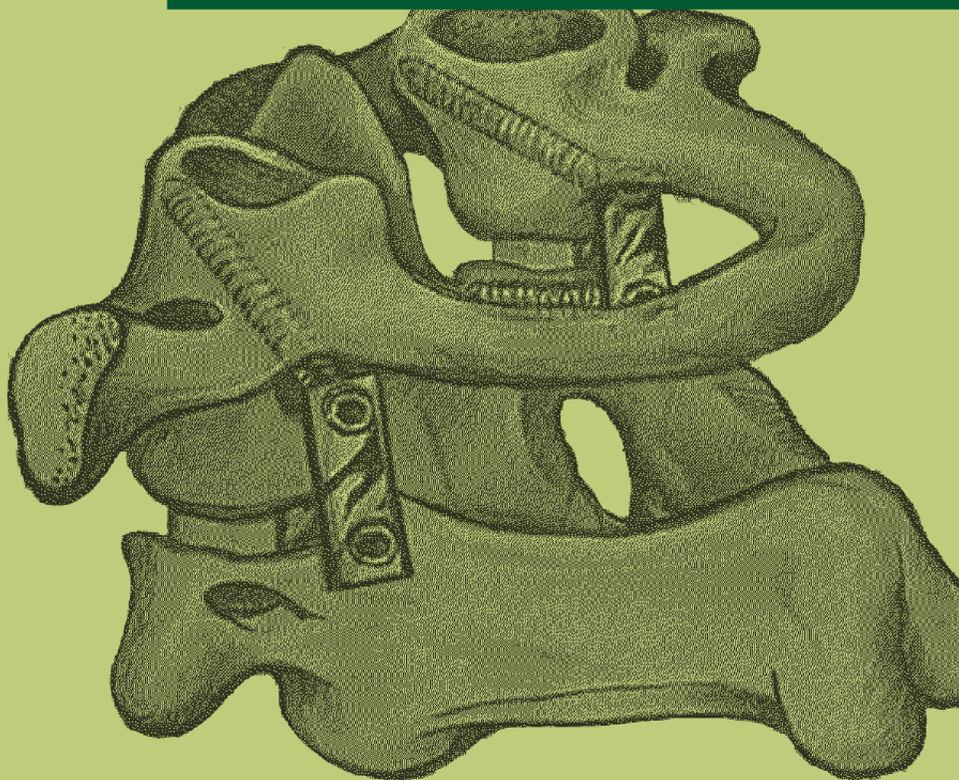


Journal of Craniovertebral Junction & Spine

www.jcvjs.com



PubMed

October-December 2018 / Volume 9 / Issue 4

Recurrent lumbar disc herniation: Is there a correlation with the surgical technique? A multivariate analysis

ABSTRACT

Purpose: The recurrence of a lumbar disc herniation (LDH) is a common cause of poor outcome following lumbar discectomy. The aim of this study was to assess a potential relationship between the incidence of recurrent LDH and the surgical technique used. Furthermore, we tried to define the best surgical technique for the treatment of recurrent LDH to limit subsequent recurrences.

Materials and Methods: A retrospective study was conducted on 979 consecutive patients treated for LDH. A multivariate analysis tried to identify a possible correlation between (1) the surgical technique used to treat the primary LDH and its recurrence; (2) technique used to treat the recurrence of LDH and the second recurrence; and (3) incidence of recurrence and clinical outcome. Data were analyzed with the Pearson's Chi-square test for its significance.

Results: In 582 cases (59.4%), a discectomy was performed, while in 381 (40.6%), a herniectomy was undertaken. In 16 cases, a procedure marked as "other" was performed. Among all patients, 110 (11.2%) had a recurrence. Recurrent LDH was observed in 55 patients following discectomy (9.45%), in 45 following herniectomy (11.8%), and in 10 (62.5%) following other surgery. Our data showed that 90.5% of discectomies and 88.2% of the herniectomies had a good clinical outcome, whereas other surgeries presented a recurrence rate of 62.5% (Pearson's $\chi^2 < 0.001$). No statistical differences were observed between discectomy or herniectomy, for the treatment of the recurrence, and the incidence for the second recurrences ($P > 0.05$). A significant statistical correlation emerged between the use of other techniques and the incidence for the second recurrences ($P < 0.05$).

Conclusions: The recurrence of an LDH is one of the most feared complications following surgery. Although the standard discectomy has been considered more protective toward the recurrence compared to herniectomy, our data suggest that there is no significant correlation between the surgical technique and the risk of LDH recurrence.

Keywords: Degenerative disc disease, low back pain, recurrent lumbar disc herniation, spinal degeneration, spinal instability, surgery

INTRODUCTION

The recurrence of a lumbar disc herniation (LDH) is a common cause of poor outcome following lumbar discectomy and can account for a variable rate of failed back surgery syndrome.^[1-4] The definition of recurrent disc herniation has varied among different authors.

According to most studies, recurrent LDH is defined as an herniation on the same disc space and on the same side of a previously operated LDH, occurring at least 6 months after surgery.^[3,5-8] The 6-month interval is fundamental to discern between a true recurrence from a complication related to the

ALESSANDRO LANDI, GIOVANNI GRASSO¹, CRISTINA MANCARELLA, DEMO EUGENIO DUGONI, FABRIZIO GREGORI, GIORGIA IACOPINO, HARRISON XIAO BAI², NICOLA MAROTTA, ANDREA IAQUINANDI, ROBERTO DELFINI

Department of Neurology and Psychiatry, Division of Neurosurgery, "Sapienza" University of Rome, Rome,

¹Department of Experimental Biomedicine and Clinical Neurosciences, University of Palermo, Palermo, Italy,

²Department of Radiology, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania, USA

Address for correspondence: Prof. Giovanni Grasso, Department of Experimental Biomedicine and Clinical Neurosciences, Policlinico Universitario Di Palermo, Via Del Vespro 129, 90100 Palermo, Italy.
E-mail: giovanni.grasso@unipa.it

Access this article online	
Website: www.jcvjs.com	Quick Response Code 
DOI: 10.4103/jcvjs.JCVJS_94_18	

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Landi A, Grasso G, Mancarella C, Dugoni DE, Gregori F, Iacopino G, *et al.* Recurrent lumbar disc herniation: Is there a correlation with the surgical technique? A multivariate analysis. J Craniovert Jun Spine 2018;9:260-6.

surgical intervention. Data from the literature have shown that recurrence of an LDH varies from 5% to 15%.^[5,9-12] To date, the factors underlying LDH recurrence are not completely clear. It has been pointed out that, following discectomy, the annular tear may remain unsealed allowing the discal material to be extruded under mechanical pressure. Risk factors for recurrent disc herniation include constitutional weakness of the fibrous annulus, exposure to heavy activities, and advanced age.^[11,13-16]

The aim of the current study was to evaluate the risk factors for recurrent LDH in a clinical experience spanning 11 years. In particular, we attempted to demonstrate the relationship between the incidence of recurrent LDH and surgical technique used. Furthermore, we investigated the best surgical technique in the treatment of recurrent LDH, to minimize the risk of a second recurrence.

MATERIALS AND METHODS

Study design

In this retrospective study, all the patients who underwent surgery for LDH with a standard open approach (discectomy or herniectomy) from January 2001 to January 2014 were analyzed. Inclusion criteria were as follows: preoperative imaging positive for the presence of LDH and negative for instability (magnetic resonance imaging and/or computed tomography scans and dynamic radiography); radicular symptoms (pain, motor weakness, and sensory deficit) congruent with the level of the LDH; electromyography and electroneurography positive for denervation and/or radicular dysfunction; and pain/paresthesia not responding to conservative treatment. Patients with cauda equina syndrome and patients treated through endoscopic discectomy were excluded from this study.

Clinical outcome measurement

For all patients, medical history was carefully investigated, and physical examination along with neurological evaluation was achieved. To obtain a more homogeneous sample, we elaborated the neurological examination defining the sensory deficits as any change in the individual perception (paresthesia, dysesthesia, and tingling numbness), and the motor weakness was defined as any variation in the muscular strength during a comparative examination with the contralateral limb. Sex, body mass index (BMI), age at the first surgery, disc involved by the herniation, side of the herniation, first surgical technique used, and surgical technique used for the recurrence were also assessed. In this regard, surgical approaches were divided into three main techniques, namely discectomy, herniectomy,^[17-19] and other (i.e., epiduroscopy, nucleolysis, and radiofrequency).

The results of the surgical management have been evaluated by a telephonic interview at least at 1-year follow-up after the last surgery. According to the answers collected during the interview, the patients were divided into three groups as follows: 1, good clinical condition; 2, occasional need of drug assumption for pain management; and 3, constant need of drug assumption for pain management. The questions administered explored the following situations: 1, techniques for pain management; 2, pain intensity; and 3, recurrence/new occurrence of symptoms to lower limbs.

Statistical analysis

Data were reported as mean \pm standard deviation, and categorical data were reported as frequencies and percentages. We determined differences in clinical outcome using the *t*-test for paired samples if a normality test was passed or a Wilcoxon signed-rank test if a normality test was failed. Furthermore, the clinical results were analyzed using the analysis of variance Chi-square test, and the correlation coefficient between the surgical techniques, the incidence of recurrence of LDH, and the clinical status during the follow-up were assessed using the Pearson's Chi-square test.

RESULTS

A total of 979 consecutive patients were included. Five hundred and twenty-one were male and 458 were female, with a mean age of 47.81 years (range 20–88 years). The mean BMI was 26.7 kg/m² (range 19.1–35.8). In 690 patients (70.5%), a combination of sensory and motor deficits was found during the neurological examination. One hundred and sixty-four patients (16.8%) presented with pure sensory deficit, whereas 125 (12.8%) patients had only motor disturbance. The analysis of the cohort is summarized in Table 1.

In 582 cases (59.4%), a discectomy was performed, while in 381 (40.6%) cases, a herniectomy was undertaken. In the remaining 16 cases, a procedure marked as “other” (i.e., epiduroscopy,^[15] nucleolysis, and radiofrequency) was performed.

Among the 979 patients, 110 (11.2%) had a recurrent LDH; 58 were male and 52 were female. The mean age was 49.91 years (51.88 in male population and 47.67 in female population), and the recurrence occurred mainly at 12 months after the first surgery. The detailed analysis of the cohort of patients with recurrent LDH is available in Table 2. Data from the recurrent cases showed that recurrent herniation was observed following discectomy in 55 patients (9.45% of the total discectomies), in 45 following herniectomy (11.8% of the total herniectomies), and in 10 (62.5%) following “other”

surgery. Recurrences were treated in 53 cases with a new discectomy, in 35 cases with herniectomy, and in 22 cases with other procedures.

Correlation between recurrence and surgical technique

Among the 979 patients, 88.8% had no recurrence during the follow-up, while 11.2% had a recurrent LDH. Analyzing the correlation between surgical technique and recurrence emerged, 90.5% of discectomies and 88.2% of herniectomies

Table 1: Characteristics of the study population (n=979)

Variables	Mean o n	Percentage	Minimum	Maximum
Age	47.81		20	88
Gender				
Female	458	46.78		
Male	521	53.22		
BMI (kg/m ²)	26.7		19.1	35.8
Neurological status				
Sensory deficit	164	16.7		
Motor-sensory deficit	690	70.48		
Motor deficit	125	12.7		
Level				
L1-L2	4	0.41		
L2-L3	24	2.45		
L3-L4	88	8.99		
L4-L5	476	48.31		
L5-S1	408	41.47		
Double level	21	2.15		
Side				
Right	433			
Left	558			
Bilateral	7			
Median	2			

BMI - Body mass index

Table 2: Patients with recurrence of lumbar disc herniation (n=110)

Variable	Mean o n	Percentage of the total (979)
Age at surgery	55.79	
Gender		
Females	52	5.92
Males	58	5.31
Age at recurrence	49.91	
Mean time at recurrence (months)	12	
Level of the herniation		
L1-L2	-	-
L2-L3	1	0.2
L3-L4	10	1.02
L4-L5	52	5.31
L5-S1	47	4.8
Double level	1	
Side of the herniation		
Right	53	
Left	58	

had a good clinical outcome. Patients treated by other surgeries presented a recurrence rate of 62.5%. In the analysis of the significance, correlation coefficient was statistically significant (Pearson's $\chi^2 < 0.001$) [Table 3]. However, although there was no clear statistical correlation between discectomy or herniectomy and the increase in the incidence of recurrence, a correlation emerged between the use of other techniques and the incidence of recurrence with a statistical significance ($P < 0.05$) [Figure 1]. Among the 110 patients with recurrent LDH, 91 had a good clinical outcome after surgery (82.73% of the recurrences), whereas 19 patients developed a second recurrence (17.27% of the total of the 110 recurrences). The 19 patients had been treated with discectomy in seven cases, herniectomy in three cases, and other procedure in nine cases. Among the 53 discectomies performed for the recurrence of LDH, seven had a second recurrence of LDH (13.21%). Among the 35 herniectomies performed for the recurrence of LDH, three had a second recurrence of LDH (8.57%). Among the 22 other procedures performed for the recurrence of LDH, nine had a second recurrence of LDH (40.9%). The patients with a second recurrence of LDH had an age between 33 and 80 years, with a mean age of 58.16 years. The mean age of incidence of the second recurrence was 55 (59.55 for males and 48.75 for females). Most of the patients developed the second recurrence at 2 years after the surgery performed for the first recurrence.

Correlation between surgical technique and second recurrence

A statistical analysis on the group of patients with a second recurrence has been performed, focusing on the correlation coefficient between surgical technique used for the treatment of the first recurrence and the incidence of the second recurrence. Among 53 discectomies performed for the

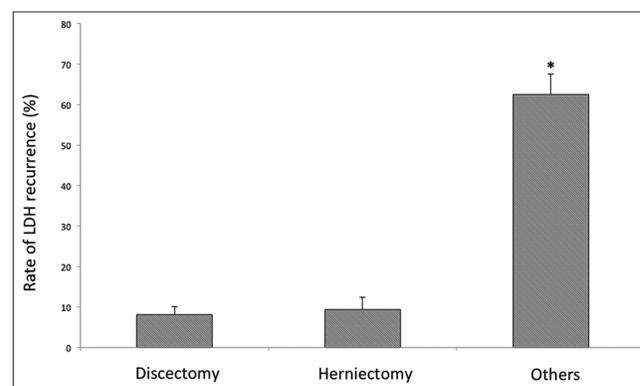


Figure 1: Bar graph showing the percentage of recurrence following lumbar disc herniation treatment. No statistical differences were observed between discectomy and herniectomy in the incidence of recurrence ($P > 0.05$). The incidence of recurrence was significantly higher for patients treated by using other techniques ($*P < 0.05$)

treatment of the first recurrence, seven patients (13.2%) had a second recurrence. Among 35 herniectomies performed for the treatment of a first recurrence, three patients (8.6%) had a second recurrence. Among 22 patients treated with other procedures, nine (40.9%) had a second recurrence. In the analysis of the significance, the correlation coefficient was statistically significant (Pearson's $\chi^2 = 0.004$) [Table 4]. The results showed the absence of statistical significance between discectomy or herniectomy, for the treatment of the recurrence, and the incidence for a second recurrence ($P > 0.05$). On the contrary, a significant statistical correlation emerged between the use of other techniques and the incidence for the second recurrences ($P < 0.05$) [Figure 2].

The 19 patients with a second recurrence of LDH have been treated in ten cases with discectomy, in six cases with herniectomy, and in three cases with arthrodesis. During follow-up, one of the patients treated with herniectomy had a third recurrence and was treated with arthrodesis with a good result.

Correlation between clinical condition and recurrence

Among the total of 979 patients with a primary LDH, 869 (88.8%) had a statistically significant good outcome after the first surgery ($P < 0.05$). In particular, 800 patients (92.1%) did not need to assume drugs for pain management and 69 (7.9%) took pain medications only occasionally following surgery. Considering the patients with the first and second recurrences, 68 (52.7%) did not need to assume drugs for pain management, 26 (20.2%) took pain medications only occasionally, and 16 (12.4%) needed a constant assumption of drugs for pain management. Analysis on the 91 patients with the first recurrence who did not develop a second recurrence showed that 63.7% of patients had a good clinical outcome,

24.2% took pain medications occasionally, and 12.1% had a constant need for pain medications. Among the patients with a second recurrence, 52.6% was in a good clinical condition, 21.1% took pain medications occasionally, and 26.3% had a continuative assumption of pain medications. The analysis of the correlation coefficient has shown a statistically significant correlation (Pearson χ^2 significance < 0.001) [Table 5]. Overall, patients with a better clinical outcome were patients with a single surgery or with a surgery for the first recurrence [Figure 3].

DISCUSSION

LDH affects a large number of patients annually. It has been reported that intervertebral disc disorders represent the largest specific diagnosis among patients with spinal pathologies (Martin *et al.*). However, the natural evolution of an LDH suggests that the preferable treatment can be the conservative^[20] because it can allow, in the absence of neurological deficits, a complete regression of the symptoms in 95% of cases.^[20,21] For small amount of patients, after a prudential trial of nonoperative care, surgical treatment has still a fundamental role in the resolution of the symptoms. Many surgical options have been developed during the last years, encompassing traditional open microscopic surgery, minimally invasive/percutaneous techniques, and endoscopy. In this regard, minimally invasive/percutaneous techniques seem to have a higher risk of LDH recurrence if compared to classic microscopic surgery.^[22,23] It has been shown that open technique allows a better clinical outcome and a lower recurrence rate if compared to endoscopic and percutaneous techniques.^[24] A Cochrane review published in 2014,^[25] analyzing the outcome of minimally invasive discectomy (MID) and open discectomy (OD), has confirmed that MID may be inferior regarding relief of leg pain, low back

Table 3: Correlation between recurrence and surgical technique

	Chi-squared tests		
	Value	df	Asymptotic significance (two sided)
Pearson's χ^2	44.924	4	0.000
Likelihood ratio	26.635	4	0.000
Linear-by-linear association	13.389	1	0.000
Number of valid cases	979		

Table 4: Correlation between surgical technique and second recurrence

	Chi-squared tests		
	Value	df	Asymptotic significance (two sided)
Pearson's χ^2	1.919	2	0.383
Likelihood ratio	1.882	2	0.390
Linear-by-linear association	1.816	1	0.178
Number of valid cases	963		

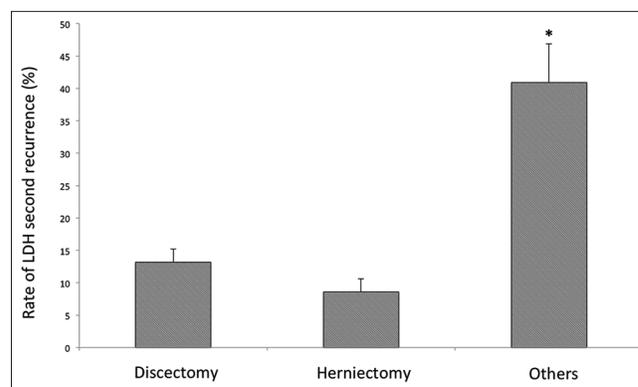


Figure 2: Bar graph showing the percentage of second recurrence following lumbar disc herniation treatment. The results showed the absence of statistical significance between discectomy or herniectomy, for the treatment of the recurrence, and the incidence for a second recurrence ($P > 0.05$). The incidence of recurrence was significantly higher for patients treated by using other techniques (* $P < 0.05$)

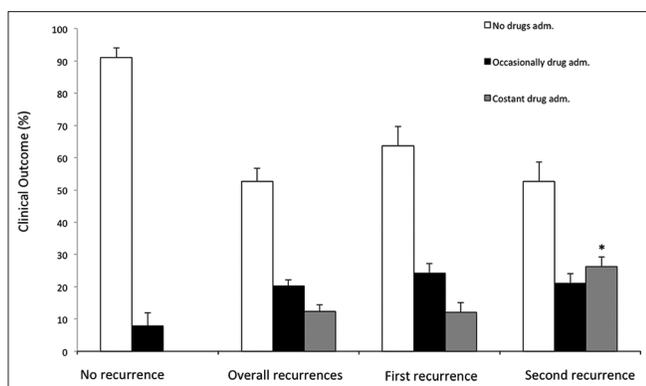


Figure 3: Bar graph showing the clinical outcome following lumbar disc herniation treatment. Among the patients, 88.8% had a good outcome after the first surgery because 92.1% did not need to assume drugs for pain management and 7.9% took pain medications only occasionally following surgery. Considering the patients with the first and second recurrences, 52.7% did not need to assume drugs for pain management, 20.2% took pain medications only occasionally, and 12.4% needed a constant assumption of drugs for pain management. Among patients with the first recurrence who did not develop a second recurrence, 63.7% had a good clinical outcome, 24.2% took pain medication occasionally, and 12.1% had a constant need for pain medications. Among the patients with a second recurrence, 52.6% was in a good clinical condition, 21.1% took pain medications occasionally, and 26.3% had a continuative assumption of pain medications. Overall, patients with a worse clinical outcome were patients with second recurrence (* $P < 0.05$)

Table 5: Correlation between clinical condition and recurrence

	Chi-squared tests		
	Value	df	Asymptotic significance (two sided)
Pearson's χ^2	1001.837	6	0.000
Likelihood ratio	690.332	6	0.000
Linear-by-linear association	774.031	1	0.000
Number of valid cases	979		

pain, and rehospitalization. The theoretical advantages of MID, such as lower risk of surgical-site infection and shorter hospital stay, are therefore inconsistent.

The occurrence of recurrence following discectomy and herniectomy has been a matter of debate, and the lack of significant data had led it to an open question.^[26-28] In this study, we found an LDH recurrence rate of 11.24% following standard open surgery. These data are in agreement with those of previous studies where the recurrence rate varies between 5% and 15%,^[20,29] based on the surgical technique employed. We observed that, even if the collected data were statistically significant (Pearson's Chi-square test < 0.001), there was no statistical correlation between the surgical technique employed (discectomy or herniectomy) and the incidence of recurrence. However, a statistical correlation emerged between the use of other techniques (laser, radiofrequency, and nucleoplasty) and the incidence of recurrence ($P < 0.05$).

Over the past several decades, two methods of disc removal have been used for open and microdiscectomy procedures. First, the discectomy, a technique based on an aggressive removal of the herniated disc fragment along with curettage of the remaining disc.^[30] Second, the sequestrectomy, described and popularized by Williams^[31] and Spengler,^[32] a procedure that involves the removal of the solely herniated disc fragment with minimal invasion of the disc space. In a systematic literature review about outcomes associated with primary lumbar discectomy for disc herniation with radiculopathy, it has been shown a greater incidence of long-term recurrent back and leg pain after discectomy but a greater reported incidence of recurrent disc herniation after sequestrectomy.^[33] Short-term outcome did not differ between discectomy techniques, but in the long run, discectomy seems to be associated with an acceleration of the degenerative cascade contributing to recurrent radicular symptoms. In a recent meta-analysis, it has been demonstrated that sequestrectomy provides equivalent reherniation rate and complications compared with discectomy but maintains a lower incidence of recurrent low back pain and higher satisfactory rate.^[34] As a conventional procedure without curettage, the sequestrectomy is associated with a significant less loss of disc height and endplate degeneration,^[35] which may reduce "failed back syndrome" as a result of better intervertebral stability and less spondylosis.^[36] Disc degeneration accompanying with facet pathology gains the risk of recurrent low back pain after discectomy, in which aggressive disc resection and space curettage lead to an aberrant axial force distribution to the annulus fibrosis and facet joints. Accordingly, discectomy should be performed when LDH is associated with disc degeneration (Pfirrmann stage 2-3-4) and based on the results of a radiological study with dynamic X-rays to discover a possible instability. Herniectomy, on the other hand, should be performed in patients with a high- and well-hydrated disc.

There has been a great deal of controversy about the treatment of recurrent LDH. Available evidence suggests that some patients may respond to nonoperative interventions and avoid the need for reoperation. For those that fail a trial of conservative management or present with neurologic deficit, both repeat lumbar discectomy and instrumented fusion appear to effectively treat patients with similar complication rates and clinical outcomes.^[37] However, a recent survey has shown that OD is the most used technique in case of LDH recurrence among spinal surgeons in the United States because it is considered to be the safest technique with less probability of second recurrence. Fusion is reserved to patients with instability to dynamic X-rays or with characteristics of microinstability on neuroimaging.^[38] Clinical studies with long-term follow-up have

shown an increased incidence of recurrence in discectomies performed with microsurgical technique if compared to standard discectomy,^[17-19] despite the advantages of operative time reduction, surgical complications, and hospitalization length that the minimally invasive techniques can provide.^[39] Yorimitsu *et al.*^[40] in their retrospective analysis reported a better clinical outcome after standard discectomy if compared with the discectomies performed with microsurgical technique. The analysis we performed on the patients with second recurrence did not show a statistical significance between the surgical technique performed for the treatment of the recurrence and the incidence of a second recurrence ($P > 0.05$). On the contrary, a significant statistical correlation emerged between the use of other techniques and the incidence for second recurrences ($P < 0.05$).

It is well known that a direct correlation between clinical outcome and number of surgical interventions performed exists.^[29,41,42] Patients with a better clinical outcome are those with a single surgery or with a surgery for a first recurrence. These data are in agreement with those of the analysis we performed in our study (Pearson's $\chi^2 < 0.001$). Patients surgically treated for subsequent recurrences had a worse clinical outcome. This evidence might be related to a progression of the degenerative cascade or the effect of scar tissue producing chronic radicular pain. Furthermore, it should be considered that patients with recurrent LDH often present with psychosomatic disturbances as a result of repeated surgeries coupled with the recurrence of pain.

CONCLUSIONS

To date, it is not clear which factors might influence the incidence of recurrence following the surgical treatment of LDH. Therefore, their definition might influence the treatment strategy and the clinical outcome. In spite of the fact that discectomy is considered to be protective against LDH recurrence, our data demonstrate that there is no significant correlation between open technique and risk of recurrence, for both primary LDH and subsequent recurrences. Large randomized controlled trials are warranted.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Shamim MS, Parekh MA, Bari ME, Enam SA, Khursheed F. Microdiscectomy for lumbosacral disc herniation and frequency of failed disc surgery. *World Neurosurg* 2010;74:611-6.
- Ebeling U, Kalbarczyk H, Reulen HJ. Microsurgical reoperation following lumbar disc surgery. Timing, surgical findings, and outcome in 92 patients. *J Neurosurg* 1989;70:397-404.
- Fandiño J, Botana C, Viladrich A, Gomez-Bueno J. Reoperation after lumbar disc surgery: Results in 130 cases. *Acta Neurochir (Wien)* 1993;122:102-4.
- Keskimäki I, Seitsalo S, Osterman H, Rissanen P. Reoperations after lumbar disc surgery: A population-based study of regional and interspecialty variations. *Spine (Phila Pa 1976)* 2000;25:1500-8.
- Suk KS, Lee HM, Moon SH, Kim NH. Recurrent lumbar disc herniation: Results of operative management. *Spine (Phila Pa 1976)* 2001;26:672-6.
- Cinotti G, Gumina S, Giannicola G, Postacchini F. Contralateral recurrent lumbar disc herniation. Results of discectomy compared with those in primary herniation. *Spine (Phila Pa 1976)* 1999;24:800-6.
- Cinotti G, Roysam GS, Eisenstein SM, Postacchini F. Ipsilateral recurrent lumbar disc herniation. A prospective, controlled study. *J Bone Joint Surg Br* 1998;80:825-32.
- O'Sullivan MG, Connolly AE, Buckley TF. Recurrent lumbar disc protrusion. *Br J Neurosurg* 1990;4:319-25.
- Gaston P, Marshall RW. Survival analysis is a better estimate of recurrent disc herniation. *J Bone Joint Surg Br* 2003;85:535-7.
- Babar S, Saifuddin A. MRI of the post-discectomy lumbar spine. *Clin Radiol* 2002;57:969-81.
- Carragee EJ, Han MY, Suen PW, Kim D. Clinical outcomes after lumbar discectomy for sciatica: The effects of fragment type and anular competence. *J Bone Joint Surg Am* 2003;85-A: 102-8.
- Mobbs RJ, Newcombe RL, Chandran KN. Lumbar discectomy and the diabetic patient: Incidence and outcome. *J Clin Neurosci* 2001;8:10-3.
- Matsui H, Terahata N, Tsuji H, Hirano N, Naruse Y. Familial predisposition and clustering for juvenile lumbar disc herniation. *Spine (Phila Pa 1976)* 1992;17:1323-8.
- An HS, Silveri CP, Simpson JM, File P, Simmons C, Simeone FA, *et al.* Comparison of smoking habits between patients with surgically confirmed herniated lumbar and cervical disc disease and controls. *J Spinal Disord* 1994;7:369-73.
- Kelsey JL, Githens PB, O'Conner T, Weil U, Calogero JA, Holford TR, *et al.* Acute prolapsed lumbar intervertebral disc. An epidemiologic study with special reference to driving automobiles and cigarette smoking. *Spine (Phila Pa 1976)* 1984;9:608-13.
- Mundt DJ, Kelsey JL, Golden AL, Pastides H, Berg AT, Sklar J, *et al.* An epidemiologic study of non-occupational lifting as a risk factor for herniated lumbar intervertebral disc. The northeast collaborative group on low back pain. *Spine (Phila Pa 1976)* 1993;18:595-602.
- Sørli A, Gulati S, Giannadakis C, Carlsen SM, Salvesen Ø, Nygaard ØP, *et al.* Open discectomy vs. microdiscectomy for lumbar disc herniation – A protocol for a pragmatic comparative effectiveness study. *F1000Res* 2016;5:2170.
- Katayama Y, Matsuyama Y, Yoshihara H, Sakai Y, Nakamura H, Nakashima S, *et al.* Comparison of surgical outcomes between macro discectomy and micro discectomy for lumbar disc herniation: A prospective randomized study with surgery performed by the same spine surgeon. *J Spinal Disord Tech* 2006;19:344-7.
- Jacobs WC, Arts MP, van Tulder MW, Rubinstein SM, van Middelkoop M, Ostelo RW, *et al.* Surgical techniques for sciatica due to herniated disc, a systematic review. *Eur Spine J* 2012;21:2232-51.
- Cheng J, Wang H, Zheng W, Li C, Wang J, Zhang Z, *et al.* Reoperation after lumbar disc surgery in two hundred and seven patients. *Int Orthop* 2013;37:1511-7.
- Martin BI, Deyo RA, Mirza SK, Turner JA, Comstock BA, Hollingworth W, *et al.* Expenditures and health status among adults with back and neck problems. *JAMA* 2008;299:656-64.
- Daffner SD, Hymanson HJ, Wang JC. Cost and use of conservative management of lumbar disc herniation before surgical discectomy. *Spine*

- J 2010;10:463-8.
23. Shriver MF, Xie JJ, Tye EY, Rosenbaum BP, Kshetry VR, Benzel EC, *et al.* Lumbar microdiscectomy complication rates: A systematic review and meta-analysis. *Neurosurg Focus* 2015;39:E6.
 24. Garg B, Nagraja UB, Jayaswal A. Microendoscopic versus open discectomy for lumbar disc herniation: A prospective randomised study. *J Orthop Surg (Hong Kong)* 2011;19:30-4.
 25. Liu WG, Wu XT, Guo JH, Zhuang SY, Teng GJ. Long-term outcomes of patients with lumbar disc herniation treated with percutaneous discectomy: Comparative study with microendoscopic discectomy. *Cardiovasc Intervent Radiol* 2010;33:780-6.
 26. Rasouli MR, Rahimi-Movaghar V, Shokraneh F, Moradi-Lakeh M, Chou R. Minimally invasive discectomy versus microdiscectomy/open discectomy for symptomatic lumbar disc herniation. *Cochrane Database Syst Rev* 2014;4:9. CD010328.
 27. Azarhomayoun A, Chou R, Shirdel S, Lakeh MM, Vaccaro AR, Rahimi-Movaghar V, *et al.* Sequestrectomy versus conventional microdiscectomy for the treatment of a lumbar disc herniation: A systematic review. *Spine (Phila Pa 1976)* 2015;40:E1330-9.
 28. Fakouri B, Shetty NR, White TC. Is sequestrectomy a viable alternative to microdiscectomy? A systematic review of the literature. *Clin Orthop Relat Res* 2015;473:1957-62.
 29. Lubelski D, Senol N, Silverstein MP, Alvin MD, Benzel EC, Mroz TE, *et al.* Quality of life outcomes after revision lumbar discectomy. *J Neurosurg Spine* 2015;22:173-8.
 30. Moore AJ, Chilton JD, Uttley D. Long-term results of microlumbar discectomy. *Br J Neurosurg* 1994;8:319-26.
 31. Williams RW. Microlumbar discectomy: A conservative surgical approach to the virgin herniated lumbar disc. *Spine (Phila Pa 1976)* 1978;3:175-82.
 32. Spengler DM. Lumbar discectomy. Results with limited disc excision and selective foraminotomy. *Spine (Phila Pa 1976)* 1982;7:604-7.
 33. McGirt MJ, Ambrossi GL, Dato G, Sciubba DM, Witham TF, Wolinsky JP, *et al.* Recurrent disc herniation and long-term back pain after primary lumbar discectomy: Review of outcomes reported for limited versus aggressive disc removal. *Neurosurgery* 2009;64:338-44.
 34. Ran J, Hu Y, Zheng Z, Zhu T, Zheng H, Jing Y, *et al.* Comparison of discectomy versus sequestrectomy in lumbar disc herniation: A meta-analysis of comparative studies. *PLoS One* 2015;10:e0121816.
 35. Barth M, Diepers M, Weiss C, Thomé C. Two-year outcome after lumbar microdiscectomy versus microscopic sequestrectomy: Part 2: Radiographic evaluation and correlation with clinical outcome. *Spine (Phila Pa 1976)* 2008;33:273-9.
 36. Mochida J, Nishimura K, Nomura T, Toh E, Chiba M. The importance of preserving disc structure in surgical approaches to lumbar disc herniation. *Spine (Phila Pa 1976)* 1996;21:1556-63.
 37. Hlubek RJ, Mundis GM Jr. Treatment for recurrent lumbar disc herniation. *Curr Rev Musculoskelet Med* 2017;10:517-20.
 38. Mroz TE, Lubelski D, Williams SK, O'Rourke C, Obuchowski NA, Wang JC, *et al.* Differences in the surgical treatment of recurrent lumbar disc herniation among spine surgeons in the United States. *Spine J* 2014;14:2334-43.
 39. Marcus JD, James AR, Härti R. Minimally invasive surgical treatment options for lumbar disc herniations and stenosis. *Semin Spine Surg* 2011;23:20-6.
 40. Yorimitsu E, Chiba K, Toyama Y, Hirabayashi K. Long-term outcomes of standard discectomy for lumbar disc herniation: A follow-up study of more than 10 years. *Spine (Phila Pa 1976)* 2001;26:652-7.
 41. Parker SL, Mendenhall SK, Godil SS, Sivasubramanian P, Cahill K, Ziewacz J, *et al.* Incidence of low back pain after lumbar discectomy for herniated disc and its effect on patient-reported outcomes. *Clin Orthop Relat Res* 2015;473:1988-99.
 42. Koerner JD, Glaser J, Radcliff K. Which variables are associated with patient-reported outcomes after discectomy? Review of SPORT disc herniation studies. *Clin Orthop Relat Res* 2015;473:2000-6.