Recurrent Lumbar Disc Herniation After Tubular Microdiscectomy: Analysis of Learning Curve Progression

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OBJECTIVE: **Tubular microdiscectomy has become a staple technique among spine surgeons. Yet the associated learning curve, especially its later stages, has not been extensively studied. With studies reporting a higher rate of recurrent herniation using tubular microdiscectomy, surgeons' level of experience becomes of primary importance for the interpretation of such findings. We aimed to analyze possible improvements in the later stages of the learning curve and to identify factors independently associated with recurrent herniation.**

METHODS: **A retrospective study was conducted using prospectively collected data from a consecutive cohort of all 1241 patients operated for single-level lumbar disc herniation with tubular microdiscectomy by a single surgeon who already had extensive experience with this technique. We collected demographic and perioperative data and consequently tracked all complications, recurrent herniations, and other reoperations. In addition, 495 patients (40%) provided complete outcome scores on a numeric rating scale for back and leg pain and the Oswestry Disability Index at baseline, 6 weeks, and 12 months postoperatively.**

RESULTS: **A decrease in surgical time ($P < 0.001$) and recurrent herniations was observed ($P = 0.012$) over time. Increased leg pain at 6 weeks was independently associated with recurrent herniation ($P = 0.01$). Fifty-six patients (4.5%) experienced ipsilateral recurrent herniation.**

CONCLUSIONS: **Relevant improvements in clinical results were seen even after the surgeon had already accumulated extensive experience. Any future studies should unambiguously report the level of experience of the participating surgeons, possibly including the number of cases previously treated using a particular technique.**

INTRODUCTION

Minimally invasive (MI) surgery has become exceedingly popular with surgeons and patients alike, even to the extent that patients often elect an MI approach themselves. In 1934, the first surgical procedure for lumbar disc herniation (LDH) was described,[1] and MI variants have been increasingly developed since. Even although many benefits of MI discectomy have been methodologically demonstrated, criticism remains.[2-4] Some studies report worse patient-reported outcome measures (PROM), higher incidences of complications, and more recurrent LDH with MI techniques.[2,5,6] It is often claimed that this is because of poor visualization of the anatomy. These disadvantages may be caused by a steep learning curve and the fact that some neurosurgeons perform discectomies sporadically, secondary to cranial procedures.[7] It is often quoted that 10,000 hours of dedicated practice are necessary to achieve mastery in any skill. For MI surgery, it certainly holds true that the more surgeries one performs, the more consistent the results will be.

Tubular microdiscectomy (tMD) using an endoscope or microscope was quickly adopted as a standard of care after its introduction in 1997.[8] The late progression of the learning curve for tMD has not been extensively studied.[9] Consequently, more research is needed to understand whether significant

Key words
- Complication
- Discectomy
- Herniated disc
- Learning curve
- Minimally invasive
- Recurrence
- Tubular

Abbreviations and Acronyms

ASA: American Society of Anesthesiologists
BMI: Body mass index
LDH: Lumbar disc herniation
MI: Minimally invasive
NRS: Numeric rating scale
ODI: Oswestry Disability Index
PROM: Patient-reported outcome measures
tMD: Tubular microdiscectomy

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improvements in the rate of recurrence, complications, surgical time, or PROM can be achieved even after extensive experience with tMD.

We analyzed a cohort of 1241 consecutive patients who underwent tMD for LDH and investigated the late learning curve progression, as well as the rate of recurrent LDH and its independently associated factors.

METHODS

Study Population

Patients were treated using tMD in an outpatient setting. All operations eligible for inclusion were performed by a single surgeon (M.S.) with extensive experience in tMDs (>2000 cases) at a single center. Preoperative inclusion criteria were single-level LDH confirmed using magnetic resonance imaging and failed conservative management for ≥8 weeks. Patients were not considered for surgery if they were aged >80 years, had a body mass index (BMI, kg/m^2) of >33, presented with malignancy or severe scoliosis (Cobb angle >30°), or had an American Society of Anesthesiologists (ASA) score >2. This situation is the result of local policies imposed on outpatient clinics by the insurance companies.

All consecutive cases of first-time tMD for LDH were included in our analysis, with a follow-up threshold of ≥6 months. Patients who did not present with a virgin disc (e.g., those with a previous history of discectomy who were referred to us from another center) were excluded. This study was approved by the Dutch Central Committee on Research Involving Human Subjects. Because this was a retrospective study of routinely collected data, no individual patient consent was sought.

Data Evaluation

The data were prospectively collected and all complications, recurrences, and reoperations were registered. Recurrent LDH was defined as a return of preoperative pain symptoms after a pain-free period, combined with ipsilateral nerve root compression visible on magnetic resonance imaging that necessitated surgical revision.[10] Gender, age, BMI, height, weight, smoking status, and ASA scores were noted. The level and side of the herniation, time of day at incision, surgical time, and length of stay were recorded. As a secondary end point, PROMs were digitally and automatically requested via e-mail and recorded using a numeric rating scale (NRS) and Oswestry Disability Index[11] (ODI) at baseline, 6 weeks, and 12 months, postoperatively. To identify any improvements throughout the study period, the patient numbers were stratified into quarters.

Surgical Technique

The surgical technique was consistent during the study period. All procedures were carried out using binoculars and a headlight. Under general anesthesia, the patient was placed in the knee-elbow position and the index level was identified using fluoroscopy. A 20-mm paramedian skin incision was made and a Kirschner wire was advanced onto the lamina of the vertebra. Several tubes of increasing diameter were used to dilate the musculature and a working channel with a diameter of 20 mm was inserted (METRx System [Medtronic, Dublin, Ireland]). After the nerve root was carefully manipulated, the prolapsed disc material was removed, and the disc space was cleared of all loose material. In all cases of incidental durotomy, the dura was sutured through the same working channel using bayonet microforceps and sealed with TachoSil (Takeda, Osaka, Japan). In rare cases of ventral durotomy, when suturing of the dura was impossible, repair was achieved by first injecting the disc space with Tissucol (Baxter, Deerfield, Illinois, USA) to provide enough resistance, followed by wedging a small piece of TachoSil in between the dural defect and the packed disc.

Table 1. Demographic and Baseline Characteristics

Characteristic	Value
Male gender, n (%)	661 (53)
Age (years), mean ± SD	44.8 ± 11.8
Body mass index (kg/m^2), mean ± SD	25.4 ± 3.5
Weight (kg), mean ± SD	81.0 ± 13.9
Height (cm), mean ± SD	177.8 ± 9.7
Active smoker, n (%)	363 (29)
American Society of Anesthesiologists score, n (%)	
1	881 (71)
2	360 (29)
Herniation level, n (%)	
L1-L2	2 (1)
L2-L3	14 (1)
L3-L4	90 (7)
L4-L5	499 (40)
L5-S1	636 (51)
Side of herniation, n (%)	
Left	617 (50)
Right	566 (45)
Midline	58 (5)
Far-lateral herniation, n (%)	53 (4)
Baseline outcome scores, median (interquartile range)	
Numeric rating scale back pain	60 (30—80)
Numeric rating scale leg pain	80 (70—90)
Oswestry Disability Index	50 (36—62)

SD, standard deviation.

Reporting and Statistics

Continuous data were reported as mean ± standard deviation for normal data or as median and interquartile range (lower quartile—upper quartile) for nonnormal data. Categorical data were reported as numbers (percentage). Analyses were carried out using SPSS version 24.0 (IBM Corp., Armonk, New York, USA). Student t tests, Mann-Whitney U tests, or χ^2 tests were performed to identify differences between the 2 groups. Multiple logistic

Table 2. Perioperative Data and Clinical Outcomes

Characteristic	Value	Range
Perioperative data, median (IQR)		
Length of follow-up, months	30 (16–46)	6–73
Length of surgery, minutes	23 (19–29)	10–120
Length of stay, hours	25 (22–26)	6–169
Time of day at incision, n (%)		
7:30–12:00	444 (36)	
12:01–15:00	564 (45)	
15:01–18:30	233 (19)	
Outcomes at 6 weeks, median (IQR)		
NRS back pain	30 (10–50)	0–100
NRS leg pain	10 (0–30)	0–100
Oswestry Disability Index	20 (10–34)	0–86
Outcomes at 12 months, median (IQR)		
NRS back pain	20 (10–50)	0–100
NRS leg pain	10 (0–30)	0–100
Oswestry Disability Index	10 (2–26)	0–80

IQR, interquartile range; NRS, numeric rating scale.

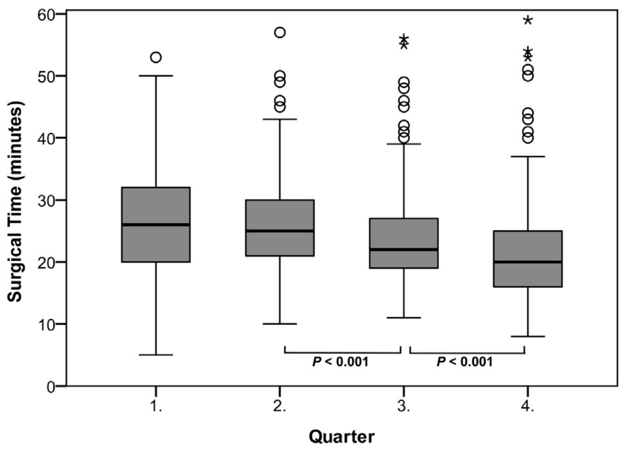

Figure 1. Boxplot graphs showing the surgical time in minutes throughout the cohort. Extreme outliers (>60 minutes) are not shown. Possible and likely outliers are marked by *circles* and *asterisks*, respectively. On average, surgical time decreased by 2.3 minutes per 310 cases. Significant differences between quarters, as determined by Mann-Whitney *U* test, are indicated by *brackets*.

regression was used to model the odds of recurrence. To adjust for potential confounders, all variables associated with a univariate $P \leq 0.2$ were considered for inclusion in the model. Possible improvements in continuous variables were assessed using linear regression. PROM were longitudinally compared using Wilcoxon signed-rank tests. A 2-tailed $P \leq 0.05$ was considered statistically significant.

RESULTS

Patient Characteristics

Between January 2011 and October 2016, 1586 patients were surgically treated using tMD. A total of 303 patients were excluded because they were not treated for single-level LDH or did not meet the follow-up threshold of ≥6 months. Forty-two patients were excluded because they were referrals with recurrent LDH. All the remaining 1241 patients were included, forming a consecutive cohort of all patients who underwent tMD procedures carried out for LDH (Table 1). The median, minimum, and maximum lengths of follow-up for this cohort were 30 months, 6 months, and 73 months, respectively.

Surgical Treatment

Detailed perioperative data is included in Table 2. Two surgeries (0.2%) had to be converted to an open approach because of unusual anatomic variants. Estimated blood loss could not be reliably identified, because it was routinely recorded only when it was >200 mL. When comparing the quarters of the cohort, surgical time decreased by 2.3 minutes per 310 cases on average ($P < 0.001$). Significant improvements were observed, especially between the second and third and between the third and fourth quarters (both $P < 0.001$) (Figure 1).

Table 3. Recurrence, Reoperations, and Complications

Characteristic	Value
Recurrence rate, n (%)	56 (4.5)
Time to recurrence, months, median (interquartile range)	4.9 (3–10)
Other reoperations, n (%)	
Contralateral rediscectomy at index level	11 (0.9)
Rediscectomy at other level	10 (0.8)
Fusion for discopathy at index level	9 (0.7)
Stenosis at index level	6 (0.5)
Dural defect repair at index level	2 (0.2)
Synovial cyst at index level	1 (0.1)
Complications, n (%)	
Incidental durotomy	47 (3.8)
Spondylodiscitis	4 (0.3)
Iatrogenic nerve root lesion	3 (0.2)
Wound infection	1 (0.1)
Wrong side (incision only)	1 (0.1)
Excessive blood loss (>500 mL)	1 (0.1)
Phlebitis	1 (0.1)
Conversion to open, n (%)	2 (0.2)

Table 4. Univariate Analysis of Possible Factors Associated

Characteristic	Recurrence (n = 56)	No Recurrence (n = 1185)	*P* Value
Demographic characteristics			
Male gender, n (%)	33 (59)	627 (53)	0.38
Age (years), mean ± SD	46.5 ± 11.7	44.7 ± 11.8	0.27
Body mass index (kg/m^2), mean ± SD	26.3 ± 3.6	25.4 ± 3.5	0.06
Height (m), mean ± SD	177.3 ± 9.0	177.9 ± 9.7	0.78
Weight (kg), mean ± SD	85.9 ± 10.1	80.8 ± 14.0	0.08
Active smoker, n (%)	20 (36)	343 (29)	0.22
American Society of Anesthesiologists score 1, n (%)	40 (71)	841 (71)	0.94
Perioperative characteristics			
Herniation level	N/A	N/A	0.28
Left-sided herniation, n (%)	24 (43)	593 (50)	0.46
Far lateral herniation, n (%)	1 (2)	52 (4)	0.35
Time of day at incision, median (IQR)	12:26 (11:10—14:03)	13:10 (11:10—14:39)	0.16
Surgical time, minutes, median (IQR)	25 (20—28)	23 (19—29)	0.43
Length of stay, hours, median (IQR)	25 (24—26)	25 (22—26)	0.05*
Outcomes at 6 weeks, median (IQR)			
NRS back pain	40 (10—60)	30 (10—50)	0.12
NRS leg pain	25 (10—50)	10 (0—30)	<0.01*
Oswestry Disability Index	28 (9—58)	20 (10—34)	0.14
Quarter	N/A	N/A	<0.01*

SD, standard deviation; N/A, not applicable; IQR, interquartile range; NRS, numeric rating scale.
*$P \leq 0.05$.

Fifty-eight patients experienced complications, for a total complication rate of 4.7%, and the complication rate did not change throughout the cohort ($P = 0.012$, Table 3). Iatrogenic nerve root lesions were seen in 3 patients (0.2%), of whom 1 fully recovered spontaneously and 2 did not recover from the resulting partial paresis.

Recurrence

True ipsilateral recurrent LDH was seen in 56 patients (4.5%). The median time to recurrence was 4.9 months (interquartile range, 3—10 months), with a range from 1 to 24 months. Variables marginally associated ($P \leq 0.2$) with recurrence were the experience of the surgeon ($P < 0.01$), high BMI ($P = 0.06$), high body weight ($P = 0.08$), earlier time of day at incision ($P = 0.16$), longer length of stay ($P = 0.05$), and high scores at the 6-week follow-up for NRS back pain ($P = 0.12$), NRS leg pain ($P < 0.01$), and ODI ($P = 0.14$) (Table 4).

After multivariate analysis and accounting for possible confounders, the experience of the surgeon ($P = 0.012$) and high leg pain at 6 weeks on NRS (odds ratio, 1.25; 95% confidence interval, 1.06—1.48; $P = 0.007$) were independently associated with recurrent LDH (Table 5). The quarters of the cohort showed recurrent LDH rates of 7.4%, 4.2%, 4.8%, and 1.6%, respectively (Figure 2). For every 310 surgeries performed, the rate of recurrent LDH decreased by 1.68% on average. The analysis of 1241 patients showed a significant reduction in recurrence, especially between the first and fourth quarters (odds ratio, 0.21; 95% confidence interval, 0.08—0.54; $P = 0.001$).

Patient-Reported Outcomes

Outcomes were analyzed only in a subgroup of 495 patients (40%) who had a complete PROM record. All outcome scores improved from baseline to the 6-week follow-up (all $P < 0.001$). NRS back pain and ODI both improved further from 6 weeks to 12 months (both $P < 0.001$), whereas NRS leg pain showed no further improvement ($P = 0.8$) (Table 2). Outcomes did not improve throughout the quarters of the cohort (all $P > 0.05$).

DISCUSSION

This study represents the largest cohort study of tMD for the treatment of single-level LDH and the first methodological analysis of the associated progression of the late learning curve.[9] We report complete data from a homogenous cohort of 1241 patients who received uniform treatment from 1 surgeon in an outpatient setting.

Table 5. Factors Associated with Recurrence as Determined by Multiple Stepwise Logistic Regression

Factor	Odds Ratio	95% Confidence Interval	*P* Value*
PROM excluded (n = 1241)			
Experience†			0.012
Quarter 1	Reference		
Quarter 2	0.55	0.27–1.1	0.09
Quarter 3	0.63	0.33–1.24	0.184
Quarter 4	0.21	0.08–0.54	0.001
PROM included (n = 495)			
Experience†			
Quarter 1	Reference		
Quarter 2	0.05	0.01–0.22	<0.001
Quarter 3	0.04	0.01–0.18	<0.001
Quarter 4	0.01	0.01–0.06	<0.001
High 6-week numeric rating scale leg pain	1.25	1.06–1.48	0.007

PROM, patient-reported outcome measure.
*Criteria for variable elimination set at $P > 0.2$.
†Analyzed as categorical variable.

Table 6. Rates of Recurrence After Tubular Microdiscectomy in the Literature

Cohort	Technique	n	Rate of Recurrence (%)
Parikh et al., 2008[9]	Microscopic tMD	141	2.8
Tomasino et al., 2009[14]	Microscopic tMD	87	2.3
Teli et al., 2010[6]	Endoscopic tMD	70	11.4
Moliterno et al., 2010[10]	Microscopic tMD	147	9.5
Arts et al., 2011[5]	Microscopic tMD	166	9.6
Belykh et al., 2016[15]	Endoscopic tMD	230	7.0
Overall		841	7.1*
Staartjes et al., 2017†	Microscopic tMD	1241	4.5

tMD, tubular microdiscectomy.
*Weighted average.
†Current cohort for comparison.

A return of preoperative symptoms caused by recurrent LDH after discectomy usually necessitates surgical revision, which produces substantial dissatisfaction and additional costs.[12] Because the anatomic plane is disrupted by scar tissue, surgical revision is technically more challenging and associated with a higher incidence of complications.[10,12,13] Our literature search for studies reporting the rate of recurrence after tMD returned a weighted average of 7.1% (**Table 6**).[5,6,9,10,14,15] In our cohort, the rate of true recurrent LDH was comparatively low at 4.5%. In some of these reports from the literature, the criteria for recurrent LDH were not clearly defined and possibly did not capture only true recurrences. Second, some studies may have had an insufficient sample size to representatively detect an event of such small incidence. A major contributor to these variations is the varying amount of experience a surgeon has with tMD.[7,16]

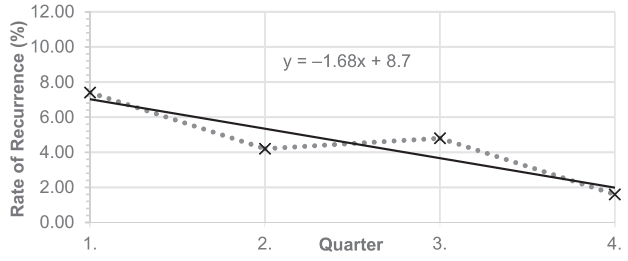

Figure 2. Graphic representation of the rates of recurrence in percent throughout the cohort. The decrease appears as a saddle-shaped curve (*interrupted line*), with the recurrence rate significantly decreasing from the first to the second quarter, then staying equal up to the third quarter and significantly decreasing towards the last quarter. A trendline graph (*uninterrupted line*) shows the mean decrease of 1.68% in recurrence per 310 cases.

We identified leg pain on the NRS scale at 6 weeks as a factor independently associated with recurrent LDH. This result was not analyzed or found in any other studies but is probably attributable to recurring radicular symptoms caused by repeated sequestration. No other factors were independently associated with recurrent LDH. Some studies identify high BMI as a risk factor.[7,17] We did not consider severely overweight patients for surgery and found only a weak, clinically irrelevant tendency. This finding corresponds to the findings of a large systematic review that identified smoking and diabetes as predictors of recurrent LDH.[18] Smoking played an insignificant role in our cohort, and we did not systematically record comorbidities such as diabetes.

The senior neurosurgeon, who performed all the procedures, spends more than 60% of his operative time performing tMDs and has been doing so for more than 13 years on over 2000 tMD procedures before 2011, which we were unable to follow-up. We observed a significant decrease in recurrence rates and surgical times throughout our study. Although the most relevant improvements are usually seen in the first few hundred cases,[9] this indicates that routine and experience can lead to improved results even after thousands of tMD procedures. With increasing experience, the neurosurgeon develops an understanding of the optimal amount of disc debulking, removing fragments that he would not have noticed at an earlier stage, thus minimizing the odds of recurrence. This is the only viable explanation of an improvement in recurrence rates, although the evidence on the influence of intradiscal debulking on recurrence is conflicting.[19,20] If the disc space is debulked too extensively, the disc may soon degenerate, causing discogenic back pain, which can possibly require fusion surgery at a later stage. The latter likely occurred in 9 patients (0.7%) in our cohort. PROMs did not improve throughout the learning curve. Another contributor to a reduced rate of recurrence may be the increasingly varied use of dedicated surgical instruments over the years.

A significant decrease in the surgical time was observed in our cohort, as described before by Parikh et al.[9] Despite shorter surgical times, the complication rates in our cohort were low compared to those in the literature[5,9,14,21] and did not change over time. This finding indicates that improvements in complication rates (if any) are presumably made at an earlier stage.

With an increasing number of MI spine surgeons, there comes a steadily increasing amount of evidence supporting MI techniques as clinically superior to conventional surgery.[2-4] Surgeons who previously used the microtubular approach only for discectomy are now starting to also apply it to fusions and deformity procedures.[22] tMD has been widely adopted and should be accepted as a gold standard. However, it is associated with a steep learning curve that affects blood loss, surgical time, and the rate of recurrence.[9,15,16] For this reason, controlled trials using tMD should be interpreted with caution. A landmark double-blinded trial reporting worse PROMs and a higher rate of recurrence with tMD also indicated longer surgical times compared with conventional microdiscectomy.[5] The latter heavily suggests that the participating surgeons were more familiar with conventional microdiscectomy.[16] No unambiguous mention of the level of training and experience with tMD was provided. This gradient of experience, besides the use of very small 14-mm working channels, may explain the higher rate of recurrence in the tMD group in that trial.[5,9,15,16] In turn, the higher rate of recurrence in that trial may constitute the reason why the tMD group did worse with respect to long-term back and leg pain. Because of the steep learning curve of truly MI techniques, prospective controlled trials that address such experience gradients, or that use surgeon-based randomization, are needed to assess with more confidence the differences between marginally different techniques. Any future retrospective or prospective studies should also unambiguously report the level of experience of all participating surgeons, preferably including the number of cases previously treated using a particular technique.

We believe that such clinically relevant differences in results are not caused by the technique used, the individual talent of the surgeon, or the instruments used; if surgeons spend 10,000 hours using any technique, they master it. The practice of medicine has moved to superspecialization over the past years, which seems to be the key to excellence.

This study has several limitations. First, it was retrospective, although all data were collected in a consequent and prospective manner. However, 303 patients who did not meet the minimum follow-up threshold of 6 months had to be excluded, which might have contributed to selection bias. Second, although we have used a definition of recurrent LDH that captures almost exclusively true reherniations, it cannot be ruled out that some of the recurrences were incomplete removals, even if a pain-free period was present.[10] Furthermore, this is a single-surgeon study. We aimed to identify any improvements in later parts of the learning curve and analyzed a cohort of patients after the surgeon had already accumulated extensive experience with this technique. This strategy is in contrast to most other studies looking at learning curves, which usually focus on the first few hundred cases. Because this study lacked a control group, no comments could be made on differences between surgical techniques and controversies regarding PROMs.[5] Through the lack of randomization, it is conceivable that this cohort may be skewed as a result of preoperative selection bias, although this is unlikely because all patients who were operated on for single-level LDH were included. In this light, it must be stated that severely overweight patients (BMI >33), and high-risk patients (ASA sore 3 and 4) in general, were not considered for surgery at our outpatient center and were first required to lose weight. This policy may have influenced our findings about BMI as a predictor of recurrence and may have contributed to a decreased complication rate and surgical time. Comorbidities were not systematically recorded and could constitute possible undetected confounders. The analyses pertaining to PROMs were conducted using a subgroup of 495 patients (40%). Subgroup analyses should always be taken with a pinch of salt despite 495 patients constituting an adequate sample size.

CONCLUSIONS

Even after the surgeon had attained extensive experience, significant reductions in surgical time and recurrent LDH after tMD were observed. In a homogenous cohort of 1241 patients, 4.5% experienced true recurrence. Early follow-up leg pain on the NRS was independently associated with recurrence, as was the experience of the surgeon. Future studies on tMD should unambiguously indicate the level of experience of the participating surgeons in performing a particular technique.

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