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ORIGINAL ARTICLE

Predictors of clinical outcome following lumbar disc surgery: the value of historical, physical examination, and muscle function variables

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Abstract

Purpose Explore the relationships between preoperative findings and clinical outcome following lumbar disc surgery, and investigate the prognostic value of physical examination findings after accounting for information acquired from the clinical history.

Methods We recruited 55 adult patients scheduled for first time, single-level lumbar discectomy. Participants underwent a standardized preoperative evaluation including real-time ultrasound imaging assessment of lumbar multifidus function, and an 8-week postoperative rehabilitation programme. Clinical outcome was defined by change in disability, and leg and low back pain (LBP) intensity at 10 weeks. Linear regression models were used to identify univariate and multivariate predictors of outcome.

Results Univariate predictors of better outcome varied depending on the outcome measure. Clinical history predictors included a greater proportion of leg pain to LBP, pain medication use, greater time to surgery, and no history of previous physical or injection therapy. Physical examination predictors were a positive straight or cross straight leg raise test, diminished lower extremity strength, sensation or reflexes, and the presence of postural abnormality or pain peripheralization. Preoperative pain peripheralization remained a significant predictor of improved disability ($p = 0.04$) and LBP ($p = 0.02$) after accounting for information from the clinical history. Preoperative lumbar multifidus function was not associated with clinical outcome.

Conclusions Information gleaned from the clinical history and physical examination helps to identify patients more likely to succeed with lumbar disc surgery. While this study helps to inform clinical practice, additional research confirming these results is required prior to confident clinical implementation.

Keywords Diskectomy · Prognosis · Lumbosacral region · Physical examination · Paraspinal muscles

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Introduction

Lumbar disc herniation is the most common cause of radicular leg pain and sometimes requires surgery [1]. While rates of lumbar disc surgery have increased in the United States [2], clinical outcomes are suboptimal owing to recalcitrant pain, disability, and reduced quality of life [3, 4]. Consequently, failed disc surgery has been described as a major problem, highlighting the importance of appropriate patient selection [5].

Patient selection for lumbar disc surgery is usually based on findings from the history and physical examination. Yet, there is limited evidence to inform clinicians' knowledge of a patient's clinical course and prognosis following lumbar disc surgery [6]. Several studies have identified the prognostic value of variables extracted from the patient history. Age [7], sex [8], time to surgery [9], preoperative pain level [10], obesity [11], and time on sick leave [7], are associated with clinical outcome following lumbar disc surgery. There is conflicting evidence regarding the prognostic value of many predictors and even less is known about the role of physical examination findings [6, 12]. Moreover, the few studies that have examined the prognostic value of physical examination outcomes are prone to methodological concerns and conflicting findings [6].

Emerging evidence suggests that lumbar multifidus (LM) function has clinical relevance to patients with lumbar disc herniation being considered for surgery. Lumbar disc herniation is associated with LM atrophy and diminished LM function at the involved spinal level [13, 14], and intraoperative LM injury may contribute to the development of "failed back syndrome" [15].

There is a clear need to better identify factors that predict outcome following lumbar disc surgery. Therefore, the aims of this study were to (1) explore the relationships between preoperative clinical history, physical examination and LM muscle function with clinical outcome following lumbar disc surgery and (2) investigate the prognostic value of physical examination findings after accounting for information acquired from the clinical history.

Methods

Study design

This was a secondary analysis of a parallel group randomized clinical trial comparing two postoperative rehabilitation protocols following lumbar disc surgery [16]. As there were no between-group differences in clinical outcome, patients from both groups were combined into a single cohort for analysis in the current study. All participants underwent a standardized preoperative evaluation by trained study personnel within 2 weeks of surgery and participated in an 8-week postoperative rehabilitation programme starting 2 weeks after surgery. The participants were then re-evaluated at the end of postoperative week 10. The study protocol was approved by the Institutional Review Board of the University of Utah, and all participants provided consent prior to study enrolment.

Participants

Participants were recruited from academic and private neurological and orthopaedic spine surgery settings. We included patients aged 18–60 years, with imaging confirmed lumbar disc herniation, and identified as candidates for single-level lumbar discectomy or microdiscectomy by their spine surgeon. Potential participants were excluded if they had prior lumbar spine surgery, surgical procedures other than discectomy (e.g., fusion), or significant comorbidities or perioperative complications representing a contraindication to exercise.

Postoperative rehabilitation

The full details of the rehabilitation programmes used in this study have been reported elsewhere [16]. Briefly, at postoperative week 2, all participants underwent an 8-week exercise programme comprising weekly supervised exercise sessions and daily home exercises. Treatment consisted of a walking programme, range of motion, and trunk muscle stability exercises as well as advice about activities of daily living and health behaviours.

Potential predictors of clinical outcome

Demographic and historical variables

Demographic data included age, sex, and body mass index (BMI). Smoking status was classified as current smoking behaviour or a lifetime history of smoking at least 100 cigarettes. Potential for secondary gain was explored by asking whether the participant was currently represented by an attorney or receiving workers compensation. Additionally, we inquired about five aspects of the clinical history pertinent to their current pain episode: (1) time from episode onset to surgery, (2) previous physical therapy treatment, (3) current pain medication use, (4) previous injection therapy (e.g., epidural steroid injection) and (5) proportion of leg pain to low back pain (LBP) calculated using reports of pain intensity from numeric pain rating scales [leg pain intensity/(LBP intensity + leg pain intensity)].

Physical examination variables

Physical examinations were performed as part of the preoperative evaluation and involved tests related to neurologic status, posture and movement, as well as procedures purported to assess spinal stability. We examined participants' lower extremity sensation, strength, and muscle stretch reflexes and performed the straight leg raise [17] and cross straight leg raise [18] manoeuvres to assess for lower extremity neural tension.

Standing posture was visually evaluated for postural deformity [19] and judged to be normal or abnormal. Abnormal standing posture was defined by the presence of excessive lumbar kyphosis, or frontal plane deviation of the pelvis to the right or left. The patient's response to end-range loading was evaluated by monitoring for pain centralization and peripheralization during sustained extension in the prone position, and single and repeated repetitions of lumber extension, flexion, and side-gliding while standing. We defined centralization as occurring when the position or movement caused an individual's symptoms to move proximally toward the midline of the spine. Peripheralization was considered to occur when symptoms moved more distally away from the midline of the spine. The identification of centralization and peripheralization with these procedures has excellent interrater agreement [20].

We examined a collection of tests associated with muscular instability of the spine. During lumbar flexion testing, the presence or absence of at least one of four aberrant movement patterns were identified: instability catch, Gower sign, reversal of lumbopelvic rhythm, painful arc of motion [21]. Additionally, we examined participant's response to the prone instability test [22].

Muscle function was assessed by measuring the percent change in LM thickness from rest to submaximal contraction. We acquired brightness-mode, real-time ultrasound images using a Sonosite MicroMaxx (Sonosite Inc. Bothell, WA) and a 60-mm, 2–5 MHz curvilinear array. The contraction task involved a contralateral arm lift while the participant held a hand weight normalized to body mass. This task results in approximately 30 % of the maximum voluntary isometric contraction for the LM [23]. Three images of each muscle, in each state, were acquired on the left and right sides of the operative spinal segment [24]. Additional details have been previously reported [25] and this approach has been demonstrated to have good rater reliability [25, 26] and concurrent validity [27].

Measures of clinical outcome

Clinical outcomes were defined by change in disability and pain intensity from the preoperative assessment to the completion of the rehabilitation programme after 10 postoperative weeks. LBP related disability was assessed using the modified Oswestry Disability Questionnaire (OSW). This questionnaire has demonstrated good test–retest reliability, responsiveness, and a minimum clinically important difference (MCID) between six and ten points [28, 29]. Low back and leg pain intensity were reported on an 11-point numeric pain rating scale (NPRS) with possible scores ranging from 0 ("no pain") to 10 ("worst imaginable pain"). We measured current pain intensity as well as the "best" and "worst" pain intensity in the preceding 24 h [30] and averaged the three scores to estimate pain intensity. The NPRS has been demonstrated to have good reliability, responsiveness, criterion validity, and an MCID of two points [28, 30].

Statistical analyses

Data management and statistical analyses were performed using IBM SPSS version 21.0 software (IBM Corp, Armonk, NY). The relationships between potential predictors and clinical outcome were explored with univariate and multivariate analyses. We calculated unstandardized beta coefficients (b) from separate univariate linear regressions between the potential predictors and 10-week change scores for each clinical outcome (disability, leg pain intensity, LBP intensity). Potential predictors included clinical history, physical examination, and muscle function variables.

Variables associated with clinical outcome at the univariate stage were then entered into separate hierarchical linear regression models. To control for the variance in clinical outcome explained by information gained from the patient history, historical variables identified by the univariate analyses ($p < 0.05$) were force entered in the first step. In addition, to control for the effect of baseline clinical status on the change in outcome, the baseline score of the relevant outcome variable was also entered into the model at this point. To investigate the prognostic value of the physical examination, beyond information gained from the clinical history, physical examination variables identified by the univariate analyses ($p < 0.10$) were introduced to the model with stepwise entry. This hierarchical approach was used to determine if the presence of the physical examination variables would further improve model fit after accounting for the variance explained by historical information. Adjusted R^2 values were calculated at each step, reflecting the variance in the dependent variable explained by the independent variables and adjusted for the number of independent variables entered into the regression model. Standardized beta coefficients (β) were generated for each variable included in the final model and adjusted R^2 values were calculated at each step. Alpha was 0.05 and missing data were handled with pairwise deletion.

Results

We were unable to acquire muscle function measures from 10 participants at the preoperative assessment. The expected bony landmarks could not be visualized in 6 participants and 4 participants were unable to tolerate the test position. Thus, clinical history and physical examination data were available from 55 participants and muscle function data from 45 participants (Fig. 1). Baseline descriptive statistics and measures of clinical outcome are presented in Tables 1 and 2, respectively.

The results of the univariate analyses between the historical and physical variables and each clinical outcome are presented in Table 3. Greater baseline leg pain relative to

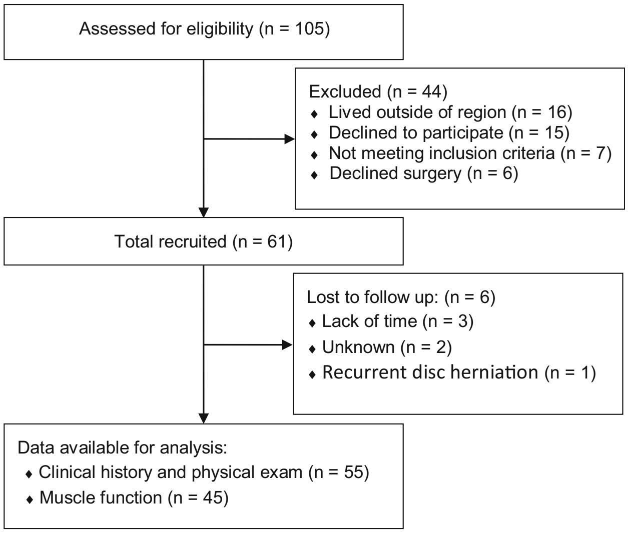

Fig. 1 Participant flow diagram

LBP was associated with more improvement in disability ($b = 0.28$, $p = 0.004$), and leg pain intensity ($b = 0.06$, $p < 0.001$), but less improvement in low back pain intensity ($b = -0.04$, $p = 0.005$). Longer time to surgery was associated with more improvement in disability ($b = 0.03$, $p = 0.030$) and more improvement in leg pain intensity was reported among participants who had received pain medication ($b = 1.97$, $p = 0.042$). Conversely, less improvement in leg pain intensity was associated with preoperative physical ($b = -1.54$, $p = 0.026$) and injection therapy ($b = -1.41$, $p = 0.049$).

Several physical examination variables were associated with clinical outcome in the univariate analyses. The presence of preoperative postural deformity was associated with greater improvement in disability ($b = 13.99$, $p = 0.029$), leg pain intensity ($b = 2.09$, $p < 0.023$), and LBP intensity ($b = 2.32$, $p < 0.003$). Greater improvement in disability was associated with the presence of a positive straight leg raise test ($b = 14.88$, $p < 0.010$), cross straight leg raise test ($b = 14.31$, $p < 0.042$), pain peripheralization ($b = 14.76$, $p < 0.036$), as well as diminished reflexes ($b = 14.10$, $p < 0.004$), sensation ($b = 12.44$, $p < 0.012$) or strength ($b = 11.87$, $p < 0.016$) prior to surgery. Finally, having a positive straight leg raise test ($b = 2.43$, $p < 0.003$), or strength deficit ($b = 1.54$, $p < 0.031$) was associated with more improvement in leg pain intensity. There were no relationships between LM function and clinical outcome.

The results of the multivariate analyses are presented in Tables 4, 5 and 6. After controlling for the variance attributable to the baseline outcome score and significant historical predictors from the univariate analyses, the presence of pain peripheralization at baseline was associated with greater improvement in both disability ($\beta = 0.24$, $p = 0.044$) and low back pain intensity ($\beta = 0.33$, $p = 0.002$) after 10 postoperative weeks. Physical examination variables were not associated with change in leg pain intensity after controlling for the variance explained by baseline leg pain intensity and information from the clinical history. The total variance in clinical outcome explained by each of the final models (adjusted R^2 values) ranged from 31 to 61 % ($p < 0.05$).

Table 1 Baseline clinical history, physical examination, and muscle function variables

	Measure
Clinical history variables ($N = 55$)	
Age (years)	40.7 (9.2)
Female sex (*n*, %)	27, 49.1
Body mass index	29.1 (6.6)
Time from episode onset to surgery (days)[a]	148.0 (164.0)
Disability (0–100)	42.8 (14.6)
Low back pain intensity (0–10)	4.0 (2.4)
Leg back pain intensity (0–10)	5.6 (2.4)
Proportion leg pain (%)	58.3 (23.9)
Currently taking pain medication (*n*, %)	48, 87.3
Smoking lifetime (*n*, %)	14, 25.5
Smoking current (*n*, %)	2, 3.6
Legal representation (*n*, %)	2, 3.6
Workers compensation (*n*, %)	2, 3.6
Previous physical therapy (*n*, %)	26, 47.3
Previous injection therapy (*n*, %)	34, 61.8
Physical examination variables ($N = 55$)	
Straight leg raise test (*n*, %)	42, 76.4
Cross Straight leg raise test (*n*, %)	8, 14.6
Lower extremity strength deficit (*n*, %)	29, 52.7
Sensory deficit (*n*, %)	31, 56.4
Loss of lower extremity MSR (*n*, %)	25, 45.5
Centralization (*n*, %)	18, 32.7
Peripheralization (*n*, %)	47, 85.5
Prone instability test (*n*, %)	11, 20.0
Postural abnormality (*n*, %)	10, 18.2
Aberrant flexion movement (*n*, %)	17, 31.0
Lumbar multifidus muscle function variables ($N = 45$)	
Percent thickness change on side of surgery[b]	4.5 (12.7)
Percent thickness change contralateral to surgery[b]	4.4 (6.9)

Values are mean (standard deviation) unless otherwise specified

[a] Median (interquartile range)

[b] Measured at spinal level of surgery

Discussion

This was the first study to investigate the value of physical examination findings, beyond the information gained from the patient history, as well as the role of preoperative LM

Table 2 Baseline and 10-week follow-up clinical outcome variables

Outcome variable ($N = 55$)	Baseline	10 weeks	Change
Disability (0–100)	42.8 (14.6)	13.9 (15.6)	28.9 (17.7)
Leg pain intensity (0–10)	5.6 (2.4)	1.2 (1.6)	4.4 (2.5)
Low back pain intensity (0–10)	4.0 (2.4)	1.7 (1.9)	2.4 (2.2)

Values are mean (standard deviation)

Table 3 Univariate analyses

	Change in disability	Change in leg pain intensity	Change in LBP intensity
Clinical history variables ($N = 55$)	*b*	*b*	*b*
Age (years)	−0.10	0.06	−0.06
Sex	−3.30	0.00	0.01
Body mass index	−0.10	−0.01	0.04
Smoking in lifetime	0.47	−0.40	0.26
Current pain medication	12.50	**1.97***	0.21
Proportion leg pain (%)	**0.28****	**0.06****	**−0.04****
Time to surgery (days)	**0.03***	0.00	0.00
Previous physical therapy	−3.64	**−1.54***	−0.26
Previous injection therapy	−4.18	**−1.41***	−0.27
Physical examination variables ($N = 55$)			
Straight leg raise test	**14.88****	**2.43****	0.65
Cross straight leg raise test	**14.31***	1.17	−0.22
Lower extremity strength deficit	**11.87***	**1.54***	0.76
Sensory deficit	**12.44***	0.91	0.46
Diminished lower extremity MSR	**14.10****	1.21	−0.11
Centralization	−3.27	−0.84	−0.06
Peripheralization	**14.76***	**1.70**	**1.63**
Prone instability test	−8.18	0.55	−0.68
Postural abnormality	**13.99***	**2.09***	**2.32****
Aberrant movement	−8.46	−0.02	0.60
Lumbar multifidus muscle function variables ($N = 45$)			
Percent thickness change on side of surgery[a]	−0.23	−0.73	−1.50
Percent thickness change contralateral to surgery[a]	−0.59	0.59	2.26

Unstandardized beta coefficients between clinical history, physical examination, and muscle function variables and clinical outcome

Bolded estimates are statistically significant at $p < 0.10$; * $p < 0.05$; ** $p < 0.01$

MSR muscle stretch reflex, *LM* lumbar multifidus

[a] Measured at spinal level of surgery

function among patients undergoing lumbar disc surgery and postoperative rehabilitation. We identified several preoperative variables from the clinical history and physical examination with evidence of prognostic importance, as demonstrated by their relation to clinical outcome. The multivariate analyses indicated that the presence of preoperative pain peripheralization was associated with improved disability and low back pain intensity, even after accounting for the variance explained by information from the patient's clinical history. Preoperative LM function demonstrated no relationship with clinical outcome following lumbar disc surgery and postoperative rehabilitation.

Previous studies have not examined the prognostic value of pain peripheralization among patients undergoing lumbar disc surgery. However, one previous study reported that among patients with low back pain and sciatica, the presence of pain peripheralization was associated with improved outcome following therapeutic lumbar traction and exercise [31]. While pain centralization has been shown in several previous studies to be a positive prognostic indicator for patients with lumbar spine disorders undergoing

Table 4 Hierarchical linear regression analysis of the relationship between preoperative physical examination variables and change in back pain related disability following lumbar disc surgery, controlling for baseline disability, proportion of leg pain, use of current pain medication, and time to surgery

Variable	Adjusted R^2	R^2 change significance	Standardized β coefficient[a]	β coefficient significance[a]
Variables from the clinical history entered in step 1	0.35	<0.001		
Baseline disability			0.46	<0.001
Proportion leg pain			0.19	0.117
Time to surgery (days)			0.15	0.203
Variables from the physical exam entered in step 2	0.39	0.044		
Pain peripheralization			0.24	0.044

[a] From final model

Table 5 Hierarchical linear regression analysis of the relationship between preoperative physical examination variables and change in leg pain intensity following lumbar disc surgery, controlling for proportion of leg pain, use of current pain medication, and time to surgery

Variable	Adjusted R^2	R^2 change significance	Standardized β coefficient	β coefficient significance
Variables from the clinical history entered in step 1	0.61	<0.001		
Baseline leg pain intensity			0.65	<0.001
Proportion leg pain			0.10	0.369
Previous injection			−0.08	0.450
Previous physical therapy			−0.13	0.224
Use of pain medication			0.09	0.351
Variables from the physical exam entered in step 2	–	–	–	–

Table 6 Hierarchical linear regression analysis of the relationship between preoperative physical examination variables and change in low back pain intensity following lumbar disc surgery, controlling for proportion of leg pain, use of current pain medication, and time to surgery

Variable	Adjusted R^2	R^2 change significance	Standardized β coefficient[a]	β coefficient significance[a]
Variables from the clinical history entered in step 1	0.46	<0.001		
Baseline LBP intensity			0.69	<0.001
Proportion leg pain			−0.05	0.660
Variables from the physical exam entered in step 2	0.55	0.002		
Pain peripheralization			0.33	0.002

[a] From final model

non-operative therapy [32], it was not associated with outcome following surgery in the current study. Traditional methods of identifying change in leg pain location in response to changes in spinal movement or position have been reported to have unacceptable rater agreement [33]. We assessed pain peripheralization using a simplified approach with excellent interrater agreement. Therefore, this method may be of value to clinicians evaluating patients being considered for lumbar disc surgery.

From a clinical perspective, it is reassuring that many of the physical examination predictors of clinical outcome included findings thought to be typical of patients with lumbar disc herniation. While this finding accords with several previous studies [34–36], it conflicts with others [37, 38]. A more consistent predictor of outcome following lumbar disc surgery has been the presence of predominant leg pain [36, 37], a finding which agrees with our results.

The current study results should be considered in light of several limitations. We explored the associations of preoperative predictors with 10-week clinical outcomes, thus their relevance to long-term outcome is unknown. Nonetheless, previous research indicates that 2-month outcomes following lumbar disc surgery are strongly associated with clinical status after 14 postoperative months, therefore the value of these predictors may extend to longer duration follow-up [39]. While there was some variation of predictors between the different outcome measures, this is consistent with previous research indicating that most patients report inconsistent outcomes following lumbar spine surgery when multiple measures are implemented [40]. Finally, the sample size relative to the number of predictor variables in some analysis may have resulted in suboptimal statistical power and model overfit.

Information gleaned from the clinical history and physical examination was associated with clinical outcome following lumbar disc surgery and postoperative rehabilitation. After accounting for the variance explained by the clinical history, the presence of preoperative pain peripheralization predicted a better clinical outcome. While this study may inform clinical practice, additional research confirming these results should be carried out prior to confident implementation by clinicians.

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Conflict of interest The authors declare no conflicts of interest.

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