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Predictive Factors for Outcomes Following Surgical Treatment of Lumbar Disc Herniation

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ABSTRACT

Background: Lumbar disc herniation (LDH) is a common cause of radicular pain with an annual incidence between 5 and 20 cases per 1000 adults. LDH is typically treated by microdiscectomy, of which more than 300,000 are performed in the United States each year. Despite this frequency, 25% to 33% of patients report poor surgical outcomes. This study sought to present a retrospective analysis of patients who underwent microdiscectomy surgery for the treatment of LDH with the aim of identifying demographic, historical, and surgical factors that may contribute to inadequate surgical results.

Methods: A retrospective study of 241 patients at Stony Brook Medicine from 2017 to 2022 was performed, 123 of whom had follow-up of 90 days or more and were included for final analysis. Data collection included demographics, medical/surgical history, and surgical methodology. Good outcomes were defined as meeting the absolute point change threshold (ACT)—3.5pt reduction in pain reported by the Numerical Rating System (NRS) or the resolution of either radicular pain or neurological symptoms.

Results: Univariate analysis revealed that 100% of patients with prior fusion surgery ($P = 0.039$) and 73.2% who underwent preoperative physical therapy (PT; $P = 0.032$) failed to meet the ACT. Additionally, 79.1% ($P = 0.021$) and 82.8% ($P = 0.026$) of patients who had PT had residual radicular pain and neurological symptoms, respectively. Multivariate logistic regression confirmed correlations between preoperative PT and failure to meet the ACT ($P = 0.030$, OR = 0.252) and resolution of radicular ($P = 0.006$, OR = 0.196) and neurological ($P = 0.030$, OR = 0.177) complaints. ACT directly correlated with higher preoperative NRS scores in univariate ($P = 0.0002$) and multivariate ($P = 0.002$, OR = 1.554) analyses.

Conclusion: Our results show that higher preoperative NRS scores, PT, and prior fusion surgery are associated with poorer outcomes. While PT is considered a viable nonoperative treatment for LDH, our findings suggest detrimental effects when preceding surgery, indicating the need for additional research into the effects of PT on patients with high grade LDH.

Lumbar Spine

Keywords: fusion, lumbar disc herniation, outcomes, physical therapy, retrospective, spine

INTRODUCTION

Lumbar radicular pain (LRP) is the most commonly occurring form of neuropathic pain, affecting up to 25% of the general population.[1] LRP is a frequent manifestation of lumbar disc herniation (LDH), which has an annual incidence ranging from 5 to 20 cases per 1000 adults.[2,3] LDH occurs when the annulus fibrosis is structurally compromised and the nucleus pulposus herniates beyond its central position in the intervertebral space. Such structural degeneration may result in narrowing of the spinal canal and associated compression of the thecal sac and/or spinal nerve roots.[4] While LDH patients may be managed nonoperatively, more than 300,000 lumbar discectomies are performed annually, making it the most common surgical intervention for patients with back and leg pain in the United States.[5–7]

Despite the general efficacy of lumbar discectomy procedures, approximately 25% to 33% of patients report poor outcomes, with more than 50% experiencing persistent radicular pain.[8–10] Several studies have investigated possible factors that may contribute to such poor outcomes. Factors correlated with persistent postoperative pain and disability include a high level of education, significant preoperative back pain, smoking, obesity, diabetes, and female gender.[11–14] Additionally, outcomes have been correlated with the level of herniation, with pathology at L2 to L3 and L3 to L4 associated with significant improvement after discectomy.[2]

Here, we conducted a retrospective analysis of patients who underwent microdiscectomy surgery for treatment of LDH, including unique variables, with the aim of identifying demographic, historical, and surgical factors that may contribute to poor surgical outcomes.

MATERIALS AND METHODS

Patient Selection

The present study was a retrospective analysis of patients who underwent surgery for the treatment of LDH by Stony Brook Department of Neurosurgery between 2017 and 2022. Patients were considered for inclusion in this study if they were diagnosed with LDH, underwent decompression surgery without fusion, and did not undergo revision of their initial surgery. A total of 259 patients were identified as potential candidates. To account for long-term outcomes of surgery, patients who were either lost to follow-up or discharged from neurosurgical care prior to 90 days postoperative were not considered eligible, leaving a total of 123 patients meeting inclusion criteria for the study.

All discectomies were performed by spine-focused neurosurgeons who are trained in and regularly practice surgical management of the spine. To determine the impact of surgical technique on outcomes, all approaches, including open microdiscectomy, tubular (minimally invasive surgery [MIS]) microdiscectomy, and use of an intraoperative microscope, were included in the study.

Independent Variable Selection

Data were collected from the electronic medical records for the 123 patients included. Care was taken to include available factors frequently identified in the existing literature as associated with desired/poor outcomes from surgical management of LDH. Additional variables were selected within the categories of demographics, medical and surgical history, details of injury, and surgical technique. Information regarding intraoperative complications, use of intraoperative steroids, and prior nonoperative therapy was ascertained.

Outcome Measures

Surgical outcomes were determined using 3 separate measures. First, changes in the patients' reported pain, scored by the Numerical Rating System (NRS), between surgical consultation and final follow-up visit were calculated. Outcomes were categorized as success or failure based on the absolute point change threshold (ACT) of 3.5 points as described by Solberg et al.[15]

Surgical consultation notes were reviewed, and patients were categorized as exhibiting preoperative radicular pain or neurological symptoms. Neurological symptoms were defined as numbness, dysesthesia, paresthesia, or motor weakness. Physician follow-up notes were reviewed for patient-reported improvement in these symptoms. The second and third outcome measures were established as success or failure in achieving complete resolution of radicular pain or neurological symptoms, respectively.

Statistical Analysis

Bivariate analysis was performed to identify independent variables significantly associated with each of the 3 outcome measures. The Mann-Whitney *U* test was used for nonparametric continuous data. Categorical data were analyzed using Pearson χ^2 and Fischer's exact test. Statistical significance was determined by $P < 0.05$ on Mann-Whitney *U* test or Fischer's exact test.

Multivariate logistic regression was used to account for confounding variables that may influence associations between pre- and intraoperative factors and outcomes identified on bivariate analysis. Independent variables associated by Mann-Whitney *U* test or Fischer's exact test with any 1 of the 3 outcome measures with $P < 0.10$ were selected for inclusion in multivariate analysis. Individual multivariate logistic regressions were then performed for each outcome measure using the same input variables. Any variable with a 95% CI ranging greater than 5.0 was not included in the final model. Variables that perfectly predicted a specific outcome or displayed collinearity would have inflated the variance and were thus removed from the final model. Statistical significance from multivariate analysis was determined by $P < 0.05$. All statistical analyses were performed using STATA, version 17.0 BE (Stata Corp., College Station, TX, USA).

RESULTS

General Characteristics

A total of 123 patients who underwent surgical management of LDH met the criteria for inclusion in this study. The mean age was 47.0 ± 15.5 years, mean body mass index (BMI) was 28.8 ± 5.3 kg/m^2, and 43.9% of the patients were women (Table 1). The majority of patients were Caucasian, comprising 84.6% of the sample, with Hispanic background accounting for an additional 8.1%. Among all patients, 83.7% underwent traditional open microdiscectomy, 12.2% had minimally invasive tubular microdiscectomy, and 2.4% were treated by surgical decompression without removal of disc material. The intraoperative microscope was

Table 1. Baseline characteristics of patients undergoing surgical management of lumbar disc herniation.

Characteristic	*N (%)*
Age, y, mean (SD)	47.0 (15.5)
Female sex	54 (43.9%)
BMI, mean (SD)	28.8 (5.3)
Race/ethnicity	
Caucasian	104 (84.6%)
Hispanic	10 (8.1%)
Asian	2 (1.6%)
African American	2 (1.6%)
Native Hawaiian or other Pacific Islander	3 (2.4%)
Medical history	
Diabetes mellitus	15 (12.2%)
Liver/kidney disease	6 (4.9%)
Alcohol use	75 (61.0%)
Current smoker	18 (14.6%)
Cannabis use	8 (6.5%)
Osteoporotic disease	4 (3.3%)
Rheumatoid arthritis	1 (0.8%)
Multiple sclerosis	1 (0.8%)
Surgical history	
Prior spine surgery	17 (13.8%)
Prior decompression	6 (4.9%)
Prior fusion	9 (7.3%)
Prior "other spine surgery"	2 (1.6%)
Cervical	6 (4.9%)
Thoracic	1 (0.8%)
Lumbar	8 (6.5%)
Level of injury	
L1–L2	1 (0.8%)
L2–L3	6 (4.9%)
L2–L4	1 (0.8%)
L3–L4	16 (13.0%)
L3–L5	1 (0.8%)
L4–L5	39 (31.7%)
L4–S1	6 (4.9%)
L5–S1	53 (43.1%)
Preoperative symptoms	
Preoperative back pain	91 (74.0%)
Preoperative radicular pain	116 (94.3%)
Preoperative neurological symptoms	90 (73.2%)
Preoperative NRS, mean (SD)	7.0 (2.4)
Time from symptom onset to surgery (wk), mean (SD)	39.7 (56.8)
Prior management	
Procedural intervention	89 (72.4%)
Physical therapy	47 (38.2%)
Acupuncture	9 (7.3%)
Chiropractic	19 (15.4%)
Surgical technique	
Use of intraoperative microscope	22 (17.9%)
Open microdiscectomy	103 (83.7%)
Tubular (MIS) microdiscectomy	15 (12.2%)
Decompression w/out discectomy	3 (2.4%)
Fat graft	45 (36.6%)
Dural tear/CSF leak	3 (2.4%)
Operative time, min, mean (SD)	79.0 (38.1)

Abbreviations: BMI, body mass index; CSF, cerebrospinal fluid; MIS, minimally invasive surgery; NRS, Numerical Rating System.
Note: Data presented as *n* (%) unless otherwise noted.

utilized in 17.9% of cases, while the remainder were performed using loupes. The use of subcutaneous fat graft to fill the laminotomy defect was employed in 36.6%. The average operative time was 79.0 ± 38.1 minutes, and complications such as dural tears and cerebrospinal fluid leaks occurred in only 3 cases (2.4%).

Medical history from each patient was collected and remarkable for diabetes mellitus (12.2%), hepatic/renal disease (4.9%), osteoporotic disease defined as osteoporosis or osteopenia (3.3%), rheumatoid arthritis (0.8%), and multiple sclerosis (0.8%). Lifestyle factors, including current smoking status (14.6%), alcohol use (61.0%), and cannabis use (6.5%), were also reported.

Data regarding preoperative, conservative management revealed that 38.2% participated in physical therapy (PT), 7.3% received acupuncture, and 15.4% were treated with chiropractic care. Furthermore, 72.4% underwent procedural interventions including steroid and nonsteroid epidural injections, facet/nerve blocks or ablations, and trigger point injections. Additionally, 17 patients had undergone previous spine surgeries for separate pathologies, 35.3% and 52.9% of which were decompressions and fusions, respectively. Lumbar surgeries accounted for 47.1% of these prior surgeries, while 35.3% were performed at the cervical level.

The average duration of symptoms prior to undergoing surgery was 39.7 ± 56.8 weeks. Additionally, 74% of patients reported preoperative back pain, 94.3% suffered from preoperative radicular pain, and 73.2% experienced neurological symptoms. Prior to surgery, the mean NRS was 7.0 ± 2.4 points. Most injuries occurred at the L5-S1 (43.1%) and L4-L5 (31.7%) levels.

NRS pain scores collected from each patient at their final follow-up appointment were compared with their preoperative scores. The average postoperative score was 4.2 ± 2.8, representing an average decrease in overall pain of 3.5 ± 2.8. Of the patients who exhibited preoperative radicular pain, 43 (37.1%) reported complete resolution by their final visit, while 31 patients (34.4%) who had experienced neurological symptoms reported complete resolution. Of note, only 17 patients (18.7%) with back pain prior to surgery reported resolution of their pain.

Bivariate Analysis of Surgical Outcomes

Bivariate analysis (Table 2) identified 4 factors that were associated with poor outcomes defined as failure to meet the NRS minimum change threshold of 3.5 points with $P < 0.05$. History of prior spine surgery at any level ($P = 0.013$), and specifically fusion ($P = 0.039$), was significantly associated with failure to meet the threshold of clinically relevant NRS change. Operative time was found to be correlated with outcomes ($P = 0.016$), with patients who failed to meet the threshold undergoing lengthier surgeries on average. The mean operative time for patients with poor outcomes was 84 ± 38.6 minutes, while surgeries resulting in successful

Table 2. Bivariate analysis of outcomes after surgical treatment for lumbar disc herniation.

	Outcome								
	Absolute Change Threshold (3.5 points)			Resolution of Radicular Pain			Resolution of Neurological Symptoms		
Variable	Success	Failure	*P*	Success	Failure	*P*	Success	Failure	*P*
Total	42 (41.2%)	60 (58.8%)	-	43 (37.1%)	73 (62.9%)	-	31 (34.4%)	59 (65.6%)	-
Age, y	47 ± 15.1	48 ± 16.6	0.8776[b]	48 47 ± 15.7	47 ± 15.6	0.6518[b]	43 ± 17.9	49 ± 13.7	0.0611[b]
Female sex	18 (41.9%)	25 (58.1%)	>0.99[a]	20 (40.8%)	29 (59.2%)	0.560[a]	16 (39.0%)	25 (61.0%)	0.505[a]
BMI	28 ± 5.0	29 ± 5.3	0.4132[b]	29 ± 5.2	29 ± 5.5	0.7526[b]	28 ± 4.4	29 ± 5.7	0.3399[b]
Medical/surgical history									
Diabetes mellitus	4 (28.6%)	10 (71.4%)	0.388[a]	6 (40.0%)	9 (60.0%)	0.783[a]	2 (22.2%)	7 (77.8%)	0.713[a]
Current smoker	5 (35.7%)	9 (64.3%)	0.774[a]	9 (56.3%)	7 (43.8%)	0.101[a]	3 (33.3%)	6 (66.7%)	>0.99
Osteoporotic disease	2 (50.0%)	2 (50.0%)	>0.99[a]	4 (100.0%)	0 (0.0%)	**0.017[a]**	3 (100.0%)	0 (0.0%)	**0.038[a]**
Prior spine surgery	1 (7.7%)	12 (92.3%)	**0.013[a]**	5 (29.4%)	12 (70.6%)	0.592[a]	5 (33.3%)	10 (66.7%)	>0.99[a]
Prior fusion surgery	0 (0.0%)	7 (100.0%)	**0.039[a]**	4 (44.4%)	5 (55.6%)	0.724[a]	4 (50.0%)	4 (50.0%)	0.439[a]
Level of injury									
L2–L3	3 (60.0%)	2 (40.0%)	0.400[a]	3 (50.0%)	3 (50.0%)	0.669[a]	1 (50.0%)	1 (50.0%)	>0.99[a]
L3–L4	4 (26.7%)	11 (73.3%)	0.265[a]	8 (50.0%)	8 (50.0%)	0.274[a]	6 (50.0%)	6 (50.0%)	0.327[a]
L5–S1	21 (52.5%)	19 (47.5%)	0.068[a]	14 (28.0%)	36 (72.0%)	0.085[a]	15 (39.5%)	23 (60.5%)	0.501[a]
History of injury									
Preoperative back pain	27 (37.5%)	45 (62.5%)	0.275[a]	36 (42.4%)	49 (57.6%)	0.055[a]	23 (35.4%)	42 (64.6%)	0.810[a]
Time from symptom onset to surgery, wk	28 ± 31.8	55 ± 72.3	0.0584[b]	38 ± 59.4	37 ± 49.6	0.5971[b]	33 ± 39.2	25 ± 26.0	0.5034[b]
Preoperative NRS	8 ± 1.7	6 ± 2.6	**0.0002[b]**	7 ± 2.6	7 ± 2.3	0.1886[b]	7 ± 2.4	7 ± 2.5	0.9548[b]
Preoperative physical therapy	11 (26.8%)	30 (73.2%)	**0.032[a]**	9 (20.9%)	34 (79.1%)	**0.021[a]**	5 (17.2%)	24 (82.8%)	**0.026[a]**
Operative time, min	72 ± 40.6	84 ± 38.6	**0.016[b]**	80 ± 37.8	79 ± 39.5	0.5932[b]	71 ± 24.3	81 ± 40.1	0.4085[b]
Surgical technique									
Use of intraoperative microscope	7 (38.9%)	11 (61.1%)	>0.99[a]	9 (40.9%)	13 (59.1%)	0.809[a]	4 (23.5%)	13 (82.4%)	0.399[a]
Open microdiscectomy	38 (44.7%)	47 (55.3%)	0.176[a]	35 (36.5%)	61 (63.5%)	0.802[a]	27 (35.1%)	50 (64.9%)	>0.99[a]
Tubular (MIS) microdiscectomy	3 (23.1%)	10 (76.9%)	0.229[a]	5 (33.3%)	10 (66.7%)	>0.99[a]	3 (27.3%)	8 (72.7%)	0.742[a]
Decompression without discectomy	1 (33.3%)	2 (66.7%)	>0.99[a]	2 (66.7%)	1 (33.3%)	0.554[a]	0 (0.0%)	1 (100.0%)	>0.99[a]
Fat graft	16 (43.2%)	21 (56.8%)	0.835[a]	15 (36.6%)	26 (63.4%)	>0.99[a]	13 (38.2%)	21 (61.8%)	0.649[a]

Abbreviations: BMI, body mass index; MIS, minimally invasive surgery.

Note: Data presented as *n* (%) or mean ± SD. Boldface indicates statistically significant findings at $P < 0.05$.

[a]Fisher Exact.

[b]Mann-Whitney *U* Test.

outcomes averaged 72 ± 40.6 minutes. Additionally, a history of conservative management with PT prior to surgery was significantly associated with poor outcomes ($P = 0.032$). Bivariate analysis also identified a single factor correlated with good outcomes: patients with higher preoperative NRS pain scores were more likely to report changes equal to or greater than 3.5 points by their final visit ($P = 0.0002$). Patients who met the ACT reported an average initial NRS score of 8.0 ± 1.7, while the score of patients who did not averaged 6.0 ± 2.6.

Analysis for the resolution of radicular pain and neurological symptoms identified 2 factors associated with outcomes. Patients suffering from osteoporotic disease achieved good outcomes ($P = 0.017$ and $P = 0.038$) in terms of resolution of radicular pain or neurological symptoms, respectively. Preoperative PT was significantly correlated with failure to resolve radicular pain and neurological symptoms ($P = 0.021$ and $P = 0.026$), respectively.

BMI, female sex, diabetes mellitus, current smoking status, and surgery at the L2-L3 or L3-L4 disc levels were not found to have significant associations with any of the 3 outcome measures. Surgical techniques, including open microdiscectomy, tubular (MIS) microdiscectomy, decompression without discectomy, and use of intraoperative microscope or fat graft, were also not correlated with any of the 3 outcome measures.

Multivariate Analysis of Surgical Outcomes

On multivariate analysis (Table 3), the correlation between higher preoperative NRS scores and success in meeting the ACT (OR 1.554, 95% CI 1.182–2.041; $P = 0.002$) was significant. Logistic regression modeling showed a significant correlation between participation in preoperative PT and failure to meet the ACT (OR 0.252, 95% CI 0.073–0.873; $P = 0.030$), resolve radicular pain (OR 0.196, 95% CI 0.062–0.621; $P = 0.006$), or resolve neurological symptoms (OR 0.177,

Table 3. Multivariate analysis of outcomes after surgical treatment for lumbar disc herniation.

	Outcome					
	Absolute Change Threshold (3.5pt)		Resolution of Radicular Pain		Resolution of Neurological Symptoms	
Variable	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Age	1.003 (0.966–1.041)	0.866	0.995 (0.961–1.031)	0.793	0.952 (0.910–0.995)	**0.030**
Osteoporotic disease	-	-	-	-	-	-
Prior spine surgery	0.119 (0.011–1.231)	0.074	-	-	-	-
L5–S1	-	-	0.483 (0.153–1.529)	0.216	-	-
Preoperative back pain	0.559 (0.154–2.029)	0.377	-	-	-	-
Time from symptom onset to surgery	0.987 (0.971–1.004)	0.136	1.000 (0.988–1.012)	0.982	1.013 (0.992–1.035)	0.219
Preoperative NRS	1.554 (1.182–2.041)	**0.002**	1.214 (0.985–1.497)	0.069	1.126 (0.877–1.445)	0.352
Preoperative physical therapy	0.252 (0.073–0.873)	**0.030**	0.196 (0.062–0.621)	**0.006**	0.177 (0.037–0.842)	**0.030**
Operative time	0.991 (0.977–1.005)	0.211	0.994 (0.983–1.006)	0.350	0.989 (0.969–1.008)	0.256

Abbreviation: NRS, Numerical Rating System.
Note: Boldface indicates statistically significant findings at $P < 0.05$.

95% CI 0.037–0.842; $P = 0.030$). Increased age was significantly associated with poor outcomes in terms of resolution of neurological symptoms (OR 0.952, 95% CI 0.910–0.995; $P = 0.030$). No significant correlation was found between preoperative back pain or operative time with any of the 3 outcome measures. Osteoporotic disease was not correlated with the resolution of either radicular pain or neurological symptoms, while prior spine surgery was not associated with meeting the ACT on multivariate analysis.

DISCUSSION

Lumbar disc herniation is 1 of the major sources and the most common indication for surgical management of LRP.[2,5–7] Although many patients experience relief of symptoms after discectomy surgery, up to 50% remain unsatisfied with their recovery.[9,10] In this study, we retrospectively studied surgically managed LDH patients to identify novel potential risk factors that may predispose individuals to poor outcomes from discectomy.

Our patient population's mean age of 47.0 ± 15.5 and BMI of 28.8 ± 5.3 kg/m^2 are consistent with populations analyzed by similar studies.[16–19] Additionally, the gender distribution of our study, with 43.9% of patients identifying as women, similarly matches the populations described by the Spine Outcomes Research Trial (SPORT; 43.0%) and Ma et al (43.2%).[16,17] Our cohort comprises 84.6% Caucasian patients, which is similar to the 89.0% reported by the SPORT trial.[16] Despite this consistency, patients of Hispanic background comprised twice the percentage of our population as reported by Weinstein et al. Relative to studies published by Weinstein et al and Shamim et al, a substantially smaller proportion of our patient population self-identified as current smokers.[16,19] Finally, the percentages of our patients with diabetes mellitus, preoperative back pain, and radicular pain were consistent with the population described by Ma et al.[17]

Bivariate analysis demonstrated that gender was not significantly associated with any of the 3 outcome measures (P = 1.000, 0.560, and 0.505). In a 2012 study, Haugen et al identified male gender as associated with worse outcomes measured by Maine-Seattle Back Questionnaire and Sciatica Bothersome Index.[11] In direct contrast, an earlier study by Graver et al found female gender to be associated with poor outcomes as measured by visual analog scale.[13] The discrepancies between these 2 articles and our own findings suggest that gender does not significantly impact surgical outcomes. These 2 studies also reported contradictory results regarding the impact of smoking status on patient outcomes. Haugen et al found that current smokers were associated with worse outcomes, while Graver et al found the association to be insignificant.[11,13] Our analysis supported the latter, as smoking status was not associated with any of our outcome measures (P = 0.774, 0.101, and >0.99).

Although patient age was not associated with resolution of neurological symptoms on bivariate analysis, our multivariate analysis demonstrated a significant correlation with poor outcomes by this metric (P = 0.03). Patients with failed resolution of neurological symptoms had a mean age of 49 ± 13.7 years, while those with resolution had a mean age of 43 ± 17.9 years. While statistical significance was detected, these results are of no clinical relevance as there is a 68% overlap between the SDs from the mean ages of the 2 cohorts (Table 2). This finding is in concordance with Graver et al, who reported patient age to have no statistically significant prognostic value.[13]

Several variables identified in the existing literature as associated with poor outcomes failed to yield significant results in our statistical analyses. Duration of symptoms prior to surgery was not significantly associated with the resolution of either radicular pain ($P = 0.5971$) or neurological symptoms ($P = 0.5034$). Although this variable met the cutoff of $P < 0.10$ for association with failure to meet the ACT, it was not included in multivariate analysis due to notable overlapping between SDs from the mean duration. Patients who successfully met the threshold had a mean time from symptom onset to surgery of 28 ± 31.8 weeks while patients who did not had a mean time of 55 ± 72.3 weeks. Furthermore, duration of symptoms failed to yield significant correlations with any of the 3 outcome measures upon multivariate analysis (P = 0.136, 0.982, and 0.219).

Haugen et al reported an association between preoperative back pain and surgical outcomes.[11] In our analysis, reported back pain was included only in the final multivariate model for ACT, in which it did not find a significant correlation (OR 0.559, 95% CI 0.154–2.029, $P = 0.377$). The discrepancy between our results and those reported by Haugen et al may be due to differences in methodology. Our study simply identified patients as reporting or not reporting preoperative back pain, whereas Haugen et al quantified the extent of back pain.

We identified a significant association on bivariate analysis between failure to meet the ACT and history of prior spine surgery. Ultimately this finding was deemed insignificant as prior surgery did not generate a P value <0.05 on multivariate analysis. Bivariate analysis also identified a similar association between outcomes and history of prior fusion surgery. Notably, all 7 patients who had previously undergone fusion surgery reported poor outcomes from their LDH surgeries.

Importantly, we show significant association between preoperative PT and poor outcomes as per all 3 outcome measures in both bivariate and multivariate analysis. Of the 41 patients who underwent PT prior to surgery, 73.2% failed to meet the ACT, 79.1% experienced residual radicular pain, and 82.8% did not have a resolution of their neurological symptoms. PT is a commonly used first-line management for LDH. A 2019 clinical guideline by Lee et al noted that despite a lack of high-quality trials, PT has shown efficacy in the improvement of both pain and function.[20] Atlas et al reported that after 1 year, 43% of patients who underwent nonsurgical management of LDH displayed improvement in symptoms.[21] Furthermore, they found that by 5 years, such conservative therapy produced results that were statistically equivalent to those treated with discectomy.[22] While such beneficial results dominate the existing literature, other authors, such as Carlesso et al, questioned whether this is due to the positive impact of PT or a failure to report adverse events.[23]

Our findings suggest that while PT may be an effective conservative management for a cohort of patients, in another subset of patients, PT may be contraindicated, specifically in patients who will eventually need to undergo surgery. The failure of time to surgery to yield any significant association with outcomes on multivariate analysis (P = 0.136, 0.982, and 0.219) contradicts the possibility that preoperative PT influences outcomes by delaying surgical treatment. Koerner et al, 2015 review of the SPORT studies provides supporting evidence through the identification of worse outcomes measured by Oswestry Disability Index (ODI) in patients who had undergone PT ($P = 0.036$).[24] Although not statistically significant, 5-year outcomes of the Maine Lumbar Spine Study showed that patients who were initially treated with PT and subsequently underwent surgery had worse outcomes than those who were initially treated with surgery.[22]

PT may be effective in the reduction of musculoskeletal pain and symptoms from compression of nerve roots by spastic muscle due to LDH, explaining its utility for nonoperative patients. However, when symptoms are due to irritation of nerve roots by the herniated disc itself, the movement involved in PT may further aggravate the nerve, worsening the injury and leading to worse surgical outcomes. A possible mechanism for such nerve injury is an increase in nerve root inflammation. Studies have demonstrated that elevated preoperative proinflammatory cytokine levels are associated with worse surgical outcomes. It is hypothesized that nerve root inflammation also leads to the formation of epidural fibrosis, another source of poor surgical outcomes.[9,10,25,26] Our findings, together with previous literature, provide justification for the development of prospective investigations into the role of preoperative PT for patients that have lumbar disk herniations with likely surgical pathology. Such studies could aim to identify a relationship between preoperative PT and elevated preoperative inflammatory markers. Additionally, our study does not differentiate between the specific modalities of PT employed. Farrokhi et al reported that patients with low back pain who were treated with passive interventions or mechanical traction were more likely to require escalated interventions such as spinal injections and hospitalization when compared with those who received only active intervention.[27] These findings suggest that the specific type of PT utilized has an impact on outcome. Therefore, future studies should also attempt to determine whether this finding extends to the impact of preoperative PT on surgical outcomes.

Bivariate (P = 0.0002) and multivariate (P = 0.002) analysis revealed that patients who initially reported a higher level of pain measured by NRS were significantly more likely to successfully reach the ACT. This finding suggests that patients who present with more pain have more room for improvement and thus more to gain from undergoing surgery. A similar finding was shown by Hao et al classification system for the determination of LDH management. Their system, which determined whether to treat conservatively or proceed directly to surgery based on clinical and radiographic features, accounted for the degree of pain at presentation reported by the patient. Patients with higher reported pain scores were more likely to meet the criteria for bypassing conservative therapy. Implementation of this system was found to improve surgical outcomes measured by ODI.[28] These findings, taken with our own, suggest that when determining whether to proceed with conservative or surgical management, surgeons should heavily consider the patient's self-reported pain level. However, a limitation of this finding is noted in the 37% overlap in SD between mean NRS reported by patients who successfully met the threshold and those who did not.

This study has multiple limitations. Outcome metrics were limited to NRS and qualitative, self-reported data due to the unavailability of more commonly reported indices such as ODI or visual analog scale in the Stony Brook medical records. Additional limitations are the retrospective design and the incorporation of patients treated by multiple different surgeons. Finally, the statistical power of the study is relatively low due to small sample sizes for many of the variables.

CONCLUSION

We retrospectively analyzed a cohort of patients treated with discectomy for LDH. Compared with the existing literature, our cohort had similar demographic and medical history characteristics. The present study identified several factors associated with surgical outcomes. A higher level of preoperative pain was associated with better outcomes, while a history of prior fusion surgery at any level and preoperative PT was associated with poor outcomes. Preoperative PT was the single variable to demonstrate a significant correlation with all 3 measures of outcome on multivariate analysis. Prospective studies are required to better elucidate the mechanism underlying this finding and how it can be implemented into clinical practice.

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