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Clinical Studies

Which North American spine society disc herniation morphology descriptors are most associated with improvements in clinical outcomes after microdiscectomy?

Rajkishen Narayanan, MD[a,*], Teeto Ezeonu, BA[a], Jeremy C. Heard, MD[b], Yunsoo A. Lee, MD[a], Caleb M. Yeung, MD[a], Tyler Henry, MD[a], Alec Kellish, MD[a], Meera Kohli, BS[a], Jose A. Canseco, MD, PhD[a], Mark F. Kurd, MD[a], Alan S. Hilibrand, MD[a], Alexander R. Vaccaro, MD, PhD, MBA[a], Gregory Schroeder, MD[a], Christopher Kepler, MD, MBA[a], Ian David Kaye, MD[a]

[a] *Department of Orthopaedic Surgery, Rothman Orthopaedic Institute, Philadelphia, PA 19107, United States*
[b] *Department Orthopaedics, Brown University, Providence, RI 02912, United States*

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ABSTRACT

Background: The North American Spine Society (NASS) assembled the first ever comprehensive naming system for describing lumbar disc disease, including lumbar disc herniation. The objectives of this study were (1) to determine which NASS descriptors are most predictive of independent patient-reported outcomes after microdiscectomy and (2) to identify the inter-rater reliability of each NASS descriptor.

Methods: Adult patients (≥18 years) who underwent a lumbar microdiscectomy from 2014-2021 were retrospectively identified. Patient-reported outcome measures (PROMs) were collected at preoperative, 3-month, and 1-year postoperative time points. Lumbar disc herniations were evaluated and classified on preoperative MRI using the NASS lumbar disc nomenclature specific to disc herniation.

Results: About 213 microdiscectomy patients were included in the final analysis. Herniation descriptors exhibiting the greatest reliability included sequestration status (κ=0.83), axial disc herniation area (κ=0.83), and laterality (κ=0.83). The descriptor with the lowest inter-rater reliability was direction of migration (κ=0.53). At 3 months, a sequestered herniation was associated with lower odds of achieving the minimal clinically important difference (MCID) for ODI (p=.004) and MCS (p=.032). At 12 months, a similar trend was observed for Oswestry Disability Index (ODI) MCID achievement (p=.001). At 3 months, a herniation with larger axial area was a predictor of MCID achievement in ODI (p=.004) and the mental component summary (MCS) (p=.009). Neither association persisted at 12 months; however, larger axial disc herniation area was able to predict MCID achievement in the Visual Analogue Scale (VAS) leg (p=.031) at 12 months.

Conclusions: The utility of the NASS nomenclature system in predicting postoperative outcomes after microdiscectomy has yet to be studied. We showed that sequestration status and disc area are both reliable and able to predict the odds of achieving MCID in certain clinical outcomes at 3 months and 12 months after surgery. Hence, preoperative imaging analysis of lumbar disc herniations may be useful in accurately setting patient expectations.

Background

Lumbar disc herniation is among the most common reasons for disability in the US [1,2]. Imaging analysis can provide useful information for making the diagnosis and determining the severity of disc herniation, both of which guide decision-making for herniation management. While many disc herniations will initially be treated nonoperatively, using stretching exercises, pain management, and steroid injections, in

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* Corresponding author: Rothman Orthopaedic Institute at Thomas Jefferson University, 925 Chestnut St, 5th Floor Philadelphia, PA 19107, Phone: (215) 955-6060, Fax: (215) 503-5651.

E-mail address: rajkishen.narayanan@gmail.com (R. Narayanan).

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more severe cases, surgeons may opt to manage disc herniations operatively. In these cases, discectomy is the favored approach [3].

MRI analysis of herniations can be used to guide management beyond symptom considerations. Previous studies have shown that location and herniation morphology are important factors to consider when deciding between operative and nonoperative management of herniations [4,5]. Divi et al. showed that disc herniations in a paracentral location were more likely to undergo operative management than centrally located herniations [4]. Separately, Carlisle et al. showed that larger disc herniations and herniations with greater canal area compromise were more likely to be treated operatively [5]. Still, there exists wide variation in the language used to describe disc herniations [6].

In 2001, the North American Spine Society (NASS) assembled the first ever comprehensive naming system for lumbar disc disease [7]. Prior to the development of the NASS nomenclature system, there was significant variation in the way lumbar disc disease was described [7,8]. Hence, it was difficult to provide guidance on the treatment of various spinal diseases given the varying natures. The NASS nomenclature system provided a common language for practitioners to consistently and accurately characterize lumbar disc morphology, including lumbar disc herniations. While this system has been effective in standardizing disc herniation characteristics, it has not yet been demonstrated how this classification system can be used to predict clinical outcomes.

Therefore, the objectives of this study were (1) to determine which NASS descriptors are most predictive of independent patient-reported outcomes after microdiscectomy and (2) to identify the inter-rater reliability of each NASS descriptor.

Methods

Upon obtaining Institutional review board (IRB) approval, all patients older than or equal to 18 years who underwent a lumbar microdiscectomy from 2014 to 2021 at a single academic institution were retrospectively identified. Patient consent was not required for this study as determined by our institution's IRB committee. The CPT codes 630330 and 63047 were used to identify a comprehensive list of patients undergoing single level decompression. Manual review of patient charts was done to confirm that a decompression with discectomy in the lumbar spine was the procedure performed. Patients were excluded if a preoperative MRI was not identified through chart review or if there was no PROM data at 1-year follow-up.

Data extraction

A Structured Query Language search was supplemented with manual chart review to extract patient demographics, surgical characteristics, and admissions data from patient charts. Demographic data included age, sex, race, body mass index (BMI), diabetes status, smoking status (non-smoker, current smoker, former smoker), and Elixhauser Comorbidity Index (ECI). Surgical characteristics included specific levels decompressed, 90-day surgical readmissions, the reason for 90-day surgical readmission (including cerebral spinal fluid leak, infection, and same level re-herniation), spine revision surgery within 1 year, and the reason for revision surgery. Patient-reported outcome measures (PROMs) were collected at preoperative, 3-month, and 1-year postoperative time points. The following were included in our analysis: Oswestry Disability Index (ODI), the Mental and Physical Component Summary of the Short Form-12 survey (MCS-12 and PCS-12), and the Visual Analog Scale Back and Leg (VAS Back and VAS Leg, respectively). The change in PROM at each time point was calculated by subtracting the preoperative PROM from the 3-month and 1-year postoperative PROM. The minimum clinically important differences (MCID), as described by Parker et al., were employed to compare groups for each respective PROM (14.9 for ODI, 4.7 for MCS-12, 8.1 for PCS-12, 2.1 for VAS back, 2.8 for VAS leg) [9].

Radiologic analysis

Preoperative MRIs were retrieved from our institution's PACS system Sectra Workstation IDS7 18.2 (Sectra AB). Each MRI was evaluated and classified by 2 independent reviewers, including an orthopedic surgery resident and a spine fellow in training. Each herniation was classified using the North American Spine Surgery lumbar disc nomenclature specific to disc herniation [7,10]. Characteristics for classification included (1) area of axial disc herniation, (2) area of central canal, (3) percent central canal displacement, (4) focal vs. broad-based displacement, (5) protrusion vs. extrusion, (6) sequestered vs. unsequestered, (7) laterality, (8) migration, (9) extent of migration, and (10) presence of a Schmorl node. In accordance with the NASS disc nomenclature, herniations were classified as protrusion or extrusion based on the shape of the displaced material. Protrusion was used to characterize herniations where the greatest measure of displaced material, in any plane, was less than the measure of the base of displaced disc material, when measured in the same plane. In contrast, extrusion described herniations where the greatest measure of the displaced disc material was greater than the base of the displaced disc material at the disc space of origin, when measured in the same plane. Focal herniations were defined as protrusions with a base less than 25% (90°) of the circumference of the disc. If the protrusion encompassed 25% to 50% of the disc circumference, it was classified as "broad-based protrusion." Laterality of the herniation was classified as either central, subarticular, foraminal, or extraforaminal. Migration was classified as either inferior or superior.

Statistical analysis

Descriptive statistics, including *n* with percentages, were reported for patient demographics, surgical characteristics, readmissions, and revisions data. Backwards multivariate logistic regressions were used to analyze the ability of each herniation characteristic to predict achievement of MCID in PROMs at 3- and twelve-month time points. Inter-rater reliability of each NASS descriptor was assessed using Cohen's kappa coefficient, with a coefficient >0.75 as excellent inter-rater reliability. Statistical significance was set at $p<.05$. All statistical analyses were performed using R Studio Version 4.02.

Results

Patient demographics, surgical characteristics, and surgical outcomes

After SQL search and exclusion based on lack of MRI and/or PROMs, a total of 213 patients were included in the final analysis. One hundred-twenty four males (58.2%) and 89 females (41.8%) were identified with a mean age of 44.1±12.8 years (Table 1). Most patients underwent microdiscectomy at either L5-S1 (61.0%) or L4-L5 (34.3%) levels. There was a total of 5 (2.35%) 90-day readmissions and 12 (5.63%) revisions.

Disc descriptors and reliability

Inter-rater reliability was analyzed using Cohen's kappa coefficient. Central canal area (κ=0.83), and sequestration status (κ=0.83), exhibited the greatest reliability between observers Other herniation descriptors with high reliability included axial disc herniation area (κ=0.83), laterality (κ=0.83), and percent central canal involvement (κ=0.82). The descriptor with the lowest inter-rater reliability was direction of migration (κ=0.53) (Table 2).

Variables predicting improvement in patient-reported outcome measures

Multivariable logistic regressions were used to assess the ability of each disc characteristic to predict achievement of MCID for patient-reported outcomes at 3- and 12-months postoperatively (Table 3 and Table 4). At 3 months, a sequestered herniation was associated with

Table 1
Demographic and surgical characteristics.

Characteristic	N=213
Age	44.1 (12.8)
Sex	
Female	89 (41.8%)
Male	124 (58.2%)
Body Mass Index	28.5 (5.95)
Diabetes Diagnosis	17 (7.98%)
Smoking	
None	172 (80.8%)
Current	19 (8.92%)
Former	22 (10.3%)
Elixhauser Comorbidity Index	0.47 (0.79)
Total Levels	1.01 (0.12)
L2-L3	3 (1.41%)
L3-L4	7 (3.29%)
L4-L5	73 (34.3%)
L5-S1	130 (61.0%)
90 day Readmissions	5 (2.35%)
CSF Leak	2 (0.94%)
Infection	1 (0.47%)
Same Level Herniation	1 (0.47%)
Revisions	12 (5.63%)
Same Level Herniation	10 (4.69%)
Adjacent Level Herniation	1 (0.47%)
Other	1 (0.47%)

Table 2
Disc herniation characteristics and inter-rater reliability.

Disc Herniation Descriptor	Average	Cohen's Kappa
Area of Axial Disc Herniation (mm^2)	115.4	**0.83**
Area Central Canal (mm^2)	282.9	**0.88**
Percent Central Canal Involvement	41.9%	**0.82**
Broad Based? (ref: Focal)	19.7%	0.69
Extrusion? (ref: Protrusion)	43.7%	0.61
Sequestered? (ref: Unsequestered)	10.8%	**0.88**
Laterality		**0.82**
Central	20.7%	
Subarticular	61.5%	
Foraminal	15.0%	
Extraforaminal	2.3%	
Migration		0.53
Superior	13.1%	
Inferior	86.7%	
Inferior Migration Disc level? (ref: Below Disc Level Herniation)	54.3%	0.61
Schmorl Node	6.6%	0.62

lower odds of achieving MCID for ODI (OR=0.11, p=.004) and MCS (OR=0.25, p=.032), in comparison to non-sequestered herniations. At 12 months, a similar trend was observed for ODI MCID achievement (OR = 0.07, p=.001), but sequestration status no longer predicted MCS MCID achievement. At 3 months, a herniation with larger axial area was a predictor of MCID achievement in ODI (OR=1.03, p=.004) and MCS (OR=1.02, p=.009). Neither association persisted at 12 months; however, larger axial disc herniation area was able to predict MCID achievement in VAS leg (OR=1.05, p=.031) at 12 months. A larger central canal area did not predict improvement in any PROM at 3 months, but by 12 months, it was associated with lower odds of achieving MCID in VAS leg (OR=0.98, p=.042). Greater percent central canal involvement was not predictive of MCID achievement at 3 months, but at 12 months, it predicted MCS MCID achievement (OR=1.07, p=.001). At 3 months, an extruded herniation was found to predict lower odds of MCID achievement in PCS, compared to protruded herniations (OR=0.37, p=.035) and at 12 months, an extruded herniation predicted lower odds of MCID achievement in MCS (OR=0.34, p=.042) and in VAS Leg (OR=0.4, p=.037). Herniation descriptors that were not found to predict achievement of

Table 3
Backwards multivariate regression analysis for 3-month PROM MCID achievement.

Disc Characteristics	3 month ODI MCID				3 Month MCS MCID				3 Month PCS MCID				3 Month VAS Back MCID				3 Month VAS Leg MCID			
	Odds Ratio	Lower 95	Upper 95	P Value	Odds Ratio	Lower 95	Upper 95	P Value	Odds Ratio	Lower 95	Upper 95	P Value	Odds Ratio	Lower 95	Upper 95	P Value	Odds Ratio	Lower 95	Upper 95	P Value
Sequestered	**0.11**	**0.02**	**0.48**	**0.004**	**0.25**	**0.07**	**0.87**	**0.032**												
Area of Axial Disc Herniation	**1.03**	**1.01**	**1.05**	**0.004**	**1.02**	**1.004**	**1.03**	**0.009**	1.01	1	1.03	0.058					1.04	0.99	1.09	0.069
Area of Central Canal																	0.99	0.97	1	0.095
Percent Central Canal																	0.91	0.81	1.01	0.08
Broad Based	0.22	0.04	1.1	0.061																
Extrusion									**0.37**	**0.14**	**0.92**	**0.035**								
Schmorl Node																				
Zone:																				
Central	Ref.																			
Subarticular									0.71	0.23	2.07	0.536								
Foraminal									0.29	0.07	1.19	0.094								
Extraforaminal									0.02	0.003	1	0.059								
Regression AUC	0.787				0.680				0.721				0.640				0.692			

MCID, minimal clinically important difference; MCS, mental component score (of SF-12); PCS, physical component score (of SF-12); ODI, Oswestry Disability Index; VAS, Visual Analogue Scale; AUC, area under the curve.
Bolded p values indicate statistical significance.

Table 4
Backwards multivariate regression analysis for 12-month PROM MCID achievement.

Disc Characteristics	12 month ODI MCID				12 Month MCS MCID				12 Month PCS MCID				12 Month VAS Back MCID				12 Month Vas Leg MCID			
	Odds Ratio	Lower 95	Upper 95	P Value	Odds Ratio	Lower 95	Upper 95	P Value	Odds Ratio	Lower 95	Upper 95	P Value	Odds Ratio	Lower 95	Upper 95	P Value	Odds Ratio	Lower 95	Upper 95	P Value
Sequestered	**0.07**	**0.01**	**0.28**	**0.001**																
Area of Axial Disc Herniation									0.95	0.88	1.01	0.095					**1.05**	**1.01**	**1.11**	**0.031**
Area of Central Canal									1.02	0.99	1.05	0.17					**0.98**	**0.96**	**0.99**	**0.042**
Percent Central Canal					**1.07**	**1.03**	**1.11**	**0.001**	1.18	1	1.43	0.057					0.89	0.78	1	0.067
Broad Based													0.51	0.21	1.24	0.139	0.37	0.12	1.17	0.087
Extrusion	0				**0.34**	**0.11**	**0.93**	**0.042**									**0.4**	**0.16**	**0.93**	**0.037**
Schmorl Node	3.61	0.68	30.31	0.168																
Zone:																				
Central																				
Subarticular																				
Foraminal																				
Extraforaminal																				
Regression AUC	0.71				0.713				0.679				0.551				0.724			

MCID, minimal clinically important difference; MCS, Mental Component Score (of SF-12); PCS, Physical Component Score (of SF-12); ODI, Oswestry Disability Index; VAS, Visual Analogue Scale; AUC, area under the curve.
All regressions were built in a backwards stepwise manner including demographic and surgical characteristics.

MCID in any PROM at the 3- or 12-month time points included focal vs. broad protrusion, presence of a Schmorl node, and zone of herniation.

Discussion

The introduction of the NASS nomenclature system allows for a common language to be used when describing disc herniations [7]. Previous studies have found correlations between herniation morphology and outcomes after surgery [11,12]. However, no study has specifically evaluated the prognostic utility of the NASS nomenclature system. Here we present the first study that assesses the reliability of NASS lumbar disc herniations descriptors and their correlation to patient-reported outcomes after microdiscectomy.

Of all the NASS herniation descriptors we evaluated, there were 3 descriptors which predicted MCID achievement during both the immediate postoperative period (3 months) and in the long-term postoperative period (12 months) including 1) sequestration status, 2) axial disc herniation area, and 3) extrusion status. Previous research has shown that sequestration status is a useful predictor of postoperative clinical outcomes [13–15]. We found that patients with sequestered herniations experienced lower odds of achieving MCID for ODI at 3 months and 12 months. In contrast, Kerr et al. examined subgroups of patients with disc herniation and showed that patients with sequestered herniations experienced significantly more improvement in ODI than patients with extruded or protruding herniations [13]. In addition to predicting changes in ODI, sequestered discs have also been associated with changes in VAS scores postoperatively [14,16]. Dewing et al. conducted a prospective clinical trial and found that patients with sequestered discs had better VAS and ODI scores compared to patients with extruded or contained herniations [14]. Similarly, Sucuoglu et al. showed that patients with sequestered lumbar disc herniations experienced significant improvements in VAS and ODI scores up to 6 months after surgery [16]. In contrast to previous research, we found no association between sequestration and VAS scores at 3 or 12 months. Rather, we found that only a greater axial disc herniation area could predict improvement in VAS leg at 12 months. We also found that a non-sequestered herniation was predictive of MCID achievement for MCS at 3 months, which has not been previously reported.

Intuitively, it makes sense that herniation size would be a significant predictor of improvement after surgery. Nevertheless, while there are several trends that indicate that larger disc herniations are more likely to be managed operatively, there is not substantial consensus regarding an association between herniation size and clinical outcomes [5,17]. Chen et al. sought to identify factors associated with poor surgical outcomes (as defined by MacNab scores and reoperation rates) and found that percent canal compromise, an indication of herniation size, was not associated with poor outcomes [11]. Similarly, Gupta et al. examined whether herniation size was predictive of the need for surgical intervention and found that the size of the herniation and the percentage of the canal that was occupied did not predict failure of nonoperative of management. Furthermore, while the patients who underwent surgery had slightly larger disc herniations (31.5% canal occupation vs. 31.2%), this difference was not significant [17]. In contrast to these findings, Carlisle et al. found that patients treated with surgery were more likely to have larger disc herniation areas and smaller canal cross-sectional areas than patients in the nonoperative group [5]. Our analysis found that axial disc herniation area was associated with MCID achievement for ODI and MCS at 3 months. In contrast to previous research, our data suggest that disc herniation size is associated with clinical outcomes. Interestingly, at 12 months there was no longer a significant difference in MCID achievement in ODI and MCS; however, the percent of the central canal occupied by the disc herniation predicted MCID achievement in MCS scores. Furthermore, disc herniation size predicted improvement in VAS leg scores at 12 months. As patients with lumbar disc herniations often experience distressing leg pain due to nerve root compression, these findings are not surprising [18,19].

We showed that extruded herniations were associated with lower odds of achieving MCID for PCS at 3 months and a similar trend for MCS and VAS leg at 12 months. In contrast, Chen et al. showed that extruded herniations were the least likely to be associated with poor surgical outcomes when compared to prolapsed and sequestered herniations [11]. The NASS herniation system is unique in that it categorizes herniations based on sequestration status and protrusion status. Previous studies analyzing disc herniation morphology often categorize herniations as sequestered, protruded, or extruded [11,13]. We found that defining herniations as sequestered vs nonsequestered was reproducible and one of the most reliable ways to categorize a lumbar disc herniation. However, defining herniations as extruded vs. protruded was far less replicable and demonstrated among poor reliability. Taken together, it is difficult to make a strong conclusion on the association that herniation extrusion has on postoperative clinical outcomes.

There is limited research evaluating how zones of disc herniation can predict postoperative outcomes. Previous studies have focused more on how herniation zone can be used to predict the need for surgery [4,5,11,13,20]. In a retrospective study, Divi et al. showed that patients with disc herniations in the paracentral location were more likely to undergo operative treatment than those with centrally located herniations [4]. Chen et al. found that herniation extension was not predictive of poorer surgical outcomes [11]. While our study is the first to assess how herniation location can be used to predict patient-reported outcomes, we found that herniation zone was not useful in predicting improvement in any outcome.

Our study is not without limitations. We excluded patients who did not have PROM data at 1-year postoperatively, which may have caused some selection bias. Additionally, each disc herniation was graded by 2 independent observers and some herniation descriptors exhibited low reliability between raters. This poor reliability may have affected our ability to assess the relationship of each descriptor to changes in PROMs. Furthermore, we did not conduct a power analysis to determine the appropriate sample size and thus it is possible that this study may not be sufficiently powered to accurately discern a statistically significant difference. Nevertheless, as this is the first study to comprehensively analyze the reliability of herniation descriptors and the association with patient-reported outcomes, this study provides valuable information on the NASS nomenclature system.

Conclusion

Associations of the NASS nomenclature system with postoperative outcomes after microdiscectomy has yet to be studied. We showed that sequestration status and area of axial disc herniation based on MRI imaging are both reliable and associated with achieving MCID in certain clinical outcomes at 3 months and 12 months after surgery. Percent of the central canal occupied by the disc herniation was another reliable metric associated with 12 month MCS scores. Extrusion was not a reliable herniation descriptor though it was associated with improvement in multiple clinical outcomes. Furthermore, we found that herniation zone was least likely to be associated with improvement in any clinical outcome. As this study is the first to evaluate this nomenclature system, additional investigation is needed to support our findings on the reliability and efficacy of the NASS system.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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