Neurospine 2020;17(1):204-212.
https://doi.org/10.14245/ns.1938448.224

Neurospine
pISSN 2586-6583 eISSN 2586-6591

Original Article

Timing of Surgery in Tubular Microdiscectomy for Lumbar Disc Herniation and Its Effect on Functional Impairment Outcomes

Corresponding Author
Victor E. Staartjes
https://orcid.org/0000-0003-1039-2098

Department of Neurosurgery, Bergman Clinics, c/o Bergman Clinics, Naarden, Rijksweg 69, 1411 GE Naarden, The Netherlands
E-mail: victor.staartjes@gmail.com

Received: December 27, 2019
Revised: February 4, 2020
Accepted: February 4, 2020

See commentary "Surgical Timing in Lumbar Disc Herniation Surgery" via https://doi.org/10.14245/ns.2040068.034.

Alessandro Siccoli[1], Marlies P. de Wispelaere[2], Marc L. Schröder[1], Victor E. Staartjes[1,3,4]

[1]Department of Neurosurgery, Bergman Clinics, Amsterdam, The Netherlands
[2]Department of Clinical Informatics, Bergman Clinics, Amsterdam, The Netherlands
[3]Amsterdam UMC, Vrije Universiteit Amsterdam, Neurosurgery, Amsterdam Movement Sciences, Amsterdam, The Netherlands
[4]Department of Neurosurgery, University Hospital Zurich, Clinical Neuroscience Centre, University of Zurich, Zurich, Switzerland

Objective: While it has been established that surgery for lumbar disc herniation, excluding emergent indications, should only be performed after weeks of conservative treatment, it has also been established that late surgery is associated with poorer outscomes in terms of leg pain. However, nothing is known concerning the timinig and functional outcome. We quantify the association of time to surgery (TTS) with functional impairment outcome and identify a maximum TTS cutoff.
Methods: A consecutive series of patients who underwent tubular microdiscectomy for lumbar disc herniation was included. A reduction of ≥ 30% in the Oswestry Disability Index from baseline to 12 months was defined as the minimum clinically important difference (MCID). TTS was defined as time of symptom onset to surgery in weeks. The maximum TTS cutoffs were derived both quantitatively by an area under the curve (AUC) analysis, as well as qualitatively based on cutoff-specific MCID rates.
Results: Inclusion was met by 372 patients, among which 327 (87.9%) achieved MCID. MCID achievement was associated with lower TTS (hazard ratio, 0.725; 95% confidence interval, 0.557–0.944; p = 0.014). The optimum maximum TTS based on AUC was 21.5 weeks. The qualitative analysis showed a continuous drop of MCID rates with increasing TTS, with values > 80% until week 14.
Conclusion: Our findings suggest that longer TTS is associated with a poorer patient-reported outcome in terms of functional impairment, and that—depending on the calculation method and according to the literature—a maximum TTS of between 14 to 22 weeks should likely be aimed for.

Keywords: Lumbar disc herniation, Discectomy, Functional impairment, Early surgery, Late surgery, Surgical timing

INTRODUCTION

In spine surgery, lumbar disc herniation (LDH) is one of the most common indications.[1] However, symptomatic LDH is often not primarily of surgical relevance,[2] since the vast majority of pain due to LDH can be resolved spontaneously through conservative methods.[3-8] However, patients suffering from neurological deficits, such as motor deficits or bladder disturbance, or unbearable pain may profit from early lumbar discectomy.[9-12] Additionally, patients with prolonged symptom duration despite conservative treatment might be considered for surgical treatment. However, especially for the latter type of patients

without emergent surgery indication, arriving at a surgical timing that is evidence-based remains difficult.[13]

Several studies have been conducted for the ideal timing in lumbar discectomy, however without consensus in their results.[6,13-16] Generally, a minimum waiting time of 6 to 8 weeks has been established due to the high probability of spontaneous symptom resolution.[7,8,13] However, it is still unclear whether a longer time to surgery (TTS) also leads to worse outcomes, and - if so - whether there is an optimal maximum TTS for favorable patient outcomes. The studies generally indicated an association between longer symptom duration and poorer surgical outcomes.[2,15,16] However, the reports often evaluate *pre hoc* defined TTS cutoffs, or do not take into account long-term patient-reported outcome, or are based on retrospective data.[2,13,15-19]

A recent analysis indicated that delayed surgery is associated with a lower probability of improvement in leg pain at 1 year postoperatively and that a TTS cutoff of 24 weeks should be aimed for to maximize chances of symptomatic improvement.[18] However, this study focused solely on leg pain outcome. In fact, little is known on the influence of TTS on patient-reported functional impairment outcomes after elective discectomy.[15] Therefore, the aim of this study was to evaluate the impact of TTS on functional outcome after lumbar discectomy, as well as to evaluate different thresholds to determine the optimal maximum TTS, up to which the most favorable surgical results can be obtained.

MATERIALS AND METHODS

1. Overview

For consistency, the methods correspond to those applied by Siccoli et al.[18] in their analysis of leg pain outcomes. A prospective registry of all lumbar spinal procedures carried out at a specialized spine surgery clinic was queried. We identified all patients who underwent primary tubular microdiscectomy (tMD) for LDH – thus, revisions were excluded for this analysis. All patients were operated on by a senior neurosurgeon (MLS) between December 2010 and January 2018, and all tMD procedures were carried out as described previously.[20] Patients with a body mass index (BMI) >33 kg/m^2 or with an American Society Score of Anesthesiologists (ASA) physical status classification $>$II or >80 years old were not regularly considered for elective surgery due to local insurance policies. Further-on, patients were only considered for surgery at the earliest 6 weeks after symptom onset, except for patients presenting signs of cauda equina syndrome, neurological deficits, or suffering from unbearable pain under adequate analgesia. No work restrictions were set preoperatively.[21] Some patients received diagnostic or therapeutic nerve blocks to bridge TTS. We also only considered patients with complete baseline and 12-month patient-reported outcome measure (PROM) record, and with complete TTS data for inclusion. Lastly, patients who had undergone prior lumbar discectomy were excluded.

2. Ethical Considerations

The prospective registry has been approved by the local Institutional Review Board (Medical Research Ethics Committees United, Registration Number W16.065), and this study was conducted according to the 2013 Declaration of Helsinki. All patients in this study provided written informed consent. The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement was applied.[22]

3. Data Collection

Every patient included in the study completed a standardized questionnaire containing the Numeric Rating Scale (NRS) for leg and back pain, as well as a validated Dutch version of the Oswestry Disability Index (ODI) as a measure of functional disability. Our primary endpoint was defined as the ODI at 12 months. At 6 weeks and 12 months after surgery, scheduled follow-up questionnaires were automatically sent to the patients via e-mail, and completed in the same fashion.[23] Additionally, complications and reoperations were tracked and noted in a separate database.

4. Outcome Measures

TTS was defined as the time range from first leg pain symptoms due to radiculopathy to surgery. It was obtained by addition of patient-reported pain history in weeks at the initial visit and the time lapse between the initial visit and the operation. Months were converted to 4 weeks, and the obtained values were rounded to full weeks.[18]

5. Statistical Analysis

Continuous data are given as mean ± standard deviation or median (interquartile range [IQR]), and categorical data as numbers and percentages. Clinical success was defined as achievement of the minimum clinically important difference (MCID) at 12 months postoperatively in terms of the primary outcome (ODI) of $\geq 30\%$, as defined by Ostelo et al.[24]

Differences in TTS among patients achieving and those not achieving MCID were assessed with the use of crude and ad-

justed Cox regressional hazard models. Variables for adjustment, such as age, sex, BMI, and baseline PROM values, were additionally selected based on previously published data, and represent potential confounders.[25-28] Sensitivity, specificity, positive predictive value, and negative predictive value (NPV) in reaching MCID were assessed for different cutoffs set at every 2 weeks, from week 2 to 52. The optimal TTS cutoff was established with the use of quantitative as well as qualitative analyses. The quantitative analysis consisted of an analysis of the area under the curve (AUC)-derived optimal cutoff ("closest-to-(0,1) criterion").[18,29] On the other hand, we conducted a qualitative analysis of the curve representing MCID percentages after each cutoff, with the objective of identifying a cutoff were a minimum 80% likelihood of MCID can still be obtained.[18]

A $p \leq 0.05$ was considered statistically significant. All analyses were carried out in R ver. 3.4.3 (The R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

1. Cohort

The flowchart for patient selection is represented in Fig. 1. Out of the 2,986 patients who underwent tMD during the study period, 372 patients (12.5%) had complete data on TTS and on baseline and 12-month PROM questionnaires for ODI, NRS leg pain, and NRS back pain. MCID in terms of ODI was achieved in 327 patients (87.9%), with a mean improvement of -33.3 ± 23.0 in ODI. NRS leg pain and NRS back pain improved on average by -5.4 ± 3.2 and -2.2 ± 3.5, respectively. Table 1 shows other baseline characteristics of the patient population. Baseline characteristics of the excluded cohort are provided in Supple-

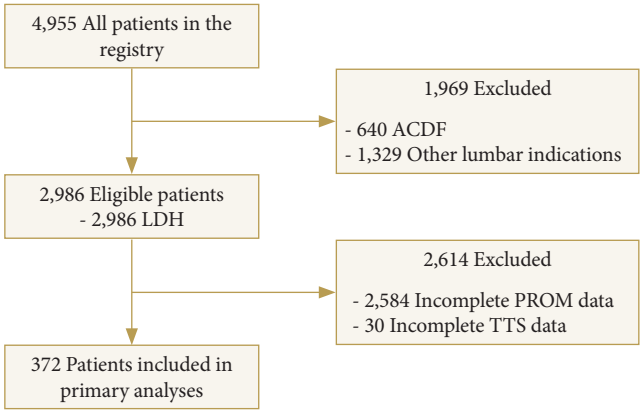

Fig. 1. Flowchart demonstrating the flow of patients throughout the analysis. ACDF, anterior cervical discectomy and fusion; LDH, lumbar disc herniation; PROM, patient-reported outcome measure; TTS, time to surgery.

Table 1. Patient characteristics of the included cohort (n = 372)

Characteristic	Value
Age (yr)	48.3 ± 11.8
Active smoker (n = 179)	94 (52.5)
Male sex	184 (49.5)
Body mass index (kg/m^2)	25.3 ± 3.3
Height (cm)	177.2 ± 10.1
Weight (kg)	79.6 ± 13.5
Operation time (min)	39.4 ± 107.3
Length of hospital stay (hr)	23.2 ± 7.3
ASA PS classification (n = 361)	
I	217 (60)
II	143 (39.6)
III	1 (0.3)
Index level	
L1–2	1 (0.2)
L2–3	4 (1.1)
L3–4	25 (6.7)
L4–5	169 (45.4)
L5–S1	173 (46.5)
Side	
Right	146 (39.2)
Left	193 (51.9)
Medial	19 (5.1)
Bilat	14 (3.8)
Baseline PROM values	
ODI	48.4 ± 18.1
NRS leg pain	7.4 ± 1.9
NRS back pain	5.2 ± 2.8
12-Month PROM change score	
ODI	-33.3 ± 23.0
NRS leg pain	-5.4 ± 3.2
NRS back pain	-2.2 ± 3.5
Achieved MCID*	327 (87.9)
TTS (wk), median (IQR)	21 (12–37)

Values are presented as mean ± standard deviation or number (%) unless otherwise indicated.
ASA PS, American Society of Anesthesiologists physical status; PROM, patient-reported outcome measure; ODI, Oswestry Disability Index; NRS, Numeric Rating Scale; TTS, time to surgery; MCID, minimum clinically important difference; IQR, interquartile range.
*Defined as a ≥ 30% improvement in NRS leg pain scores from baseline to the 12-month follow-up.

https://doi.org/10.14245/ns.1938448.224

mentary Table 1. The following complications occurred in a total of 8 patients (2.2%): incidental durotomy in 7 patients (1.9%) and major bleeding in 1 patient (0.3%).

2. Time to Surgery

The TTS averaged 49.1±97.1 weeks, though consisting of a wide range from 1 week to 14.5 years. The median TTS was measured to be 21 weeks (IQR, 12–37 weeks). The median time period from initial visit to surgery was 10 days (IQR, 6–19 days). The TTS distribution is shown in Fig. 2.

3. Association With Functional Outcome

The achievement of MCID was associated with lower TTS in the crude model (p=0.014; hazard ratio [HR], 0.725; 95% CI, 0.557–0.944). Fig. 3 shows the according to Kaplan-Meier curve. After adjustment for age, sex, and BMI, a similar result was obtained (p=0.025; HR, 0.730; 95% CI, 0.554–0.962). In the final model adjusted for age, sex, BMI, baseline NRS leg pain and back pain, as well as baseline ODI, the statistical significance was preserved (p=0.049; HR, 0.745; 95% CI, 0.557–0.998).

4. Maximum TTS

The surgical results according to TTS are outlined by Table 2. The AUC-derived optimal maximum TTS was calculated to be

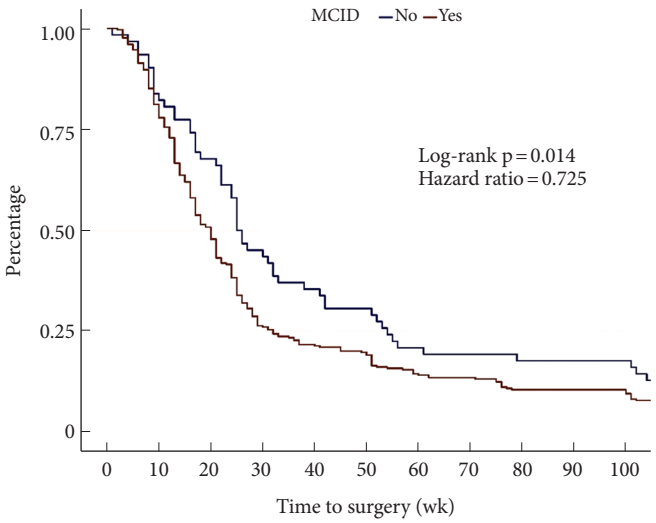

Fig. 3. Kaplan-Meier curve for time to surgery among patients achieving minimum clinically important difference (MCID) and those not achieving MCID at 12 months.

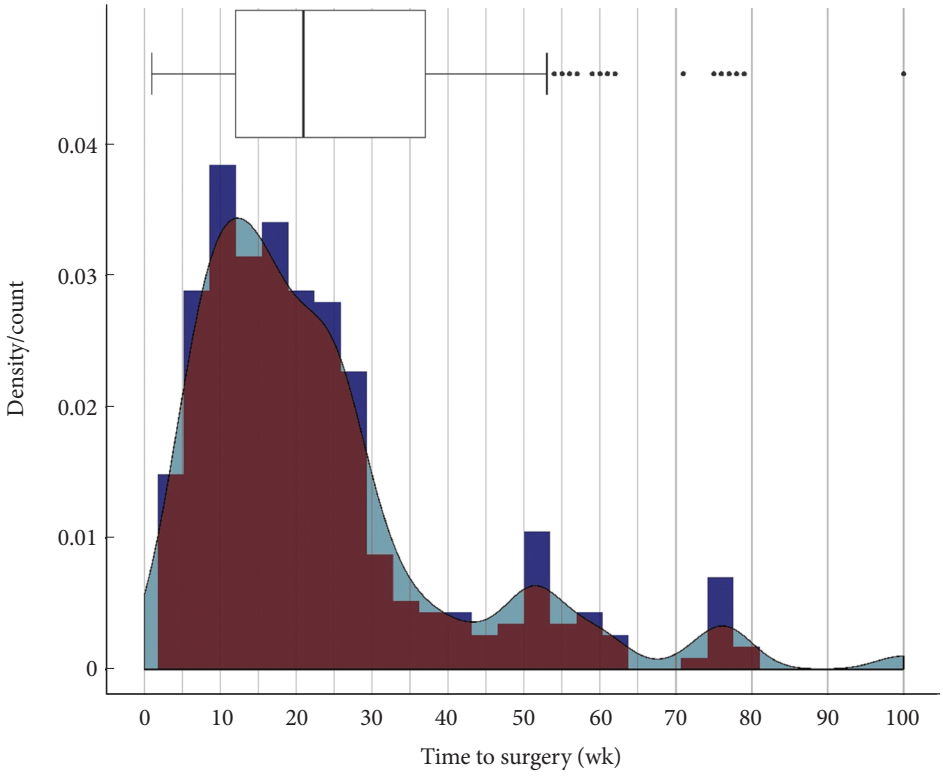

Fig. 2. Distribution of time to surgery. The density plot (curve) demonstrates a nonparametric probability density function smoothed over the patient counts (bins), with the *y*-axis demonstrating the proportion of patients within these bins. The histogram demonstrates the distribution of patients among the timepoints. The *x*-axis is cut off at 2 years.

Table 2. Tabulation of surgical results as stratified by time to surgery (TTS) in weeks

Week (TTS cutoff)	MCID after threshold (%)	Sensitivity	Specificity	PPV	NPV
2	83.2	0.000	1.000	-	0.168
4	82.9	0.040	0.968	0.857	0.171
6	82.7	0.086	0.935	0.867	0.173
8	82.2	0.149	0.903	0.882	0.178
10	82.2	0.221	0.823	0.859	0.178
12	81.5	0.270	0.807	0.872	0.184
14	80.1	0.363	0.774	0.887	0.200
16	79.3	0.419	0.742	0.881	0.207
18	78.8	0.485	0.677	0.880	0.212
20	77.5	0.521	0.678	0.888	0.225
22	77.0	0.581	0.613	0.880	0.230
24	76.3	0.617	0.581	0.878	0.237
26	77.0	0.680	0.468	0.862	0.230
28	75.7	0.713	0.452	0.864	0.244
30	74.5	0.739	0.436	0.865	0.255
32	75.5	0.756	0.387	0.858	0.245
34	75.8	0.762	0.371	0.856	0.242
36	75.0	0.772	0.371	0.857	0.250
38	75.0	0.782	0.355	0.856	0.250
40	74.7	0.786	0.354	0.856	0.253
42	77.1	0.789	0.307	0.848	0.229
44	77.1	0.789	0.307	0.848	0.229
46	76.3	0.799	0.307	0.849	0.238
48	76.3	0.799	0.307	0.849	0.238
50	75.3	0.809	0.307	0.851	0.247
52	74.2	0.838	0.274	0.850	0.258

The ratio of patients achieving a favorable outcome (MCID after threshold) is provided.
MCID, minimum clinically important difference; PPV, positive predictive value; NPV, negative predictive value.

21.5 weeks.[18,29] Fig. 4 shows the percentage curve of the patients achieving MCID after the predetermined TTS cutoffs, which show a continuous drop with progressive TTS, reaching values of >80% from week 14 and onwards. At this stage, the specificity for MCID drops below 0.750, and the NPV for nonachievement of MCID surpasses ≥0.200.

DISCUSSION

In an analysis of 372 patients undergoing first-time lumbar discectomy from a prospective registry, lower TTS was associated with a higher probability for a favorable surgical outcome in terms of functional disability. The qualitative method based on MCID achievement percentages at different cutoffs showed a continuous drop of the MCID achievement with increasing TTS values, with values of >80% MCID up to week 14. The quantitative AUC-anchored analysis both indicated an optimal maximum TTS of 22 weeks. Therefore, based on the calculation method, our data suggest that a maximum TTS of 14 to 22 weeks should be targeted for a favorable postoperative outcome in functional disability, while surgery after these thresholds leads to the lower likelihood for success.

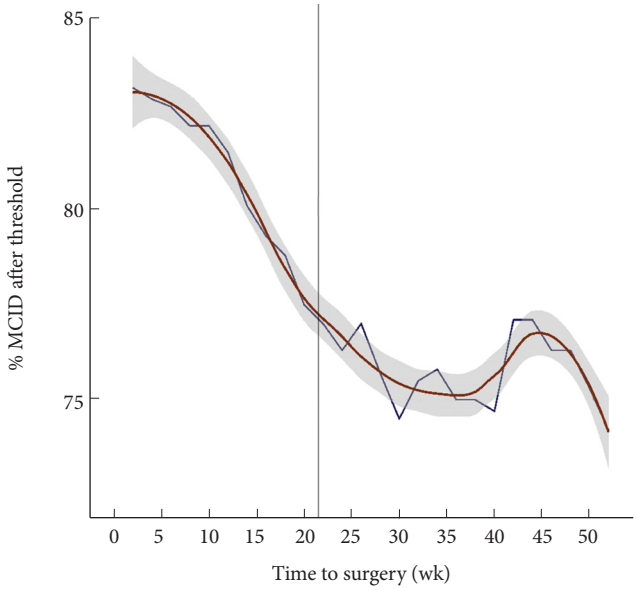

Fig. 4. Minimum clinically important difference (MCID) percentages for patients operated after different cutoffs. The vertical line indicated the area under the curve-derived cutoff at 21.5 weeks.

TTS is an important topic of surgical planning. There are only a few absolute indications to immediate discectomy to avoid permanent functional deficits, such as cauda equina syndrome or progressive motor weakness.[9-12] Another more relative indication to near-term surgical intervention is unbearable pain, were an operation can lead to a better health-related quality of life.[30,31] In addition, it was shown that a prolonged noxious stimulus can lead to changes in the neural system, such as preservation of the pain even after removing the stimulus.[32]

However, without these indications, conservative methods should be primarily considered before surgery, as over a third of LDH tend to regress without therapy at all.[11] Nonetheless, as symptom duration is prolonged, the probability of a conserva-

https://doi.org/10.14245/ns.1938448.224

tive cure is reduced. In addition, longer symptom duration may also lead to worse outcome.[13] Our data as well suggests that patients achieving MCID were generally operated earlier on.[18] These findings reinforce the idea of starting with conservative therapy, but already taking surgery into consideration early on, especially if no improvement can be achieved after 6 to 8 weeks.

However, the optimal maximum TTS for a favorable surgical outcome in terms of functional impairment outcomes—as measured by ODI here—remains unclear.[33,34] Several studies investigating surgical timing provide different results. Some studies implied a maximum duration of conservative treatment only for 2–3 months or less,[2,8,35] as for instance it was shown that earlier decompression was associated with more pronounced regenerative effects in rat spines.[36] On the other hand, some studies found conservative management and surgery to be equivalent in their 1-year outcomes.[14,37]

In a recent analysis of our data, focusing on NRS leg pain outcomes in association with TTS, we established that a maximum waiting time of 24 weeks—or 6 months—should be considered if patients are to have the highest likelihood of improvement in terms of leg pain severity.[18] Interestingly, the current analysis of our data, focusing on functional impairment as measured by ODI, provided slightly differing results: While the detrimental effect of waiting too long for surgery remains obvious in all analyses, it appears that improvement of functional impairment generally requires earlier surgical intervention (at 14–22 weeks after symptom onset) than for improvement of leg pain severity. While it is certainly hard to explain this difference, it is possible that—in the presence of (subclinical) motor deficits—motoric nerve fibers may be less resilient than sensory nerve fibers. However, we are unable to corroborate this potential explanation with published data from the literature.

Sabnis and Diwan[13] conducted a meta-analysis in 2014, and found that long duration of preoperative sciatica was associated with poor outcome. They further were only able to derive a broad time range of 2–12 months, underlining the heterogeneity in the different studies. They stated, therefore, a minimum conservative treatment of 2 months, as earlier surgery without indications might be superfluous due to spontaneous regression, and a maximum TTS of 12 months, as longer waiting time decreases the likelihood of positive surgical outcome. In addition, they were able to outline a most common optimal maximum TTS of 6 months. One of our methods of analyzing the influence of TTS resulted in an optimum TTS of 22 weeks (= 5.5 months), which may reinforce the results of Sabnis and Diwan[13] as well as Siccoli et al.[18]

In addition, our qualitative analysis showed a continuous decrease in MCID achievement with increasing TTS, and this finding is supported by most of the studies.[13,16,18,19,35,38-41] For example, Støttrup et al.[19] found that even surgery after 3 months leads to worsened outcomes at 1 year already. However, their analysis was focused solely on leg pain. In our study, we also see a drastic decrease in MCID achievement just before the 12-month mark in our analyses, which would imply a poor outcome after this cutoff and would underline the very maximum threshold defined by Sabnis and Diwan.[13]

Our data also suggest that very early surgery within 14 weeks had better MCID achievement than longer TTS. Nevertheless, this finding must be taken with a grain of salt. As the general management of LDH is strictly conservative in the first weeks, these very early operation are mainly patients with surgical indication, such as neurological deficits, and were a MCID achievement may be easier due to a much worse baseline value. In addition, most patients with radiculopathy due to LDH are most hampered by their pain or by functional impairment secondary to pain, and in this context surgery at up to 24 weeks has been shown to lead to favorable outcomes.[18]

Our study should not be taken as a call for early discectomy in the general symptomatic LDH population. It is still proper therapeutic management to propose conservative methods to the patients before surgery. However, it is also important to early discuss surgical treatment with the patients, especially when no improvement can be achieved conservatively after a few weeks. At the end, LDH treatment remains a shared decision-making between physicians and patients, and must also be adapted to the patients somatic and psychological characteristics. However, our data suggest that surgery should be carried out without delay and within 14–22 weeks from symptom onset.

Our study is primarily limited by its retrospective nature. Although all data were collected in a prospective registry and events captured systematically, and all patients with sufficient data and meeting the inclusion criteria were included, the presence of selection bias cannot be ruled out. In addition, all data stems from a single center and by one senior surgeon, possibly creating center bias. The analysis was not predefined, and we observed a high rate of loss of follow-up, as seen in other prospective registries before.[26] It remains unclear if this occurrence may be associated with further biases.[42-44] Further-on, our data and results cannot be claimed as generalized, as for the lack of external validation. Because this registry only included low-risk patients, thus those with a BMI < 33 kg/m^2, ASA physical status classification I or II, and age up to 80 years, our data and con-

clusions should not be expanded to high-risk patients such as octo- and nonagenarians, or such with systemic comorbidities. Moreover, our results may only be valid for patients undergoing tMD, and some patients received analgesic medication, nerve blocks, or manual- or physiotherapy preoperatively, on which we do not have robust data. We also do not have data on outcomes of patients who did not, in the end, undergo surgery. Therefore, our results can only indicate that, among patients who finally underwent surgery, earlier surgery was clearly associated with a better chance at MCID. However, another interesting point which cannot be inferred from our data is that the true utility of waiting longer is not postoperative outcomes, but rather the possibility that patients' symptoms will improve to the point that they can avoid surgery altogether. The TTS values are based on the patients' medical histories, and might, therefore, vary in their reliability and accuracy—recall bias may be present. We, therefore, only used integer values for weeks to better counteract such interpatient differences in TTS reporting during medical history taking. We rated subjective functional impairment based on the ODI. While the ODI is certainly a widely adopted and gold-standard outcome measure, other questionnaires like the Short Form 36 may have captured other dimensions of functional disability.

CONCLUSION

Our data suggest that patients undergoing lumbar discectomy earlier on are generally associated with a better improvement in terms of functional impairment after 1 year postoperatively. Different methods suggested an optimum TTS of 14–22 weeks, which is further validated by different other literature reports. Moreover, we find that improvement in functional impairment may potentially require earlier surgical intervention than improvement in leg pain severity does. Further studies have to be conducted for an improved understanding of surgical timing of lumbar discectomy, to improve personalized decision-making medicine for the optical therapeutic management of LDH.

CONFLICT OF INTEREST

The authors have nothing to disclose.

SUPPLEMENTARY MATERIALS

Supplementary Table 1 can be found via https://doi.org/ns.1938448.224.

REFERENCES

1. GBD 2015 DALYs and HALE Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 315 diseases and injuries and healthy life expectancy (HALE), 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016;388:1603-58.
2. Nakagawa H, Kamimura M, Takahara K, et al. Optimal duration of conservative treatment for lumbar disc herniation depending on the type of herniation. J Clin Neurosci 2007;14:104-9.
3. Gibson JN, Waddell G. Surgical interventions for lumbar disc prolapse: updated Cochrane Review. Spine (Phila Pa 1976) 2007;32:1735-47.
4. el Barzouhi A, Vleggeert-Lankamp CL, Lycklama à Nijeholt GJ, et al. Magnetic resonance imaging in follow-up assessment of sciatica. N Engl J Med 2013;368:999-1007.
5. Gugliotta M, da Costa BR, Dabis E, et al. Surgical versus conservative treatment for lumbar disc herniation: a prospective cohort study. BMJ Open 2016;6:e012938.
6. Peul WC, van Houwelingen HC, van den Hout WB, et al. Surgery versus prolonged conservative treatment for sciatica. N Engl J Med 2007;356:2245-56.
7. Lequin MB, Verbaan D, Jacobs WC, et al. Surgery versus prolonged conservative treatment for sciatica: 5-year results of a randomised controlled trial. BMJ Open 2013;3:e002534.
8. Rothoerl RD, Woertgen C, Brawanski A. When should conservative treatment for lumbar disc herniation be ceased and surgery considered? Neurosurg Rev 2002;25:162-5.
9. Saal JA, Saal JS. Nonoperative treatment of herniated lumbar intervertebral disc with radiculopathy. An outcome study. Spine (Phila Pa 1976) 1989;14:431-7.
10. Komori H, Shinomiya K, Nakai O, et al. The natural history of herniated nucleus pulposus with radiculopathy. Spine (Phila Pa 1976) 1996;21:225-9.
11. Splendiani A, Puglielli E, De Amicis R, et al. Spontaneous resolution of lumbar disk herniation: predictive signs for prognostic evaluation. Neuroradiology 2004;46:916-22.
12. Postacchini F. Results of surgery compared with conservative management for lumbar disc herniations. Spine (Phila Pa 1976) 1996;21:1383-7.
13. Sabnis AB, Diwan AD. The timing of surgery in lumbar disc prolapse: A systematic review. Indian J Orthop 2014;48:127-35.
14. Peul WC, van den Hout WB, Brand R, et al. Prolonged con-

servative care versus early surgery in patients with sciatica caused by lumbar disc herniation: two year results of a randomised controlled trial. BMJ 2008;336:1355-8.
15. Petr O, Glodny B, Brawanski K, et al. Immediate versus delayed surgical treatment of lumbar disc herniation for acute motor deficits: the impact of surgical timing on functional outcome. Spine (Phila Pa 1976) 2019;44:454-63.
16. Rihn JA, Hilibrand AS, Radcliff K, et al. Duration of symptoms resulting from lumbar disc herniation: effect on treatment outcomes: analysis of the Spine Patient Outcomes Research Trial (SPORT). J Bone Joint Surg Am 2011;93:1906-14.
17. Quon JA, Sobolev BG, Levy AR, et al. The effect of waiting time on pain intensity after elective surgical lumbar discectomy. Spine J 2013;13:1736-48.
18. Siccoli A, Staartjes VE, de Wispelaere MP, et al. Association of time to surgery with leg pain after lumbar discectomy: is delayed surgery detrimental? J Neurosurg Spine 2019;32:160-7.
19. Støttrup CC, Andresen AK, Carreon L, et al. Increasing reoperation rates and inferior outcome with prolonged symptom duration in lumbar disc herniation surgery - a prospective cohort study. Spine J 2019;19:1463-9.
20. Staartjes VE, de Wispelaere MP, Miedema J, et al. Recurrent lumbar disc herniation after tubular microdiscectomy: analysis of learning curve progression. World Neurosurg 2017;107:28-34.
21. Staartjes VE, de Wispelaere MP, Schröder ML. Improving recovery after elective degenerative spine surgery: 5-year experience with an enhanced recovery after surgery (ERAS) protocol. Neurosurg Focus 2019;46:E7.
22. von Elm E, Altman DG, Egger M, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. BMJ 2007;335:806-8.
23. Schröder ML, de Wispelaere MP, Staartjes VE. Are patient-reported outcome measures biased by method of follow-up? Evaluating paper-based and digital follow-up after lumbar fusion surgery. Spine J 2019;19:65-70.
24. Ostelo RW, Deyo RA, Stratford P, et al. Interpreting change scores for pain and functional status in low back pain: towards international consensus regarding minimal important change. Spine (Phila Pa 1976) 2008;33:90-4.
25. Jackson KL 2nd, Devine JG. The effects of obesity on spine surgery: a systematic review of the literature. Global Spine J 2016;6:394-400.
26. McGirt MJ, Sivaganesan A, Asher AL, et al. Prediction model for outcome after low-back surgery: individualized likelihood of complication, hospital readmission, return to work, and 12-month improvement in functional disability. Neurosurg Focus 2015;39:E13.
27. Siccoli A, Staartjes VE, de Wispelaere MP, et al. Gender differences in degenerative spine surgery: do female patients really fare worse? Eur Spine J 2018;27:2427-35.
28. Rushton A, Zoulas K, Powell A, et al. Physical prognostic factors predicting outcome following lumbar discectomy surgery: systematic review and narrative synthesis. BMC Musculoskelet Disord 2018;19:326.
29. Perkins NJ, Schisterman EF. The inconsistency of "optimal" cutpoints obtained using two criteria based on the receiver operating characteristic curve. Am J Epidemiol 2006;163:670-5.
30. Atlas SJ, Keller RB, Wu YA, et al. Long-term outcomes of surgical and nonsurgical management of sciatica secondary to a lumbar disc herniation: 10 year results from the maine lumbar spine study. Spine (Phila Pa 1976) 2005;30:927-35.
31. Weinstein JN, Lurie JD, Tosteson TD, et al. Surgical vs nonoperative treatment for lumbar disk herniation: the Spine Patient Outcomes Research Trial (SPORT) observational cohort. JAMA 2006;296:2451-9.
32. Coderre TJ, Katz J, Vaccarino AL, et al. Contribution of central neuroplasticity to pathological pain: review of clinical and experimental evidence. Pain 1993;52:259-85.
33. Ferguson SA, Marras WS, Burr DL, et al. Quantification of a meaningful change in low back functional impairment. Spine (Phila Pa 1976) 2009;34:2060-5.
34. Fairbank JC, Couper J, Davies JB, et al. The Oswestry low back pain disability questionnaire. Physiotherapy 1980;66:271-3.
35. Hurme M, Alaranta H. Factors predicting the result of surgery for lumbar intervertebral disc herniation. Spine (Phila Pa 1976) 1987;12:933-8.
36. Jancalek R, Dubovy P. An experimental animal model of spinal root compression syndrome: an analysis of morphological changes of myelinated axons during compression radiculopathy and after decompression. Exp Brain Res 2007;179:111-9.
37. Weber H. Lumbar disc herniation. A controlled, prospective study with ten years of observation. Spine (Phila Pa 1976) 1983;8:131-40.
38. Nygaard OP, Kloster R, Solberg T. Duration of leg pain as a predictor of outcome after surgery for lumbar disc hernia-

tion: a prospective cohort study with 1-year follow up. J Neurosurg 2000;92(2 Suppl):131-4.
39. Fisher C, Noonan V, Bishop P, et al. Outcome evaluation of the operative management of lumbar disc herniation causing sciatica. J Neurosurg 2004;100(4 Suppl Spine):317-24.
40. Quigley MR, Bost J, Maroon JC, et al. Outcome after microdiscectomy: results of a prospective single institutional study. Surg Neurol 1998;49:263-7.
41. Barrios C, Ahmed M, Arrotegui JI, et al. Clinical factors predicting outcome after surgery for herniated lumbar disc: an epidemiological multivariate analysis. J Spinal Disord 1990; 3:205-9.
42. Schröder ML, de Wispelaere MP, Staartjes VE. Predictors of loss of follow-up in a prospective registry: which patients drop out 12 months after lumbar spine surgery? Spine J 2019;19: 1672-9.
43. Sielatycki JA, Parker SL, Godil SS, et al. Do patient demographics and patient-reported outcomes predict 12-month loss to follow-up after spine surgery? Spine (Phila Pa 1976) 2015;40:1934-40.
44. Højmark K, Støttrup C, Carreon L, et al. Patient-reported outcome measures unbiased by loss of follow-up. Single-center study based on DaneSpine, the Danish spine surgery registry. Eur Spine J 2016;25:282-6.

 https://doi.org/10.14245/ns.1938448.224

Supplementary Table 1. Baseline characteristics of the 2,614 patients who did not fulfil the inclusion criteria or who did not have the necessary data available

Characteristic	Value
Age (yr)	48.3 ± 11.8
Active smoker	526 (56.2)
Male sex	1,447 (55.4)
Body mass index (kg/m^2)	25.4 ± 3.4
Height (cm)	177.4 ± 10.3
Weight (kg)	79.9 ± 13.0
Operation time (min)	39.6 ± 106.8
Length of hospital stay (hr)	23.1 ± 7.1
ASA PS classification	
I	1,474 (65)
II	767 (34)
III	6 (0.3)
Index level	
L1–2	3 (0.1)
L2–3	37 (1.5)
L3–4	162 (6.4)
L4–5	1,121 (44)
L5–S1	1,214 (48)
Side	
Right	1,093 (45)
Left	1,243 (51)
Median	75 (3.1)
Both sides	16 (0.7)
Baseline PROM values	
ODI	49.4 ± 17.3
NRS leg pain	7.4 ± 2.1
NRS pack pain	5.4 ± 2.9

Values are presented as mean ± standard deviation or number (%).
ASA PS, American Society of Anesthesiologists physical status; PROM, patient-reported outcome measure; ODI, Oswestry Disability Index; NRS, Numeric Rating Scale.