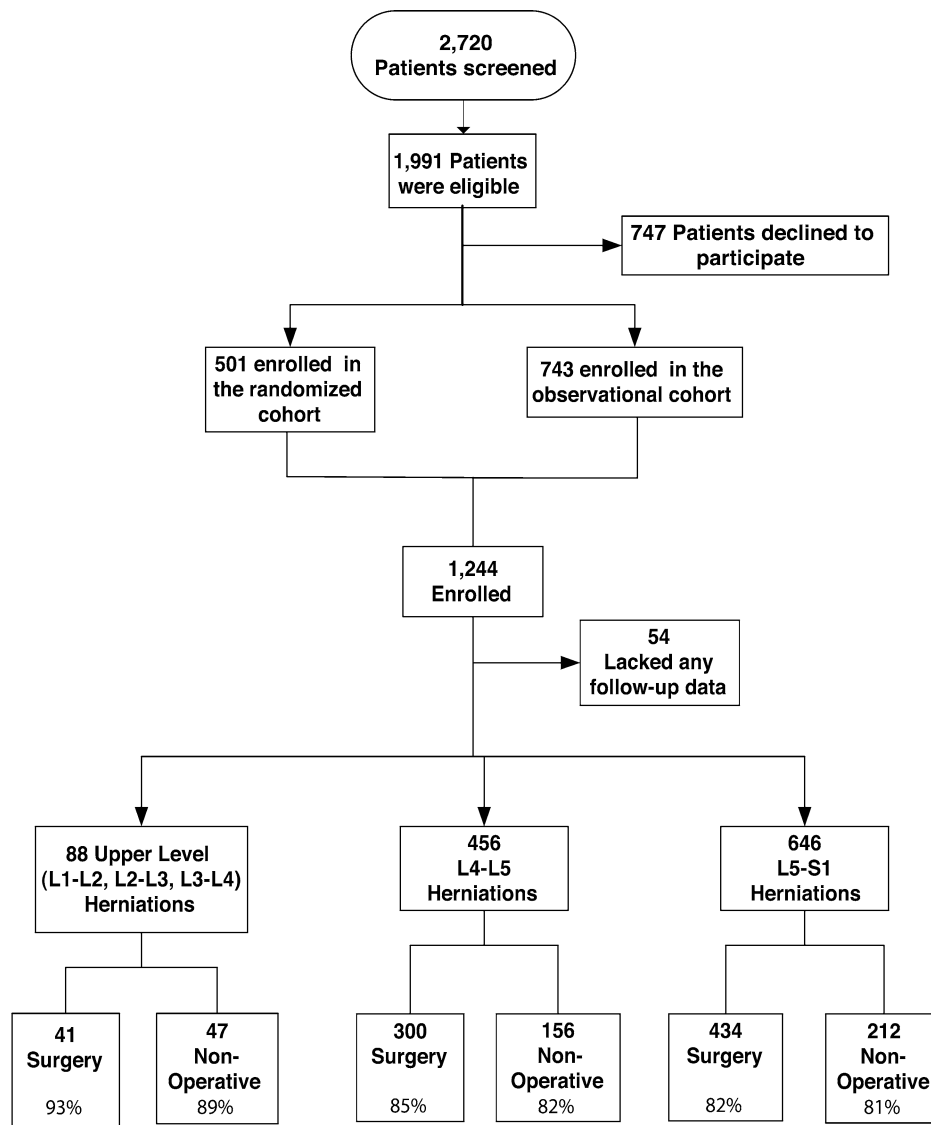


Fig. 1

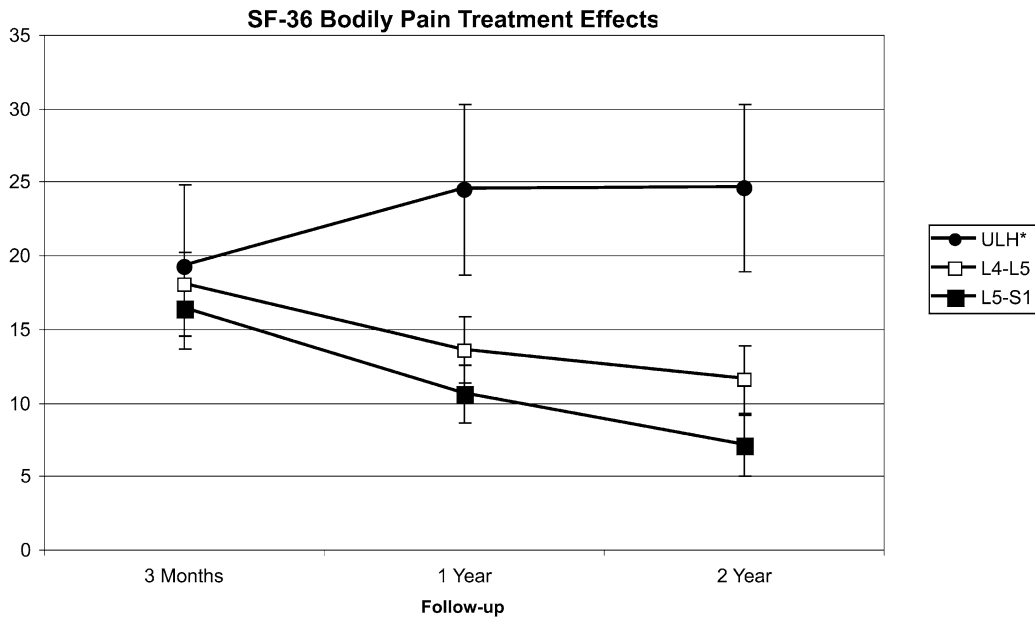
Spine Patient Outcomes Research Trial (SPORT) intervertebral disc herniation enrollment and randomization. This flow diagram describes the group enrollment. The percentages in the final row of boxes are the percentage of patients seen at the time of the two-year follow-up by the treatment received within two years of enrollment.

greater improvement with nonoperative treatment for the lower level herniations, as well as a slightly better operative outcome for the upper level herniations.

### Discussion

Our data showed that, following lumbar discectomy, patients had a greater difference in improvement between operative and nonoperative treatment for upper level herniations (L2-L3 and L3-L4) than for herniations at the L4-L5 and L5-S1 levels. Patients with the upper level herniations had less improvement with nonoperative treatment and slightly better operative outcomes than those with lower level herniations. The magnitude of the difference between the upper level

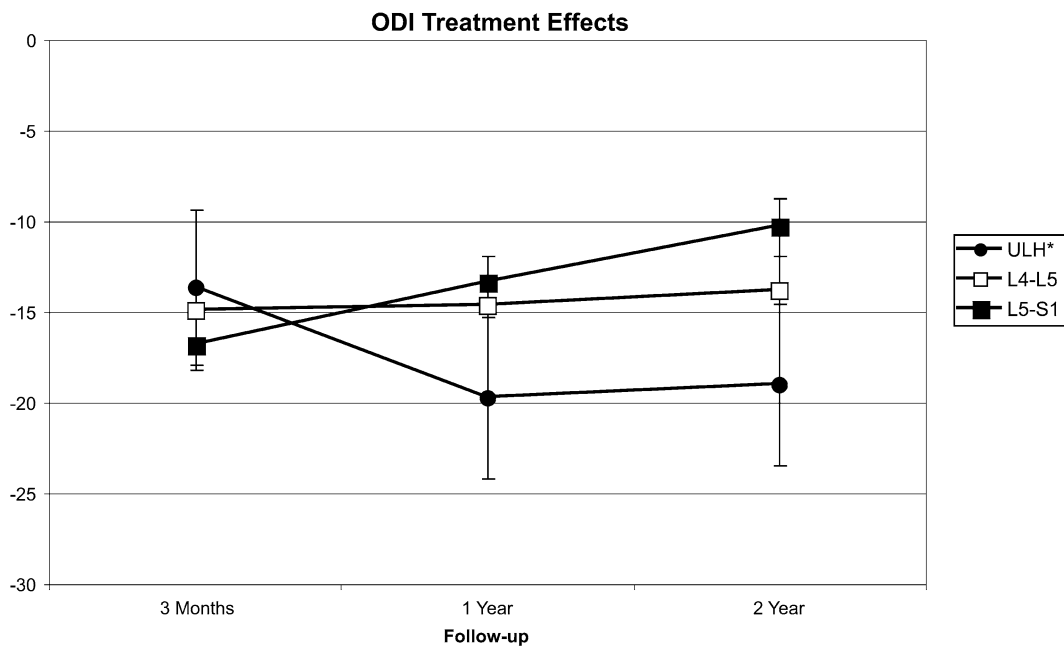
herniations and herniations at L5-S1 was in the range of 10 to 15 points on the SF-36 bodily pain and physical functioning scales and the Oswestry Disability Index. This is in the range that is generally considered to be clinically important and the size of effect that the overall SPORT was powered to detect<sup>5</sup>. Some of these comparisons were significant; however, the size of the group with upper level herniations was modest, limiting the statistical power. Furthermore, the effect was highly consistent with a monotonic (dose-response-like) relationship between level and outcome (upper level herniation results were greater than the L4-L5 results, which were greater than the L5-S1 results), which was consistent at both one and two years and was similar across all three primary dimensions of outcome,



\*Upper Level Herniation

Fig. 2

The Short Form-36 (SF-36) bodily pain treatment effects. The data points represent the differences in the change of bodily pain scores between the operative and nonoperative groups at each follow-up time period (that is, the improvement in the operative group minus the improvement in the nonoperative group). The vertical bars represent the 95% confidence intervals.



\*Upper Level Herniation

Fig. 3

Oswestry Disability Index (ODI) treatment effects. The data points represent the differences in the change of ODI scores between the operative and nonoperative groups at each follow-up time period (that is, the improvement in the operative group minus the improvement in the nonoperative group). The vertical bars represent the 95% confidence intervals.

TABLE IV Two-Year Treatment Effects by Disc Herniation Level\*

	Treatment Effect			Comparison of Herniation Levels ( <i>p</i> value)		
	Upper Level Herniation (N = 88)	L4-L5 (N = 455)	L5-S1 (N = 643)	Upper Levels and L4-L5	Upper Levels and L5-S1	L4-L5 and L5-S1
SF-36 bodily pain score	24.6 (13.2, 36)	11.6 (7, 16.1)	7.1 (3.1, 11.1)	0.018	0.002	0.073
SF-36 physical functioning score	23.4 (11.9, 34.9)	17.1 (12.8, 21.4)	9.9 (6.2, 13.6)	0.16	0.014	0.006
Oswestry Disability Index	-19 (-27.7, -10.2)	-13.8 (-17.3, -10.3)	-10.3 (-13.4, -7.2)	0.14	0.033	0.073

\*Treatment effect is defined as the change in the operative group minus the change in the nonoperative group. As-treated randomized and observational cohorts combined, adjusted for age, gender, race, marital status, work status, disability compensation status, body mass index, smoking, joint problems, migraines, any neurological deficit, herniation (type and location), baseline score, baseline leg-symptom severity, baseline satisfaction with symptoms, self-rated health trend, center, and insurance. Upper level herniations are at L2-L3 and L3-L4. SF-36 = Short Form-36.

i.e., pain, function, and disability. This consistent pattern lends strength to the inference that herniation level has a significant effect on outcome.

Similar to the results reported by Osterman et al., surgery for herniations affecting the L4-L5 disc had a greater treatment effect than did surgery for L5-S1 lesions<sup>2</sup>. However, our results showed a significant treatment effect for surgery at L5-S1 ( $p < 0.001$ ), a finding not evident in the report by Osterman et al. This may be related to the substantially larger sample size in the current study. Our results are consistent with the conclusion by Spangfort that the upper level herniations have better relief of radicular symptoms than do the lower levels<sup>9</sup>.

There are several possible explanations for these findings. A number of studies have shown that reduced spinal canal cross-sectional area is associated with an increased probability of symptomatic disc herniation and greater intensity of herniation symptoms<sup>19</sup>. The spinal cross-sectional area is the smallest at the most cranial lumbar segment and increases caudally<sup>19</sup>. The smaller canal area at upper levels may contribute to the observed outcomes differences, but further analysis comparing outcomes to cross-sectional area is required.

The location of the disc herniation (foraminal compared with posterolateral compared with central) may also contribute to these differences. In this study, upper lumbar herniations were more likely to occur in the far lateral and foraminal positions than were those at the lower two intervertebral levels. This finding is similar to the observation by Tamir et al., in a study of eighty-nine patients, which suggested upper level herniations are less likely to be posterolateral and are more commonly in the far lateral or foraminal positions<sup>11</sup>. It is possible that an increased number of far lateral herniations partially contributed to the difference in outcomes, although again this was controlled for in the analysis.

A prior retrospective cohort study of sixty-nine upper lumbar herniations by Sanderson et al. found that they had worse surgical outcomes than lower level herniations<sup>20</sup>. How-

ever, methodological limitations in that study may account for the different outcomes observed. Those authors included a high proportion of reoperations and arthrodeses at the higher levels, which likely contributed to their poorer surgical outcomes. Furthermore, they had no control group, and we found that worse nonoperative outcome among those with an upper lumbar herniation was a major contributor to the improved treatment effect.

There are a number of limitations to our study. The level of disc herniation was based on the clinician report after evaluation of the magnetic resonance imaging studies. Transitional vertebrae of the lumbar spine are identified in 5% to 20% of lumbar radiographs<sup>6,21-23</sup>. Since imaging occasionally did not include the first non-rib-bearing vertebrae, it is possible that some levels were categorized incorrectly. Far lateral herniations may have contributed to misclassifications, as extraforaminal connections are sometimes found between the L3, L4, and L5 nerve roots, which may cause a mixed presentation of neurological signs and symptoms. Perhaps more importantly, like any subgroup analysis, the study was not powered to assess differences between groups, and the upper lumbar herniation group was relatively small. The results of these subgroup comparisons may also be confounded by unmeasured differences between the groups.

Overall, analysis of the SPORT disc herniation cohort showed that, in as-treated analyses, both the patients managed operatively and those managed nonoperatively had considerable improvement over two years, but that the discectomy group reported better outcomes. In this subgroup analysis, these results seem to hold regardless of herniation level; however, the relative advantage for surgery was greater for patients with herniations at higher lumbar levels, with nonoperative treatment being less effective in these patients compared with those with herniations at L4-L5 and L5-S1. ■

NOTE: This study is dedicated to the memory of Brianna Weinstein.

J.D. Lurie, MD, MS  
S.C. Faucett, MD, MS  
B. Hanscom, MS  
T.D. Tosteson, ScD  
P.A. Ball, MD  
W.A. Abdu, MD, MS  
J.W. Frymoyer, MD

J.N. Weinstein, DO, MSc  
Multidisciplinary Clinical Research Center (J.D.L., B.H., T.D.T., P.A.B., W.A.A., J.W.F., and J.N.W.), Department of Medicine, Dartmouth Medical School (J.D.L.), and the Dartmouth Institute for Health Policy and Clinical Practice (J.N.W.), Dartmouth-Hitchcock Medical Center (S.C.F.), One Medical Center Drive, Lebanon, NH 03756. E-mail address for J.D. Lurie: jon.d.lurie@dartmouth.edu

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