Review Article
Volume 9:6, 2020
DOI: 10.37421/jsp.2020.9.462

Journal of Spine

ISSN: 2165-7939

Open Access

Assessment of Functional Outcome and Complications in the Surgical Decompression of Lumbar Spinal Stenosis: A Systematic Review

Vamsi Reddy*, Luca H. Debs and Samuel D. Macomson
Department of Neurological Surgery, Medical College of Georgia, Augusta, Georgia, USA

Abstract

Background: Surgical intervention may become necessary for chronic pain secondary to Lumbar Spinal Stenosis (LSS). It can be effectively achieved by using Conventional Decompression Surgery (CDS) or Minimally Invasive Spine Surgery (MISS). This study aimed to compare the functional outcome and complications associated with these two techniques.

Methods: Online database sources (PMC and Cochrane Library) were utilized to identify 1,050 publications, which were narrowed down to 18 studies included in this systematic review. The mean postoperative improvement in Oswestry Disability Index (ODI) and Visual Analog Scale/ Numeric Pain Rating Scale (VAS/NPRS) scores was statistically evaluated by using SPSS-23 and compared for the two techniques through independent t-test. A p-value <0.05 was considered significant.

Results: A total of 1,724 patients [CDS=705; MISS=1019] were included in the study. MISS cases had a significantly greater mean ODI preoperatively and the mean ODI improvement was significantly better in this cohort. The patients undergoing MISS also had a significant decline in the VAS/NPRS scores for Low Back Pain (LBP) and Leg Pain (LP). A significantly higher rate of operative complications and reoperation were seen in CDS patients.

Conclusion: In cases of LSS, this review suggests that MISS carries a lower risk of complications and appears to yield better functional outcomes when compared to CDS.

Keywords: Spinal stenosis • Decompression • Laminectomy • Minimally invasive surgical procedures • Vertebral fusion • Complications

Introduction

Lumbar spinal stenosis is a pathological condition originating from decreased space available for the neural elements resulting in compressive forces on the conus medullaris, cauda equina, or individual lumbar nerve roots. It is linked to the insidious onset of a severe Low Back Pain (LBP) accompanied by a lower limb pain. Some potential pathological causes of LSS include developmental abnormalities (e.g. achondroplasia) or age-related degenerative phenomena (including osteoporosis). Moreover, narrowing of vertebral canal or intervertebral foramina may also occur due to lumbar disc protrusion, osteophytic growth of the lumbar vertebrae or presence of short, thickened pedicles etc. Stenosis of the lumbar spine is also a common occurrence secondary to ankylosing spondylitis, spondylosis and spondylolisthesis of the L1-L5 vertebrae [1]. In addition to spinal pain, [2] there are a number of other clinical symptoms that can be tied to LSS. There is a strong correlation of LSS with dull, cramping pain in the legs, termed claudication. Those cases having a herniated disc, also report recurrent episodes of sciatica [3]. Position-dependent neurogenic pain is also a common feature of lumbar stenosis. It is characterized by a stabbing leg pain, stimulated by extension of the spinal column upon standing up. On the contrary, this pain is likely to be relieved upon vertebral flexion. Management of LSS is accomplished through conservative or invasive measures. Surgical decompression is indicated when compression of the neural elements results in profound neurological deficits or pain that is refractory to non-invasive treatment.

In the past few decades, chronic backache due to lumbar stenosis has been increasingly treated via surgical intervention [4]. Presently, two options are available for an effective surgical management of LSS. These include open spinal decompression, which is conventionally carried out through a larger incision and usually involves laminectomy or laminotomy (with or without vertebral fusion surgery) of the involved vertebral segments. On the other hand, there is the minimally invasive decompression procedure that has an immensely growing popularity among the spine surgeons and patients alike [5]. It involves the placement of a tubular retraction system which allows a much smaller incision and minimal dissection and damage to the surrounding soft tissues. The recent literature suggests that Minimally Invasive Spine Surgery (MISS) has an upper hand over the Conventional Decompression Surgery (CDS) in terms of operating time, length of admission, and overall complication rates [6,7]. However, there is a lack of statistical evidence comparing these two operative techniques with respect to their functional outcome. The functional outcome can be adequately assessed by using statistical parameters such as Oswestry Disability Index (ODI score) [8,9] to compare the preoperative and postoperative functional status of the patients. Further, it can also be used to evaluate postoperative pain relief. In the light of the above rationale, the authors designed a systematic review to analyze the functional outcome as well as the operative complications of CDS and MISS among the patients diagnosed with LSS.

Literature Search

This study was designed as a systematic review.

Selection criteria

This systematic review was carried out in July, 2020. The authors used

***Address for Correspondence:** Reddy V, Department of Neurological Surgery, Medical College of Georgia, Augusta, Georgia, USA, E-mail: vareddy@augusta.edu*

Received 29 September 2020; **Accepted** 20 October 2020; **Published** 27 October 2020

online medical database sources (PubMed Central and Cochrane Library) to search for prospective or retrospective studies assessing surgical outcome pertaining to either conventional or minimally invasive decompression of the Lumbar Spinal Stenosis (LSS). The following keywords were used: Laminectomy; Minimally invasive surgery; Lumbar spinal stenosis. Initially, a total of 1,050 records were identified. Forty five articles were segregated after a comprehensive title and abstract study. Exclusion criteria were then applied to exclude those articles which had discussed the patients suffering from spinal stenosis of regions other than the lumbar vertebral column. In addition, the articles which had not described the functional outcome of surgery in terms of ODI (Oswestry Disability Index) score were also excluded. Eventually, eighteen studies (conventional decompression=9; minimally invasive decompression=9) were included into the systematic review.

Operational Definitions and Statistical Analysis

Types of spine surgery

Patients were categorized into conventional decompression and minimally invasive spine intervention groups. Conventional spine decompression included the “open” laminectomy or laminotomy procedures performed with or without lumbar spine fusion and instrumentation. On the contrary, MISS involved the minimally invasive spine decompression with or without spine fusion and instrumentation. MISS was carried out with the aid of a tubular retraction system by using either an endoscope or a microscope.

Functional outcomes

Functional outcome of these two methods was assessed in terms of the preoperative and postoperative ODI scores of patients. The ODI scores are evaluated on a scale of 0-100 while lower scores are associated with an improved surgical outcome. In addition, pain scores of patients (both Low Back Pain; LBP and Leg Pain; LP) were also estimated by using Visual Analog Scale (VAS) or Numeric Pain Rating Scale (NPRS) with lower scores indicating a better outcome. The mean improvement in ODI and pain scores was compared between the two surgical techniques by using independent / unpaired t-tests (p-value <0.05 was considered significant).

Operative complications

Complications of both operative methods were evaluated. Their relative incidence was also contrasted between the two techniques by using chi-square test (p-value < 0.05 was considered statistically significant). The entire statistical analysis was performed on SPSS (Statistical Package for Social Sciences) version 23. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were strictly followed throughout the study (Figure 1).

Results

Patient characteristics

A total of 1,724 LSS patient records were identified through the eighteen articles included within the study. The Conventional Decompression Surgery (CDS) group consisted of 705 individuals while the Minimally Invasive Spine Surgery (MISS) group included 1,019 patients of lumbar stenosis. The basic characteristics of these cases are described in the Table 1. It is noteworthy that a total of 113 patients could not adhere to the long-term follow-up schedule and therefore, these cases were not considered during the estimation of mean ODI/pain scores. Their exclusion however, did not alter the overall ratio of the two patient cohorts (CDS: MISS=1:1.5). As many as 377 (21.9%) patients underwent a simultaneous spine fusion. The minimally invasive technique was found to be significantly associated with the procedure of spine fusion surgery (p<0.001). The mean preoperative ODI values indicate that patients placed in the MISS cohort had a significantly higher score (p=0.009), indicating that the MISS group had more functional impairment prior to surgery. Within the ODI values, the extent of low back pain was comparable in both CDS and MISS patients; however, leg pain scores were markedly higher for the latter (p=0.03), as depicted in Table 1.

Functional outcome of spinal cord decompression

Out of 1,611 patients who were evaluated at regular follow-up visits, it was estimated that both CDS and MISS groups had comparable postoperative ODI scores. Despite having a higher pre-intervention ODI, the minimally invasive technique managed to provide a significantly greater mean ODI reduction than the CDS cohort (p=0.006). In terms of pain scores, both low back pain and leg pain were significantly relieved among the MISS patients postoperatively. Moreover, the mean postoperative reduction in LBP scores (as found by using VAS/NPRS) was higher for the patients undergoing minimally invasive intervention (p=0.045). Similarly, preoperative LP showed a better mean reduction in the MISS cases (p<0.001). These results are further illustrated in Table 2.

Operative complications

Data analysis shows a significantly higher incidence of complications during open surgery as compared to minimally invasive technique (p<0.001; OR=2.94). Among these complications, intraoperative dural tears were the

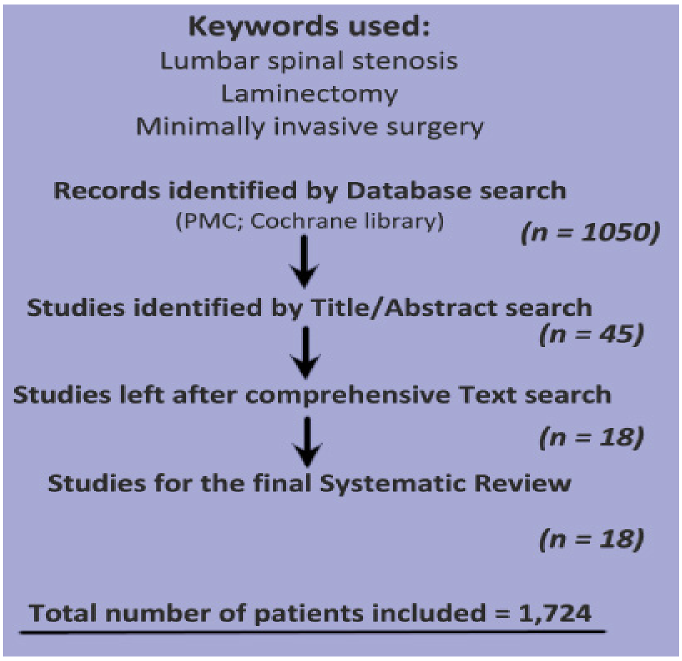

Figure 1. Literature search by using PRISMA guidelines.

Table 1. Patient parameters compared for CDS and MISS.

Patient characteristics		Operative technique	Number of patients	
Total patients (n=1724)		CDS	705 (40.9%)	
		MISS	1019 (59.1%)	
Mean patient age (± SD)		CDS	66.8 (± 4.4)	
		MISS	66.6 (± 5.7)	
Mean follow-up in months (± SD)		CDS	25.5 (± 19.4)	
		MISS	17.8 (± 7.8)	
Patients presenting in follow-up (n=1611)		CDS	650 (40.3%)	
		MISS	961 (59.7%)	
Mean preoperative scores (± SD)	ODI score (n=1611)	CDS	42.4 (± 10.9)	
		MISS	57.8 (± 10.9)	(p=0.009)
	LBP score (n=1392)	CDS	6.4 (± 1.1)	
		MISS	6.8 (± 1.5)	(p=0.642)
	LP score (n=661)	CDS	6.5 (± 0.3)	(p=0.03)
		MISS	7.6 (± 0.6)	

CDS: Conventional Decompression Surgery; MISS: Minimally Invasive Spine Surgery; ODI: Oswestry Disability Index; LBP: Low Back Pain; LP: Leg Pain

Table 2. Functional outcome of CDS and MISS techniques in spinal stenosis.

Functional Outcome (Number of patients)		Type of Spine Surgery		p-value
		CDS (Mean ± SD)	**MISS (Mean ± SD)**	
Mean ODI Score (Scale: 0-100)	**Postoperative** (n=1611)	23.8 (± 7.2)	20.1 (± 6.1)	0.252
	Mean Improvement (n=1611)	18.6 (± 8.4)	37.7 (± 15.0)	0.006
Mean LBP Score (Scale: 0-10)	**Postoperative** (n=1392)	3.3 (± 0.6)	2.1 (± 1.1)	0.032
	Mean Improvement (n=1392)	3.1 (± 1.2)	4.7 (± 1.5)	0.045
Mean LP Score (Scale: 0-10)	**Postoperative** (n=661)	3.6 (± 0.4)	1.6 (± 0.8)	0.008
	Mean Improvement (n=661)	3.0 (± 0.5)	6.0 (± 0.4)	<0.001

CDS: Conventional decompression surgery; MISS: Minimally invasive spine surgery; ODI: Oswestry disability index; LBP: Low Back Pain; LP: Leg Pain

Table 3. Operative complications observed in lumbar spinal stenosis surgery.

Surgical Complications		Type of Spine Surgery		p-value	Odds Ratio (OR)
		CDS (n=619)	**MISS** (n=1019)		
Total Number of Patients (n=1638)	**Total Complications** (n=149)	92 (5.6%)	57 (3.4%)	<0.001	2.94
	Uncomplicated Cases (n=1489)	527 (32.2%)	962 (58.7%)		
	1. Dural Tears (n = 61)	47 (2.9%)	14 (0.9%)	<0.001	5.90
	2. Superficial / Deep Wound Infections (n=13)	12 (0.7%)	1 (0.06%)	<0.001	20.13
	3. Neuropathic Pain (n=9)	0	9 (0.5%)	N/A	N/A
	4. Excessive Intraoperative Bleeding (n=9)	9 (0.5%)	0	N/A	N/A
	5. Screw Malposition/Incorrect Rod Fixation (n=7)	1 (0.06%)	6 (0.3%)	0.199	0.27
	6. Urinary Tract Infections (n=5)	1 (0.06%)	4 (0.2%)	0.411	0.41
	7. Spine Fracture / Spondylolisthesis (n=4)	3 (0.2%)	1 (0.06%)	0.124	4.96
	8. Facet Dysfunction (n=3)	3 (0.2%)	0	N/A	N/A
	9. CSF leakage (n=3)	0	3 (0.2%)	N/A	N/A
	10. Chest Infections (n=3)	3 (0.2%)	0	N/A	N/A
	11. Epidural Hematoma (n=3)	1 (0.06%)	2 (0.1%)	0.873	0.82
	12. Urinary Retention (n=2)	0	2 (0.1%)	N/A	N/A
	13. DVT (n=1)	1 (0.06%)	0	N/A	N/A
	14. Pulmonary Embolism (n=1)	0	1 (0.06%)	N/A	N/A
	15. Cauda Equina Syndrome (n=1)	1 (0.06%)	0	N/A	N/A
	16. Pseudoarthrosis (n=1)	1 (0.06%)	0	N/A	N/A
	17. Paralytic Ileus (n=1)	0	1 (0.06%)	N/A	N/A
	18. Spinal Nerve palsy (n=1)	1 (0.06%)	0	N/A	N/A
	19. Others (n=21)	8 (0.5%)	13 (0.8%)	N/A	N/A

CDS: Conventional Decompression Surgery; MISS: Minimally Invasive Spine Surgery

Table 4. Functional outcome and complications seen in Conventional Decompression Surgery (CDS) and Minimally Invasive Spine Surgery (MISS) for spinal stenosis.

Authors	Sample size (Patients in follow-up)	Mean Follow-up (in months)	Patient Diagnosis	Type of Surgery	Fusion Surgery (%)	Functional Outcome						Percentage Complications (%)	
						Mean ODI		Mean LBP		Mean LP		Yes	No
						Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op		
Jakola A.S et al. [10]	101 (82)	12	LSS (101)	CDS	None	44.2	27.9	5.57	3.59	6.02	3.36	18 (12.1%)	83 (5.6%)
Gunzburg R. et al. [11]	36 (36)	20.4	LSS (36)	CDS	None	42.07	30.9	6.59	3.61	N/A	N/A	N/A	N/A
Kim E.H et al. [12]	61 (61)	39	LSS (61)	CDS	PLIF=61 (3.5%)	34.6	14.1	8.1	3.4	N/A	N/A	17 (11.4%)	44 (3%)
Williams M.G et al. [13]	133 (119)	12	LSS (133)	CDS	None	45.55	29.87	4.99	3.33	6.76	3.44	27 (18.1%)	106 (7.1%)
Jones A.D.R et al. [14]	119 (119)	12	LSS (119)	CDS	None	44.82	28.39	5.14	3.07	6.7	3.3	18 (12.1%)	101 (6.8%)
Slatis P. et al. [15]	50 (CDS cases only) [46 presented at follow-up]	72	LSS (50)	CDS	Non-specific=10 (0.6%)	34	24.2	6.9	4.1	6.6	4.2	N/A	N/A

Lu H. et al. [16]	50 (48)	22.8	LSS (50)	CDS	None	31.14	14.02	6.92	2.16	N/A	N/A	3 (2%)	47 (3.2%)
Ghogawala Z. et al. [17]	66 (57)	24	LSS (66)	CDS	Non-specific =31 (1.8%)	37.55	15.45	N/A	N/A	N/A	N/A	3 (2%)	63 (4.2%)
Ücer M. et al. [18]	89 (82)	15.6	LSS (89)	CDS	None	68	29.66	7.19	3.17	N/A	N/A	6 (4%)	83 (5.6%)
Aleem I.S et al. [19]	109 (109)	12	LSS (109)	MISS	Non-specific=41 (2.4%)	42.46	21.41	N/A	N/A	N/A	N/A	12 (8.1%)	97 (6.5%)
Staats P.S et al. [20]	143 (99)	24	LSS (143)	MISS	None	53	22.7	7.7	3.6	N/A	N/A	2 (1.3%)	141 (9.5%)
Wen B et al. [21]	64 (57)	36	LSS (64)	MISS	Non-specific=3 (0.2%)	72.4	12.5	7.7	0.8	N/A	N/A	1 (0.6%)	63 (4.2%)
Polikandriotis J.A et al. [22]	320 (320)	18	LSS (320)	MISS	None	40.1	22.6	6	3	N/A	N/A	7 (4.7%)	313 (21%)
Senker W et al. [23]	229 (229)	12	LSS (229)	MISS	TLIF=229 (13.3%)	60	30	7.6	2.8	8.1	2.5	19 (12.8%)	210 (14.1%)
You K et al. [24]	35 (35)	16	LSS Grade C (20) LSS Grade D (15)	MISS	TLIF=1 (0.06%)	63.82	11.33	4.51	0.66	6.91	0.91	3 (2%)	32 (2.1%)
Pao J.L et al. [25]	60 (53)	15.7	LSS (60)	MISS	None	64.3	16.7	N/A	N/A	N/A	N/A	11 (7.4%)	49 (3.3%)
Caralopoulos I.N et al. [26]	28 (28)	12	LSS (28)	MISS	None	57	26	8.6	2.3	N/A	N/A	1 (0.7%)	27 (1.8%)
Kim J.E et al. [27]	31 (31)	14.8	LSS (31)	MISS	TLIF=1 (0.06%)	66.81	17.39	5.13	1.52	7.87	1.45	1 (0.7%)	30 (2%)
Total	1724 (1611)	N/A	1724	N/A	377 (21.9%)	N/A	N/A	N/A	N/A	N/A	N/A	149 (100%)	1489 (100%)

ODI: Oswestry Disability Index; LBP: Low Back Pain; LP: Leg Pain; LSS: Lumbar Spinal Stenosis; CDS: Conventional Decompression Surgery; MISS: Minimally Invasive Spine Surgery; PLIF: Posterior Lumbar Inter-Body Fusion; TLIF: Trans-Foraminal Lumbar Inter-Body Fusion

most common, and were approximately 6 times more prevalent in the CDS patients as compared to MISS cohort (p<0.001) [10-27]. Moreover, the risks of superficial or deep wound infections and intraoperative bleeding were also significantly greater in the former group. All of these complications are listed in Table 3. In addition, 3.4% cases (out of 619) in the CDS group underwent re-operation following the primary intervention, whereas this percentage was 1.9% for the MISS group (p=0.052; OR=1.85). The distinguishing features of the literature covered by this systematic review are elaborated below in Table 4.

Discussion

In this systematic review the authors analyzed the overall efficacy of two different spine decompression techniques in the treatment of lumbar spinal stenosis. Preoperative parameters (ODI scores) were worse for the patients placed in the MISS group. However, greater ODI scores do not necessarily correlate to a higher degree of spinal stenosis [28]. Analysis of postoperative ODI scores revealed statistically significant differences between operative outcomes of the two surgical techniques i.e., conventional decompression and minimally invasive surgery. The mean improvement in ODI scores was significantly greater for MISS (p<0.05). Mobbs R. J, et al. [29] carried out a comparative analysis of the open laminectomy procedure versus the minimally invasive approach, reporting a statistical trend between the two groups in terms of mean ODI improvement (p=0.055). Additionaly, Nerland U. S et al. [30] estimated a similar postoperative ODI outcome for both operative techniques (p>0.05). In contrast, Imada A. O et al. found a significantly better operative outcome for the minimally invasive TLIF surgery (Transforaminal Lumbar Inter-body Fusion) as compared to the open TLIF approach (p=0.05). Their review was based on the results obtained from a total of 32 studies [31]. The findings of the present systematic review hold significance as a comparatively larger number of patients (93.4%) underwent follow-up evaluation in contrast to the follow-up analysis carried out by Mobbs R. J (68.4%) and Nerland U. S (81.5%). Further, a considerable factor in this scenario is the mean follow-up duration, which is a major determinant of the surgical outcome. In this respect, Nerland et al. had set a shorter standard follow-up protocol as opposed to the current review (12 months versus 25.5 ± 19.4 months for CDS and 17.8 ± 7.8 months for MISS, respectively).

The statistical analysis in this review reveals a significantly better mean improvement in the VAS / NPRS pain scores for the patients undergoing MISS as compared to open technique (p=0.045 for LBP and p<0.001 for LP). Despite not finding an improvement in the mean ODI scores, Mobbs et al. did report a better VAS outcome among the patients undergoing minimally invasive surgery (p=0.013). Significant reduction of VAS scores was also reported in the MISS cohort by Phan K et al. [7] Similarly, Chang F et al. [32] reported a significant postoperative improvement in VAS scores for low backache in the cases undergoing minimally invasive surgery (p=0.01). However, Chang F did not find any statistically significant difference between the ODI scores obtained by the two surgical methods. Nevertheless, it is a well-established fact that minimally invasive approach results in pain reduction during the postoperative follow-up period. Ang C. L et al. [33] have contradicted these results by concluding that MISS lumbar laminotomy lacks any clear-cut advantages over its counterpart approach. However, the sample size in this study was significantly limited (n=113) with approximately 75% patients undergoing minimally invasive procedure, potentially underestimating the effect of the MISS approach.

In the current analysis, open laminectomy/laminotomy procedures had an approximately three times increased risk of operative complications. Furthermore, incidence of dural tears, wound infections and bleeding complications was significantly higher for the open procedures (p<0.05). Multiple research articles have reported a similar outcome. One study found a 5.77 times increased risk of wound infections associated with the open approach [34]. A number of authors have also noted a remarkably reduced blood loss in the MISS patients in contrast to the conventional approaches [35,36]. Lower prevalence of wound infections and decreased blood loss may be attributable to smaller incisions and less tissue dissection and damage. Hammad A et al. have also found a lower complication rate in MISS (11.3%) than CDS technique (14.2%) but these results did not show statistical significance [37]. The reoperation rate, as determined by this review, was higher in the conventional decompression group (3.4%>1.9%; OR=1.85). Evidence from the work of authors, such as Phan K et al. also supports our results (p=0.02). It has been observed by the authors that MISS (27%) was complemented by a fusion procedure more frequently than CDS (14.5%). This significant correlation (p<0.001) between MISS and vertebral fusion might be an important decisive factor in the better operative outcome of the minimally invasive approach to LSS [38].

Limitations

The authors of this systematic review could not accurately evaluate the rate of complications from all of the included literature as they had not been uniformly summarized. In addition to the non-homogenous distribution of statistical data, the authors suspect that the varying periods of mean postoperative follow-up for the two intervention groups might have played a confounding effect in estimation of mean ODI/VAS improvement. However, it is worth mentioning that the variation of mean follow-up durations was not statistically significant (p=0.287). The heterogeneity of data also prevented the authors from correlating the procedure of fusion surgery with the degree of lumbar spinal stenosis. Also, not every study revealed diagnosis or levels prior to operation which could indicate different indications for MISS versus CDS; however, this effect is mitigated by the presence of preoperative ODI scores showing statistically significantly higher scores for the MISS cohort

Conclusion

This review has shown a statistically significant improvement in functional outcome of Minimally Invasive Spine Surgery (MISS) compared to the open decompression approach in Lumbar Spinal Stenosis (LSS). Minimally invasive approaches yielded a greater mean improvement in ODI scores (p=0.006) as well as VAS/NPRS pain scores (p=0.045 for low back pain and p<0.001 for leg pain) compared to Conventional Decompression Surgery (CDS). CDS was also associated with an approximately 3 times greater rate of surgical complications. Overall, there is a role for MISS in lumbar pathologies. The appropriate procedure to perform remains dependent on patient's preference and expectation, disease treated, and surgeon's experience. Future studies should aim at evaluating operative outcome and safety in MISS versus CDS.

References

1. Ciricillo, Strayer. "Lumbar Spinal Stenosis." *West J Med* 158 (1993): 171-177.
2. Leonid Kalichman, Robert Cole, David H. Kim and Ling Li, et al. "Spinal Stenosis Prevalence and Association with Symptoms: The Framingham Study." *Spine J* 9 (2009): 545-550.
3. Tom Amundsen, Henrik Weber, Finn Lilleas and Helge J. Nordal, et al. "Lumbar Spinal Stenosis." *Clin Radiol Feat Spine* 20 (1995): 1178-1186.
4. Marcia A. Ciol, Richard A. Deyo, Eric Howell and Suzanne Kreif. "An Assessment of Surgery for Spinal Stenosis: Time Trends, Geographic Variations, Complications, and Reoperations." *J Am Geriat Soc* 44 (1996): 285-290.
5. Jeffrey H. Oppenheimer, Igor DeCastro and Dennis E. McDonnell. "Minimally Invasive Spine Technology and Minimally Invasive Spine Surgery: A Historical Review." *Neurosurg Focus* 27 (2009): 9.
6. Rahman, Mimran. "Comparison of Techniques for Decompressive Lumbar Laminectomy: The Minimally Invasive *Versus* the "Classic" Open Approach." *Min Invas Neurosurg* 51 (2008): 100-105.
7. Kevin Phan and Ralph J. Mobbs. "Minimally Invasive *Versus* Open Laminectomy for Lumbar Stenosis: A Systematic Review and Meta-Analysis." *Spine* 41 (2016): 91-100.
8. Jeremy C. T. Fairbank and Paul B. Pynsent." The Oswestry Disability Index." *Spine* 25 (2000): 2940-2952.
9. Arto Herno, Tapani Saari, Olavi Suomalainen and Olavi Airaksinen. "The Degree of Decompressive Relief and its Relation to Clinical Outcome in Patients Undergoing Surgery for Lumbar Spinal Stenosis." *Spine* 24 (1999): 1010-1014.
10. Asgeir S Jakola, Andreas Sørlie, Sasha Gulati and Oystein P Nygaard, et al. "Clinical Outcomes and Safety Assessment in Elderly Patients Undergoing Decompressive Laminectomy for Lumbar Spinal Stenosis: A Prospective Study." *BMC Surg* 10 (2010): 34.
11. Gunzburg, Robort. "Clinical and Psychofunctional Measures of Conservative Decompression Surgery for Lumbar Spinal Stenosis: A Prospective Cohort Study." *Euro Spine J* 12 (2003): 197-204.
12. Eung-Ha Kim and Hyung-Tae Kim. "En Bloc Partial Laminectomy and Posterior Lumbar Interbody Fusion in Foraminal Spinal Stenosis." *Asian Spine J* 3 (2009): 66-72.
13. Mark G. Williams, Ahmad M. Wafai and Malcolm D. Podmore. "Functional Outcomes of Laminectomy and Laminotomy for the Surgical Management Lumbar Spine Stenosis." *J Spine Surg* 3 (2017): 580-586.
14. Alistair Daniel Robert Jones, Ahmad Mounir Wafai and Amy Louise Easterbrook. "Improvement in Low Back Pain following Spinal Decompression: Observational Study of 119 Patients." *Euro Spine J* 23 (2014): 135-141.
15. Pär Slätis, Antti Malmivaara, Markku Heliövaara and Päivi Sainio, et al. "Long-Term Results of Surgery for Lumbar Spinal Stenosis: A Randomised Controlled Trial." *Euro Spine J* 20 (2011): 1174-1181.
16. Ali Erhan Kayalar, Mehmet Resid Onen, Aydin Gerilmez and Sait Naderi, et al. "Efficacy of Unilateral Laminectomy for Bilateral Decompression in Lumbar Spinal Stenosis." *Turk Neurosurg* 17 (2007): 100-108.
17. Zoher Ghogawala, James Dziura, William E. Butler and Feng Dai, et al. "Laminectomy plus Fusion *versus* Laminectomy Alone for Lumbar Spondylolisthesis." *New Eng J Med* 374 (2016): 1424-1434.
18. Ücer Muslum and Aydin Ioannis. "Surgical Outcomes of Decompressive Laminectomy by Transspinous Approach for Degenerative Lumbar Spinal Stenosis." *JPMA* 68 (2018): 1618-1624.
19. Ilyas S. Aleem and Raja Y. Rampersaud. "Elderly Patients have Similar Outcomes Compared to Younger Patients after Minimally Invasive Surgery for Spinal Stenosis." *Clin Orthop Relat Res* 472 (2014): 1824-1830.
20. Peter S. Staats, Timothy B. Chafin, Stanley Golovac and Christopher K. Kim, et al. "Long-Term Safety and Efficacy of Minimally Invasive Lumbar Decompression Procedure for the Treatment of Lumbar Spinal Stenosis With Neurogenic Claudication: 2-Year Results of MiDAS ENCORE." *Reg Anesth Pain Med* 43 (2018): 789-794.
21. Bingtao Wen, Xifeng Zhang, Lin Zhang and Peng Huang, et al. "Percutaneous Endoscopic Transforaminal Lumbar Spinal Canal Decompression for Lumbar Spinal Stenosis." *Med* 95 (2016): 5186.
22. John A. Polikandriotis, Elizabeth M. Hudak and Michael W. Perry. "Minimally Invasive Surgery through Endoscopic Laminotomy and Foraminotomy for the Treatment of Lumbar Spinal Stenosis." *J Orthop* 10 (2013): 13-16.
23. Wolfgang Senker, Andreas Gruber, Matthias Gmeiner and Harald Stefanits, et al. "Surgical and Clinical Results of Minimally Invasive Spinal Fusion Surgery in an Unselected Patient Cohort of a Spinal Care Unit." *Orthop Surg* 10 (2018): 192-197.
24. Kemin You, Bo Li, Hongze Chang and Yan Zhang, et al. "The Therapeutic Evaluation of Spinal Canal Decompression by Using the TBEIS Technique in the Treatment of Lumbar Spinal Stenosis." *Bio Med Res Int* 2020 (2020): 6183027.
25. Jwo-Luen Pao, Wein-Chin Chen and Po-Quang Chen. "Clinical Outcomes of Microendoscopic Decompressive Laminotomy for Degenerative Lumbar Spinal Stenosis." *Euro Spine J* 18 (2009): 672-678.
26. Caralopoulos, Imada. "Minimally Invasive Laminectomy in Spondylolisthetic Lumbar Stenosis." *Ochsner J* 14 (2014): 38-43.
27. Ju-Eun Kim, Dae-Jung Choi and Eugene J. Park. "Clinical and Radiological Outcomes of Foraminal Decompression Using Unilateral Biportal Endoscopic Spine Surgery for Lumbar Foraminal Stenosis." *Clin Orthop Surg* 10 (2018): 439-447.
28. Mustafa Sirvanci, Mona Bhatia, Kursat Ali Ganiyusufoglu and Cihan Duran, et al. "Degenerative Lumbar Spinal Stenosis: Correlation with Oswestry Disability Index and MR Imaging." *Euro Spine J* 17 (2008): 679-685.
29. Ralph Jasper Mobbs, Jane Li, Praveenan Sivabalan and Darryl Raley, et al. "Outcomes after Decompressive Laminectomy for Lumbar Spinal Stenosis: Comparison between Minimally Invasive Unilateral Laminectomy for Bilateral Decompression and Open Laminectomy: Clinical Article." *J Neurosurg Spine* 21 (2014): 179-186.
30. Nerland, Ush. "Minimally Invasive Decompression *versus* Open Laminectomy for Central Stenosis of the Lumbar Spine: Pragmatic Comparative Effectiveness Study." *J Neurosurg* 350 (2015): 1603.
31. Allicia Imada, Tridu R Huynh and Doniel Drazin. "Minimally Invasive v*ersus* Open Laminectomy/Discectomy, Transforaminal Lumbar, and Posterior Lumbar Interbody Fusions: A Systematic Review." *Cureus* 9 (2017): 1488.

32. Chang Fang and Zhang Tung. "Comparison of the Minimally Invasive and Conventional Open Surgery Approach in the Treatment of Lumbar Stenosis: A Systematic Review and a Meta-Analysis." *Ann Acad Med* 46 (2017): 124-137.

33. Chia-Liang Ang, Benjamin Phak-Boon Tow, Stephanie Fook and Chang-Ming Guo, et al. "Minimally Invasive Compared with Open Lumbar Laminotomy: No Functional Benefits at 6 or 24 Months after Surgery." *Spine J* 15 (2015): 1705-1712.

34. Wen Wei Gerard Ee, Wen Liang Joel Lau, William Yeo and Yap Von Bing, et al. "Does Minimally Invasive Surgery Have a Lower Risk of Surgical Site Infections Compared With Open Spinal Surgery." *Clin Orthop Relat Res* 472 (2014): 1718-1724.

35. Farbod Asgarzadie and Larry T. Khoo. "Minimally Invasive Operative Management for Lumbar Spinal Stenosis: Overview of Early and Long-Term Outcomes." *Orthop Clin North Am* 38 (2007): 387-399.

36. Branko, Skovrlj. "Perioperative Outcomes in Minimally Invasive Lumbar Spine Surgery: A Systematic Review." *World J Orthop* 6 (2015): 996-1005.

37. Ahmed Hammad, André Wirries, Ardavan Ardeshiri and Olexandr Nikiforov, et al. "Open *versus* Minimally Invasive TLIF: Literature Review and Meta-Analysis." *J Orthop Surg Res* 14 (2019): 229.

38. Kevin T. Foley, Langston T. Holly and James D. Schwender. "Minimally Invasive Lumbar Fusion." *Spine* 28 (2003): 26-35.

How to cite this article: Vamsi Reddy, Luca H. Debs, and Samuel D. Macomson. "Assessment of Functional Outcome and Complications in the Surgical Decompression of Lumbar Spinal Stenosis: A Systematic Review" *J Spine* 9 (2020): 462. Doi: 10.37421/jsp.2020.9.462