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Pain Recurrence after Discectomy for Symptomatic Lumbar Disc Herniation

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Abstract

Study Design—Secondary analysis of data from a concurrent randomized trial and cohort study.

Objective—To determine risks and predictors of recurrent pain following standard open discectomy for subacute/chronic symptomatic lumbar disc herniation (SLDH).

Summary of Background Data—Most prior studies of recurrence after discectomy do not explicitly define pain resolution and recurrence, and do not account for variable durations of time at-risk for recurrence.

Methods—We used survival analysis methods to examine predictors of leg pain recurrence. For individuals with initial resolution of leg pain, we defined recurrent leg pain as having leg pain, receiving lumbar epidural steroid injections, or undergoing lumbar surgery subsequent to initial leg pain resolution. We calculated cumulative risks of leg pain recurrence using Kaplan-Meier survival curves, and examined predictors of recurrence using Cox proportional hazards models. We used similar methods to examine LBP recurrence.

Results—1- and 3-year cumulative risks of leg pain recurrence were 20% and 45%, respectively. 1- and 3- year leg pain recurrence risks were substantially lower in participants with complete initial resolution of leg pain (17% and 41%, respectively) than in those without (27% and 54%, respectively). In multivariate analyses, complete leg pain resolution (adjusted hazard ratio [aHR]

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0.69 [95% CI 0.52-0.90]), smoking (aHR 1.68 [95% CI 1.22-2.33]), and depression (aHR 1.74 [95% CI 1.18-2.56]) predicted leg pain recurrence. The 1- and 3-year risk of LBP recurrence was 29% and 65%, respectively. LBP recurrence risk at 3 years was substantially lower in participants with complete initial resolution of LBP than in those without, but not at 1 year.

Conclusions—Recurrence of leg pain and LBP is common after discectomy for SLDH. Cumulative risks of both leg pain and LBP recurrence were generally lower in participants achieving complete initial resolution of pain post-discectomy.

Keywords

discectomy; decompression; surgery; operative; herniation; sciatica; radiculopathy; intervertebral disk displacement; outcomes; lumbar; reherniation; relapse; recovery

Introduction

Lumbar discectomy is commonly performed for lumbosacral radicular syndrome due to symptomatic lumbar disc herniation (SLDH). Although most patients improve with surgical treatment, subsequent recurrence of radicular pain and/or low back pain (LBP) is not unusual. Recurrent pain after lumbar discectomy may be due to a variety of causes, including recurrent disc herniation involving the operated level, a new disc herniation at other spinal levels, epidural fibrosis or scarring, or other anatomical changes involving the spinal canal aside from the intervertebral disc¹.

There are several limitations to currently available data that can be used to counsel post-discectomy patients who experience pain resolution regarding their risk of future leg pain or LBP recurrence. First, most prior studies of 'recurrence' after discectomy actually report on *prevalent* pain, without separating individuals with persistent symptoms from those who experienced initial resolution of pain^{2,3}. Estimates of pain prevalence from such studies do not actually reflect pain recurrence, since they also include individuals whose pain never resolved, and were therefore never eligible to have a recurrence of pain⁴. Second, most studies of post-discectomy recurrence do not account for different durations of time prior to or following pain resolution (or other recovery criteria used), in calculations of recurrence rates⁵. The importance of this is illustrated by considering two hypothetical patients followed for 2 years post-discectomy, where patient #1 had resolution of leg pain at 1 month post-discectomy followed by recurrence at 5 months (4 months at-risk for recurrence), and patient #2 recovered from leg pain and LBP by 6 months without subsequent recurrence (at-risk for 18 months). These two patients have been at-risk for recurrence for very different periods of time. Third, and perhaps most important, is the fact that many studies of recurrence after discectomy examine *symptomatic recurrent lumbar disc herniation*, and not recurrent pain. Symptomatic recurrent lumbar disc herniation is a complex outcome requiring the convergence of multiple factors such as the persistence or recurrence of pain or neurological deficits post-discectomy, symptom severity sufficient to warrant a return visit to the treating surgeon, and new imaging findings confirming reherniation at the operated spinal level (but not at another spinal level). The risk of symptomatic recurrent lumbar disc herniation will always be substantially lower than the risk of pain recurrence, since the former is essentially a specific case of the latter. However, pain recurrence after discectomy,

irrespective of the putative cause, may be a more relevant outcome from the patient's perspective.

We conducted a secondary analysis of data from the Spine Patient Outcomes Research Trial (SPORT) to examine pain recurrence after standard open discectomy for SLDH. We used clear definitions of pain resolution and recurrence defined by patient-reported outcomes and procedures or surgeries indicating recurrence had occurred. In addition, we used survival analysis methods to account for variable lengths of time prior to pain resolution and subsequent recurrence, as has been advocated previously for studies of recurrence after SLDH⁵. The objectives of this study were to identify 1) cumulative risks of recurrent leg pain and LBP over 3-year follow-up, and 2) predictors of leg pain and LBP recurrence, following discectomy for SLDH.

Methods

Study Design

SPORT was a randomized trial with a concurrent observational cohort study conducted at 13 multidisciplinary spine practices throughout the United States. Study procedures were approved by institutional review boards at each study site. Participants were adults >18 years of age presenting with radicular pain of duration ≥ 6 weeks, positive nerve root tension signs and/or neurologic deficits, and lumbar MRI/CT imaging demonstrating a disc herniation corresponding with their clinical presentation. Further details regarding recruitment, data collection, and inclusion/exclusion criteria have been reported previously⁶⁻⁹. Participants were offered participation in a randomized trial (where operative vs. non-operative care was randomly allocated), or in an observational cohort study (where operative vs. non-operative care was chosen by the participant). Operative care involved standard open discectomy with examination of the involved nerve root. Due to high rates of crossover from assigned treatments, this analysis included all participants who underwent discectomy either as part of the randomized trial or the cohort study.

Definitions of Resolution and Recurrence

Patient-reported outcomes were evaluated at baseline and 3 months, 1 year, 2 years, 3 years, and 4 years post-discectomy. Leg pain bothersomeness was assessed using the leg pain item from the Sciatica Bothersomeness Index (SBI), a valid and commonly used scale of sciatica-related symptom bothersomeness¹⁰. This scale rates leg pain bothersomeness on a 7-point scale ranging from 0 to 6, with lower scores indicating less severe leg pain. Participants were classified as having 'leg pain resolution' if they reported radiating dermatomal pain with a leg pain bothersomeness ≥ 2 prior to discectomy, and a leg pain bothersome score <2 following discectomy. Participants with post-discectomy leg pain resolution were followed prospectively from the time of leg pain resolution until subsequent 'leg pain recurrence', defined as a leg pain bothersomeness score ≥ 2 , or receiving lumbar spine surgery or an epidural steroid injection (ESI), at any time up to 4 years post-discectomy.

Post-discectomy LBP resolution and recurrence were defined using similar methods. LBP bothersomeness was rated using a 7-point scale with scores ranging from 0 to 6, with lower

scores indicating less severe LBP¹¹. We identified the subgroup of participants with a LBP bothersomeness score of ≥ 2 prior to discectomy who went on to have post-discectomy 'LBP resolution', defined as a LBP bothersomeness score <2 . Receiving an ESI or lumbar spine surgery was not considered a LBP recurrence outcome, since these procedures are typically offered for the treatment of radicular leg pain, and not for LBP. These participants were then followed prospectively from the time of LBP resolution for subsequent 'LBP recurrence', a LBP bothersomeness score ≥ 2 , up to 4 years post-discectomy. It is important to note that the subgroups of participants with leg pain resolution and LBP pain resolution were not mutually exclusive, in that participants could have both leg pain resolution and LBP resolution.

Potential Predictors of Recurrence

We examined selected variables as potential predictors of recurrence based on conceptual importance or their prognostic value in earlier studies¹²⁻¹⁷. Our primary predictor of interest was 'complete pain resolution' ('0' pain bothersomeness at the time of initial pain resolution) vs. 'near-complete pain resolution' (a '1&' pain bothersomeness rating at initial pain resolution), based on prior work demonstrating this as an important predictor of pain recurrence in SLDH SPORT participants managed nonoperatively¹¹. Other potential predictors of recurrence included participant age, gender, race, educational attainment, marital status, body mass index (kg/m²), smoking, depression, joint problems, other medical comorbidities, expectations of being pain-free after discectomy, current employment, lifting demands at work, disability compensation, baseline leg pain and LBP bothersomeness, and early (≤ 3 months) vs. late (> 3 months) post-discectomy pain resolution^{11,18}. Potential imaging-based predictors of recurrence included herniation location, morphology, and level as assessed on baseline lumbar MRI/CT scans¹¹. Operative characteristics examined as potential predictors of recurrence included operation time (minutes), blood loss (milliliters), length of hospital stay, and intraoperative dural tear/spinal fluid leak. Most operative characteristics were not examined as potential predictors of recurrence due to low event frequencies (e.g. most individual intraoperative or postoperative complications), strong intercorrelations with other variables, or being part of the recurrence definition (e.g. indications for additional surgical procedures).

Statistical Analysis

Among participants with post-discectomy pain resolution, we compared those with initial resolution of leg pain only, those with initial resolution of LBP only, and those with initial resolution of both leg pain and LBP, using the chi-square test for categorical variables and analysis of variance (ANOVA) for continuous variables. For participants with initial resolution of leg pain, we plotted Kaplan-Meier (KM) survival curves for leg pain recurrence. Participants were censored at the first occasion of missing leg pain bothersomeness outcome data, at study withdrawal, or at the 4-year follow-up. We calculated cumulative recurrence risks at 1-, 2- and 3-years, and the recurrence incidence density. We tested potential predictor variables for the assumption of proportional hazards using cumulative sums of Martingale residuals and visual inspection of KM survival curves. We used bivariate Cox proportional hazards regression models to examine associations between potential predictors of recurrence and recurrent leg pain. We then examined

associations between potential predictors of recurrence (excluding operative characteristics) and recurrent leg pain using multivariate Cox proportional hazards regression with a stepwise variable selection procedure (entry $p < 0.10$, removal $p < 0.10$). Age, gender, and complete initial leg pain resolution were forced into the multivariate models if they met assumptions for proportional hazards, and other variables were tested based on significance. We calculated adjusted hazard ratios (aHR) and 95% confidence intervals (CI) for the association of each predictor variable with leg pain recurrence, with CIs excluding unity reflecting statistical significance at $p < 0.05$. Operative characteristics were allowed into the multivariate proportional hazards regression models in a subsequent step, so that the initial multivariable models would be comparable with those from our earlier analysis of nonoperative SPORT SLDH participants¹¹. We calculated optimism-corrected Harrell's c -statistics with bootstrapping for each multivariate model¹⁹. This analytic process was repeated for LBP recurrence. Analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC).

Results

Among 1244 participants from the observational cohort ($n=743$) and randomized trial ($n=501$), 805 patients received surgery during the first 4 years, of which 788 had at least 1 follow-up visit and were included in this analysis. 589 participants had initial resolution of leg pain or LBP post-discectomy, including 558 (71%) with resolution of leg pain, and 413 (52%) with resolution of LBP (Table 1). There were 3 mutually exclusive subgroups within the 589 participants with pain resolution: 176 participants with leg pain resolution only, 31 participants with LBP resolution only, and 382 participants with concurrent leg and LBP resolution. Participants with leg pain resolution, LBP resolution, and concurrent leg and LBP resolution were largely similar, except for differences in baseline leg pain and LBP bothersomeness, and operation time in minutes (Table S1, Supplement Digital Content).

KM survival curves for leg pain recurrence and LBP recurrence are presented in Figures 1 and 2. Recurrence events clustered between months 9 and 12 of each year due to the timing of the scheduled study follow-ups in relation to the time of initial pain resolution (which most commonly occurred at the 3-month or 1-year follow-up). The cumulative risk of leg pain recurrence was 20% (95% CI: 17-24) at 1 year and 45% (95% CI: 41-50) at 3 years (Table 2). The cumulative risk of LBP recurrence was 29% (95% CI: 25-34) at 1 year and 65% (95% CI: 60-71) at 3 years. All estimates of cumulative recurrence risks were substantially lower in participants with complete pain resolution, as compared to those with near-complete pain resolution, except for 1-year risk of LBP recurrence.

Complete initial leg pain resolution predicted a lower risk of leg pain recurrence, and current smoking, depression, and joint problems predicted a greater risk of leg pain recurrence, in bivariate analyses (Table 3). In the multivariate analysis, complete leg pain resolution (aHR 0.69 [95% CI 0.52-0.90]) predicted a lower risk of recurrence, and depression (aHR 1.74 [95% CI 1.18-2.56]) and smoking (aHR 1.68 [95% CI 1.22-2.33]) predicted a greater risk of recurrence (Table 3). The final multivariate model had an optimism-corrected Harrell's c -statistic of 0.79, indicating acceptable model discrimination. Figure 3 depicts the KM

survival curve for leg pain recurrence, stratified by complete vs. near-complete initial pain resolution.

In examining predictors of LBP recurrence, complete initial LBP resolution failed testing of the proportional hazards assumption, and was therefore not included in the proportional hazards models. The KM survival curve showed similar risks of recurrence with complete vs. near complete initial LBP resolution before 12 months, but a greater risk of recurrence with near-complete LBP resolution thereafter (Figure 4). Current full- or part-time employment predicted a lower risk of LBP recurrence, and joint problems predicted a greater risk of LBP recurrence, in bivariate analyses (Table 4). In the multivariate analysis, greater age (aHR per year 0.98 [95% CI 0.97-0.99]), and current employment (aHR 0.67 [95% CI 0.49-0.90]) predicted a lower risk of recurrence, and being divorced or widowed (aHR 1.84 [95% CI 1.01-3.34]) and joint problems (aHR 1.95 [95% CI 1.36-2.80]) predicted a greater risk of recurrence (Table 4). The final multivariate model had an optimism-corrected Harrell's *c*-statistic of 0.86, indicating excellent model discrimination.

Among operative characteristics examined in separate multivariate analyses, none were significant predictors of leg pain recurrence. Blood loss, however, was a significant negative predictor of LBP recurrence (aHR 0.98 per 10ml greater blood loss [95% CI 0.96-1.00]) (other data not shown).

Discussion

This study found a cumulative risk of recurrent leg pain following discectomy for SLDH of 20% at 1 year and 45% at 3 years. The risk of recurrent LBP was 29% at 1 year and 65% at 3 years. Cumulative risks of leg pain and LBP recurrence were generally lower in participants with complete initial post-discectomy resolution of pain, compared to those without, with the exception of LBP recurrence at 1-year.

Although many prior studies have examined prevalent pain after discectomy for SLDH, to our knowledge this is the first study examining post-discectomy pain recurrence. Estimates of post-discectomy 1-year pain recurrence risk from the current study were comparable to those we reported in a prior study of nonoperative management in SPORT, where 1-year leg pain and LBP recurrence risks were 23% and 28%, respectively). Two- and three-year post-discectomy pain recurrence risks from the current study were also comparable, with the exception of 3-year leg pain recurrence, which was slightly higher in the nonoperative setting (51%)¹¹. However, direct statistical comparisons of recurrence risk between operative and nonoperative SPORT participants are prevented by the fact that these groups are not mutually exclusive, since some participants had initial pain resolution first with nonoperative treatment, but went on to have surgery and subsequent post-discectomy resolution. Estimates of 2-year post-discectomy pain recurrence risk from the current study are generally higher than rates reported in prior studies of leg pain or LBP prevalence at >2 years following discectomy for SLDH (5-36%)², and studies of same-level recurrent lumbar disc herniation (0-23%)². However, this is well explained by the different recurrence definitions and analytic methods used, as described above. Although risks of post-discectomy pain recurrence from the current study may seem discouragingly high at first

glance, they are less so when one takes into account the annual rate of new radiating leg pain or LBP in the general population irrespective of SLDH, which can be as high as 10% and 36%, respectively¹¹.

Although complete LBP resolution violated the proportional hazards assumption and could not be examined as a predictor of recurrence using proportional hazards regression, our findings from the KM survival curves and proportional hazards regression models taken together demonstrate that complete initial pain resolution predicts lower pain recurrence risk, for both leg pain and LBP. This confirms an association also seen in the nonoperative SPORT SLDH participants¹¹. Moreover, the finding that patients with lower pain intensity are more likely to remain pain-free at follow-up is analogous to the common scenario in studies of spinal pain where individuals with higher pain intensity are more likely to have pain at follow-up²⁰⁻²². Many of the other predictors identified in this analysis—such as smoking and depression as predictors of leg pain recurrence and joint pain as a predictor of LBP recurrence—are also well-known predictors of recurrent¹¹, incident²³, or persistent pain²⁴ in prior studies. In contrast, our finding that greater operative blood loss was actually associated with *decreased* risk of LBP recurrence is counterintuitive and difficult to explain.

Other predictors of pain recurrence identified in the current study were also unexpected, such as older age predicting a lower risk of LBP recurrence. Although counterintuitive, this finding was seen in an earlier study of LBP recurrence after SLDH using similar methods to our study⁴. Older age is associated with lower reoperation rates for SLDH patients in SPORT²⁵ and elsewhere²⁶, which may be explained by a tendency for surgeons to be less inclined to reoperate for older patients with attendant comorbidities. However, another explanation for lower reoperation rates in older adults is that older adults are less likely to develop recurrent symptoms²⁵. It is possible that putative LBP mechanisms mediated by disc-related structures (such as internal disc disruption, nerve ingrowth into annular fissures, endplate changes, and posterior longitudinal ligament innervation, etc.) are modified by the known changes that occur in the disc and endplates with aging²⁷⁻³⁰. Confounding due to less physical labor/activity in older adults did not seem to explain the age-LBP recurrence association in the current study, since work-related lifting was not associated with recurrence risk, and employment predicted *lower* LBP recurrence risk. Another interesting aspect of the current study was that being divorced or widowed, and not being employed, predicted LBP recurrence. Although marital status has not been previously examined as a predictor of pain recurrence, it is a known predictor of post-discectomy treatment outcomes in SPORT^{24,31}.

This study has some potential limitations. Our assessments of recurrence examined increased pain at specific time intervals post-discectomy, or new procedures indicating recurrent pain, but did not inquire about all intercurrent pain episodes that had happened since the time of pain resolution. This approach might not have included brief recurrences that resolved without epidural steroid injections or surgery, thereby underestimating recurrence risks. Conversely, our methods for defining leg pain recurrence may have inadvertently included cases of leg pain that were not due to lumbosacral radicular pain, such as osteoarthritis. Future studies of post-discectomy pain recurrence may benefit from design considerations and measures intended to examine recurrence specifically, including frequent assessments inquiring about current or past recurrences, and further steps to

discriminate other causes of leg pain from true recurrent sciatica. Lastly, our study examined many predictors of recurrence, so type I error is possible and our findings require replication. A strength of this study is the enhanced generalizability due to the multicenter design including 13 U.S. sites.

Conclusions

Pain recurrence is an important outcome that has not been examined in studies of post-discectomy outcomes. This study found that leg pain and LBP recurrence was common after discectomy, and that risks were generally comparable to those in SLDH managed nonoperatively. Cumulative risks of both leg pain and LBP recurrence were lower in participants achieving complete post-discectomy initial resolution of pain.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Kaplan-Meier survival curve for leg pain recurrence

Figure 2. Kaplan-Meier survival curve for low back pain (LBP) recurrence

Figure 3. Kaplan-Meier survival curve for leg pain recurrence, according to complete vs. near-complete leg pain resolution

Figure 4. Kaplan-Meier survival curve for low back pain (LBP) recurrence, according to complete vs. near-complete leg pain resolution

Table 1
Baseline characteristics of participants with resolution of leg pain or low back pain with discectomy for symptomatic lumbar disc herniation*

Baseline Characteristics	Leg pain resolution	Low back pain resolution
	(n=558)	(n=413)
Age (years)	41.1 (11.2)	41 (10.6)
Female	246 (44%)	186 (45%)
Race - White ^a	496 (89%)	366 (89%)
Education - At least some college	426 (76%)	315 (76%)
Marital Status		
Married	400 (72%)	300 (73%)
Divorced/Widowed	60 (11%)	38 (9%)
Single	90 (16%)	69 (17%)
Body Mass Index, kg/m ²	28.1 (5.7)	27.9 (5.6)
Smoking Status		
Smoker	127 (23%)	98 (24%)
Used to	143 (26%)	108 (26%)
Never	288 (52%)	207 (50%)
Comorbidities		
Depression	60 (11%)	35 (8%)
Joint Problem	79 (14%)	55 (13%)
Other ^b	228 (41%)	157 (38%)
Work Status		
Full or part time	334 (60%)	244 (59%)
Disabled	73 (13%)	50 (12%)
Other	151 (27%)	119 (29%)
Any compensation ^c	98 (18%)	64 (15%)
Important work lifting demands	320 (57%)	232 (56%)
High expectation of being free of pain with surgical treatment ^d	447 (80%)	333 (81%)
Baseline Leg Pain Bothersomeness (0-6) ^e	5.2 (1.1)	5.1 (1.3)
Baseline Back Pain Bothersomeness (0-6) ^f	4.1 (1.9)	4.5 (1.3)
Posterolateral herniation	457 (82%)	335 (81%)
Herniation Type		
Protrusion	139 (25%)	96 (23%)
Extrusion	377 (68%)	286 (69%)
Sequestration	42 (8%)	31 (8%)
Herniation Level		
L2-L3 / L3-L4	30 (5%)	23 (6%)
L4-L5	227 (41%)	175 (42%)

Baseline Characteristics	Leg pain resolution	Low back pain resolution
	(n=558)	(n=413)
L5-S1	301 (54%)	215 (52%)
No ('0') leg pain bothersomeness at the time of leg pain resolution (vs '1')	368 (66%)	NA
Early leg pain recovery ('0' or '1' at the 3-month postoperative follow-up)	293 (53%)	NA
No ('0') LBP bothersomeness at the time of LBP resolution (vs '1')	NA	204 (49%)
Early LBP recovery ('0' or '1' at the 3-month postoperative follow-up)	NA	202 (49%)
Operative Characteristics	(n=556)**	(n=412)**
Discectomy Level***		
L2-L3	11 (2%)	7 (2%)
L3-L4	19 (3%)	15 (4%)
L4-L5	234 (42%)	177 (44%)
L5-S1	299 (54%)	216 (53%)
Operation time, minutes	75.3 (35.6)	77.9 (41.1)
Blood loss, ml	60.3 (84.1)	63.7 (105.5)
Intraoperative blood replacement***	2 (0%)	3 (1%)
Length of stay, days	0.9 (0.9)	1 (1)
Intraoperative complications ^g		
Dural tear/spinal fluid leak	19 (3%)	17 (4%)
Nerve root injury***	1 (0%)	2 (0%)
Vascular injury***	1 (0%)	1 (0%)
Other***	2 (0%)	2 (0%)
None***	534 (96%)	391 (95%)
Postoperative complications/events ^h ***		
Nerve root injury	1 (0%)	0 (0%)
Wound Hematoma	1 (0%)	0 (0%)
Wound Infection	4 (1%)	3 (1%)
Other	16 (3%)	11 (3%)
None	532 (96%)	397 (97%)
Indication for additional surgical procedures***		
Recurrent disc herniation	19 (3%)	16 (4%)
Complication or other	2 (0%)	1 (0%)
New condition	6 (1%)	3 (1%)

* Values presented are means (standard deviations), or numbers (%)

^a Race was self-assessed. Whites and blacks could be either Hispanic or non-Hispanic

^b Other medical problems related to stroke, diabetes, osteoporosis, cancer, fibromyalgia, chronic fatigue syndrome (CFS), post-traumatic stress disorder (PTSD), alcohol, drug dependence, heart, lung, liver, kidney, blood vessel, nervous system, hypertension, migraine, anxiety, stomach or bowel.

^cReceiving or applications pending for workers compensation, Social Security compensation, or other compensation.

^dPatient expectation of being free of pain with surgical treatment was dichotomized as 'certain' or 'big chance' vs. 'no chance', 'small chance', or 'moderate chance'.

^eLeg Pain Bothersomeness Scale ranges from 0 to 6, with lower scores indicating less severe symptoms.

^fLow Back Pain Bothersomeness Scale ranges from 0 to 6, with lower scores indicating less severe symptoms.

^{**}Surgical information was available for 556 leg pain resolution patients and 412 for low back pain resolution patients.

^gNone of the following were reported: aspiration, operation at wrong level.

^hAny reported complications up to 8 weeks post operation. None of the following were reported: bone graft complication, CSF leak, paralysis, cauda equina injury, wound dehiscence, pseudarthrosis.

^{***}Some operative characteristics were not examined in further analytic steps due to low event frequencies, strong intercorrelations with other variables, or being part of the recurrence outcome definition.

Table 2
Cumulative incidence of leg pain and LBP recurrence post-discectomy, according to complete vs. near-complete initial recovery*

	Leg pain resolution (all participants) n=558			Complete leg pain resolution n=368			Near-complete leg pain resolution n=190		
	n _r	% (95% CI)		n _r	% (95% CI)		n _r	% (95% CI)	
Leg pain recurrence (1-year risk) *	108	20% (17%-24%)		59	17% (13%-21%)		49	27% (21%-34%)	
Leg pain recurrence (2-year risk) *	188	39% (34%-43%)		112	35% (30%-41%)		76	45% (37%-53%)	
Leg pain recurrence (3-year risk) *	213	45% (41%-50%)		125	41% (35%-47%)		88	54% (46%-62%)	
	LBP resolution (all participants) n=413			Complete LBP resolution n=204			Near-complete LBP resolution n=209		
	n _r	% (95% CI)		N _r	% (95% CI)		N _r	% (95% CI)	
LBP recurrence (1-year risk) *	115	29% (25%-34%)		55	28% (22%-34%)		60	30% (24%-37%)	
LBP recurrence (2-year risk) *	192	53% (48%-59%)		79	43% (36%-51%)		113	62% (55%-70%)	
LBP recurrence (3-year risk) *	223	65% (60%-71%)		92	53% (46%-61%)		131	77% (70%-84%)	

LBP=low back pain, CI=confidence interval, n=total sample size, n_r=number of recurrence events

* One-, two- and three-year pain recurrence risks are Kaplan-Meier estimates. For leg pain recurrence, the average (min, max) years of follow-up (per person) was 1.89 (0.13, 3) years, number of person-years follow-up was 1054 person-years, and recurrence incidence density was 213 per 1054 person-years. For LBP recurrence, the average (min, max) years of follow-up (per person) was 1.67 (0.54, 3) years, number of person-years follow-up was 691 person-years, and recurrence incidence density was 223 per 691 person-years.

Table 3
Associations between potential predictors and leg pain recurrence, for patients with initial post-discectomy leg pain resolution*

Baseline Characteristics	Bivariate Associations	Multivariate Associations**
	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)
Age (years)	1.00 (0.99, 1.01)	1.00 (0.99-1.01)
Female	1.15 (0.88, 1.51)	1.12 (0.86-1.47)
Race - White ^d	1.29 (0.8, 2.06)	-
Education - At least some college	1.06 (0.76, 1.48)	-
Marital Status		-
Married vs. Single	0.96 (0.65, 1.42)	-
Divorced/Widowed vs. Single	1.50 (0.9, 2.49)	-
Body Mass Index, kg/m ²	1.02 (1.00, 1.05)	1.02 (1.00, 1.04)
Smoking status		-
Smoker vs. Never	1.61 (1.17, 2.22)	1.68 (1.22, 2.33)
Used to vs. Never	0.96 (0.69, 1.35)	0.97 (0.69, 1.37)
Comorbidities		-
Depression	1.91 (1.3, 2.79)	1.74 (1.18, 2.56)
Joint Problem	1.48 (1.05, 2.08)	-
Other ^b	1.11 (0.84, 1.45)	-
Work Status		-
Full or part time vs. Other	0.76 (0.55, 1.04)	-
Disabled vs. Other	1.28 (0.83, 1.96)	-
Any compensation ^c	1.12 (0.79, 1.59)	-
Important work lifting demands	1.18 (0.90, 1.55)	-
High expectation of being free of pain with surgical treatment ^d	0.90 (0.64, 1.26)	-
Baseline Leg Pain Bothersomeness (0-6) ^e	1.07 (0.94, 1.23)	-
No ('0') leg pain bothersomeness at the time of leg pain resolution (vs '1')	0.68 (0.52, 0.90)	0.69 (0.52, 0.90)
Posterolateral herniation	1.06 (0.75, 1.5)	-
Herniation Type		-
Extrusion vs. Protrusion	1.15 (0.83, 1.59)	-
Sequestration vs. Protrusion	0.87 (0.48, 1.58)	-
Herniation Level		-
L2-L3 / L3-L4 vs. L4-L5	0.63 (0.32, 1.25)	-
L5-S1 vs. L4-L5	0.89 (0.67, 1.17)	-
Operative Characteristics		
Operation time, minute	1.001 (0.997, 1.005)	NA [†]
Blood loss, ml	0.999 (0.997, 1.001)	NA [†]

Baseline Characteristics	Bivariate Associations	Multivariate Associations**
	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)
Length of stay, day	0.96 (0.83, 1.11)	NA [†]
Dural tear/spinal fluid leak	0.78 (0.35, 1.76)	NA [†]

CI=confidence interval; variables significant at $P < .05$ are shown in bold.

* Early leg pain recovery violated the assumption of proportional hazards and was not included in the proportional hazards models for leg pain recurrence.

** Potential predictors of recurrence (baseline characteristics) that were retained in the multivariate Cox proportional hazards regression model, using a stepwise variable selection procedure (entry $P < .10$, removal $P < .10$); age, gender, and complete initial leg pain resolution were forced into the model.

^a Race was self-assessed. Whites and blacks could be either Hispanic or non-Hispanic.

^b Other medical problems related to stroke, diabetes, osteoporosis, cancer, fibromyalgia, chronic fatigue syndrome (CFS), post-traumatic stress disorder (PTSD), alcohol, drug dependence, heart, lung, liver, kidney, blood vessel, nervous system, hypertension, migraine, anxiety, stomach or bowel

^c Receiving or applications pending for workers compensation, Social Security compensation, or other compensation

^d Patient expectation of being free of pain with surgery was dichotomized as 'certain' or 'big chance' vs. 'no chance', 'small chance', or 'moderate chance'.

^e Leg Pain Bothersomeness Scale ranges from 0 to 6, with lower scores indicating less severe symptoms

[†] Operative characteristics were excluded from the main multivariate models.

Table 4
Associations Between Potential Predictors and Low Back Pain (LBP) Recurrence, for
Patients with Initial Post-Discectomy LBP Resolution*

Baseline Characteristics	Bivariate Associations	Multivariate Associations**
	Hazard Ratio (95% CI)	Hazard Ratio (95% CI)
Age (years)	0.99 (0.98, 1)	0.98 (0.97, 0.99)
Female	1.21 (0.93, 1.57)	1.17 (0.88, 1.54)
Race - White ^a	0.86 (0.57, 1.3)	-
Marital Status		-
Married vs. Single	1.21 (0.82, 1.79)	1.47 (0.96, 2.23)
Divorced/Widowed vs. Single	1.45 (0.85, 2.48)	1.84 (1.01, 3.34)
Body Mass Index, kg/m ²	1.02 (0.99, 1.04)	-
Smoking status		-
Smoker vs. Never	1.15 (0.83, 1.59)	-
Used to vs. Never	0.81 (0.58, 1.12)	-
Comorbidities		-
Depression	0.81 (0.48, 1.37)	0.62 (0.36, 1.07)
Joint Problem	1.76 (1.24, 2.49)	1.95 (1.36, 2.80)
Other ^b	0.95 (0.72, 1.25)	-
Work Status		-
Full or part time vs. Other	0.71 (0.53, 0.95)	0.67 (0.49, 0.90)
Disabled vs. Other	0.92 (0.59, 1.43)	0.86 (0.53-1.38)
Any compensation ^c	0.96 (0.66, 1.38)	-
Important work lifting demands	1.06 (0.81, 1.38)	-
High expectation of being free of pain with surgical treatment ^d	1.02 (0.72, 1.44)	-
Baseline LBP Bothersomeness (0-6) ^e	1.03 (0.93, 1.13)	-
Herniation Type		-
Extrusion vs. Protrusion	1.12 (0.81, 1.56)	-
Sequestration vs. Protrusion	0.92 (0.51, 1.65)	-
Herniation Level		-
L2-L3 / L3-L4 vs. L4-L5	0.79 (0.42, 1.48)	-
L5-S1 vs. L4-L5	1.04 (0.8, 1.37)	-
Operative Characteristics		
Blood loss, ml	0.998 (0.996, 1)	NA [†]
Dural tear/spinal fluid leak	0.63 (0.28, 1.41)	NA [†]

CI=confidence interval; variables significant at P < .05 are shown in bold.

* Early low back pain recovery, education, herniation location, complete initial LBP resolution, operation time, and length of stay violated the assumption of proportional hazards and were not included in the proportional hazards models for LBP recurrence.

^{**} Potential predictors of recurrence (baseline characteristics) that were retained in the multivariate Cox proportional hazards regression model, using a stepwise variable selection procedure (entry $P < .10$, removal $P < .10$); age and gender were forced into the model.

^a Race was self-assessed. Whites and blacks could be either Hispanic or non-Hispanic

^b Other medical problems related to stroke, diabetes, osteoporosis, cancer, fibromyalgia, chronic fatigue syndrome (CFS), post-traumatic stress disorder (PTSD), alcohol, drug dependence, heart, lung, liver, kidney, blood vessel, nervous system, hypertension

^c Receiving or applications pending for workers compensation, Social Security compensation, or other compensation

^d Patient expectation of being free of pain with surgery was dichotomized as 'certain' or 'big chance' vs. 'no chance', 'small chance', or 'moderate chance'.

^e Low Back Pain Bothersomeness Scale ranges from 0 to 6, with lower scores indicating less severe symptoms

^f Operative characteristics were excluded from the main multivariate models.