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Original article

Outcomes after decompressive laminectomy for lumbar spinal stenosis: Comparison between minimally invasive unilateral laminectomy for bilateral decompression versus open laminectomy

Mohamed Shaban [1], Ahmed Gaber Mostafa [2], Ahmed S. Kamel Abdelwahed [3]

[1] *Department of Neurosurgery, Beni-Suef University, Egypt*

[2] *Department of Orthoptic surgery, Beni-Suef University, Egypt*

[3] *Department of Neurosurgery, Cairo University Egypt*

Article Info

***Corresponding Author**:*

Ahmed S.Kamel Abdelwahed

askamel@gmail.com

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Abstract

Background: Lumbar spinal stenosis (LSS) is typically caused by degenerative facet joint , ligament hypertrophy, and broad-based disc bulging, leading to lateral recess and lumber canal compression, resulting in walking debility and also leg pain. LSS is a progressive degenerative disease that most commonly affects elderly patients over 60 years old and can significantly impact the daily activities and quality of life leading to progressive disability. **Aim:** comparing the outcomes following minimally invasive unilateral laminectomy for bilateral decompression (ULBD) to standard open laminectomy for lumbar spinal stenosis. **Patients & Methods:** Randomized controlled prospective clinical trial- single-blinded study for 30 patients with lumbar canal stenosis who were randomly allocated to one of the two interventional groups; group (A) 15 patients underwent conventional Laminectomy, group (B) 15 patients underwent microsurgical decompression from March 2019 till March 2021 in a bani-siuf university and cairo university department of neurosurgery.

Results: There was no statistically significant difference between both groups regarding the motor power, sensory nerve affection, straight leg raising, and stenotic level (p-value >0.05**).** Four patients (26.6%) in group A presented with motor affection (ankle dorsiflexion grade 2_3) versus one patient in group B presented motor affection (ankle dorsiflexion grade 4). Five patients (16.7%) presented with sensory affection. SLR was affected in 6 patients (20%). L4-5 was the more level affected (58%) then L3-4 (26%) and L5-S1 (16%). 7 patients (23.3%) need discectomy. **Conclusion**: This study demonstrated the possibility of decompressing the lumber canal by the use of a unilateral approach. Surgical experience is mandatory to adequately decompress the neural structures. ULBD is effective as laminectomy in the treatment of LSS with the benefit of respecting the integrity of the neural elements with a little amount of blood loss**.**

1. Introduction:

Lumbar spinal stenosis (LSS) is typically caused by degenerative facet joint , ligament hypertrophy, and broad-based disc bulging, leading to lateral recess and lumber canal compression, resulting in walking debility and also leg pain. LSS is a progressive degenerative disease that most commonly affects elderly patients over 60 years old and can significantly impact the daily activities and quality of life leading to progressive disability.[1]. Patients usually complain from many symptoms as neurogenic claudication, which can be increased by standing and decreased by flexion at the waist, as in the sitting position. Patients may also have tingling, numbness, and lower extremities weakness [2]. Conservative treatment consider is the main option in therapy for most patients with LSS and may include physiotherapy, rest , medication, and epidural injections of steroid. [3]

Surgery is indicated when acute event for patients occur as rapidly progressive neurological impairment or sphincteric dysfunction[1]. Surgical decompression in cases of failed conservative treatment has similar result to the patients who are initially treated with surgical decompression [4].

LSS is a chronic disease in which conservative management fails to relieve the symptoms in many patients. Ciol et al. in a conservatively managed cohort found that 70% of the patients described similar symptoms, 15% experienced worsened symptoms, and only 15% reporting symptoms improvement after 4 years [5]. The traditional surgical approach in cases of LSS involves generally a laminectomy associated with foraminotomy and partial facetectomy. In the case of spondylolisthesis, lumbar spine fusion can be performed [1]. However, in selected patients with listhesis, recent literature supports simple decompression alone as a method of treatment without instrumentation [6]. Surgery is more usually elective, intend to improve the life quality rather than prevent neurological impairment [1]. This study aims to compare the safety and the clinical outcomes after microsurgical decompression, and conventional laminectomy in patients with lumbar canal stenosis.

2. Patient and methods:

Study Methods: From March 2019 to March 2021 in Bani-Siuf university and cairo university department of neurosurgery.

Randomized controlled prospective clinical trial-single-blinded study for patients with lumbar canal stenosis who were randomized to one of the two treatment groups, group (A) 15 patients underwent conventional Laminectomy, and group (B) 15 patients underwent microsurgical decompression.

Inclusion criteria include symptoms of radiculopathy or neurogenic claudication not improved after medical treatment (at least 3 months), radiological/ neuroimaging evidence of lumbar canal stenosis (bony, discogenic, or ligamentous) not more than 3 levels of stenosis. Patients presented by associated pathological entities as instability or deformity and a history of previous surgery for lumbar spine were excluded from the study.

Data about age and sex were recorded. Clinical data; symptoms of low backache , leg pain (sciatica or claudication), subjective numbness, subjective weakness, sphincteric problems, and duration of symptoms. Neurological assessment; motor power, sensation, and reflexes. Radiological assessment; MRI and dynamic x-ray lumbosacral spine and routine pre-operative labs. Intra-operative assessment; duration of surgery and estimated blood loss. Peri-operative complication; incidental durotomy, increased radicular pain, re-operate, hematoma, wound infection motor deficit, or sphincter affection. Post-operative assessment; Symptom's improvement: Using visual analog score (VAS) and Neurogenic claudication outcome score (NCOS) [7]

Blinding techniques were used and the patients didn't know to which group patients belong and what intervention the patient was receiving until the conclusion of the study.

Surgical techniques: for both groups, the procedure was performed under general anesthesia. Prophylactic antibiotics were provided at the initiation of the procedure. The patient was lie in prone position on the Wilson frame which kept abdomen free without compression and give access for x-ray imaging, extremities were carefully padded, and care was taken that the belly hangs are free so the venous structures are not compressed to minimize the blood loss.

At the proposed location of the surgical incision, A spinal needle is introduced, and the needle position relative to the neural compression site is checked with C-arm fluoroscopy. The midline skin incision was made after confirming the correct needle localization.

Group (A): conventional Laminectomy; Para spinal muscles (multifidus) were dissected sub-periosteally to expose the facet capsules bilaterally at each level, then bilateral laminectomies were performed with central and lateral recess decompression.

Group (B): Microsurgical decompression; For (a) ipsilateral decompression a small Cobb elevator was placed where the muscle elevated sub-periosteally away from the spinal lamina. The c-Arm lateral view was used to confirm localization. The microscope was used to visualize the surgical field.

For (b) Ipsilateral decompression; a dissector was used to separate the ligamentum flavum from the lamina undersurface then, the Kerrison rongeur was used to do the ipsilateral laminotomy in which it should advanced to reach the ligamentum flavum cranial edge. the ligamentum flavum was then removed. After removal of the ligamentum flavum, the pedicle is observed by palpation with a probe for identify the canal pathology, and also good visualization of the nerve root as needed to decompress of the lateral recess.

To decompress the lateral recess a kerrison rongeur was used while preserving the overlying facet complex to avoid iatrogenic fracture. The decompression of the ipsilateral foramen is done by resection of the superior tip of the superior articular process as needed for exiting nerve root decompression. The disc was visualized and removed if needed.

Contralateral Decompression ;if bilateral decompression is indicated , the ligamentum flavum will left intact until ipsilateral decompression was done then, the operative table is angled away from the surgeon, and reposition of the microscope .was made to provide visualization of the base of spinous process . Kerrison rongeur was used to remove away the ipsilateral spinous process base dorsal to the ligamentum flavum. A dissector was used for ligamentum flavum separation from the contralateral lamina, and the undermining was progress through the contralateral lamina until the contralateral facet joint reached. After the undercutting maneuver, the ligament flavum was removed after separation from its bony attachments.

The neural elements are visualized for remaining ligamentous or bony compression and the probe is used to confirm the adequate decompression.

Early return to ambulation and normal daily activities was encouraged. Pain management was generally provided by oral NSAIDs. Rehabilitation is also advice postoperative period.

Statistical analysis

Analysis of data was performed using SPSS v. 22 (Statistical Package for Social science) for Windows. Description of variables was presented as follows: Description of quantitative variables was in the form of mean, standard deviation (SD), minimum and maximum. Description of qualitative variables was in the form of numbers (No.) and percent (%).

Comparison between quantitative variables was carried out by independent sample T-test (or the independent sample Mann-Whitney U test as a non-parametric test) which was used to test the difference between the means of several subgroups of a variable (multiple testing).

Comparison between categorical data was done using the Chi-square test, to test the statistical difference between the two groups. The significance of the results was set at P-value ≤ 0.05.

3. Results:

This randomized controlled trial was conducted at Beni-Suef University hospital department of neurosurgery and orthopedic surgery to compare the safety and efficacy after microsurgical decompression, and conventional laminectomy in patients with lumbar canal stenosis who were randomly allocated to one of the two interventional groups; Group (A) underwent conventional Laminectomy, Group (B) underwent microsurgical decompression.

There was no statistically significant difference between both groups regarding age distribution (P- value=0.713). The mean duration of symptoms till the operation was 27.2 ±14.5 months and 19.1±13.4 months for group A and group B, respectively (P-value= 0.125) **(Table 1**). The male to female ratio was (53.3/46.7) and (60/40) for groups A, B respectively

Table (1): age and duration of the study :

	Group (A)	Group (B)	P-value
Age	47.2±8.8	39.4±9.2	0.025
Duration of symptoms	27.2±14.5 SD	19.1±13.4 SD	0.125

Neurogenic claudication and back pain were the main symptoms in both groups, (13.3%) versus (33.3) patients complained of sciatica in groups A, B respectively. Sphincteric affection was present only in one case (6.7%) in group A **(Table 2)**

Table (2): Clinical presentation of patients among both groups:

Complaints	**Group**		**Chi-value**	**P-value**
	Group A 15(100%)	**Group B 15(100%)**		
LBP Absent Present	2(13.3) 13(86.7)	2(13.3) 13(86.7)	0.000??	1.000
Claudication Unilateral Bilateral	5(33.3) 10(67.7)	6(40) 9(60)	0.144	0.705
Sciatica Absent Present	13(86.7) 2(13.3)	10(66.7) 5(33.3)	1.67	0.195
Sphincteric affection Absent Present	14(93.3) 1(6.7)	15(100) 0(0)	1.04	0.309

There was no statistically significant difference in both groups regarding the motor power, sensory nerve affection, straight leg raising, and stenotic level (p-value >0.05**).**

Four patients (26.6%) in group A presented with motor affection (ankle dorsiflexion grade 2_3) versus one patient in group B presented motor affection (ankle dorsiflexion grade 4). Five patients (16.7%) presented with sensory affection. SLR was affected in 6 patients (20%). L4-5 the more affected level (58%) then L3-4 (26%) and L5-S1 (16%). 7 patients (23.3%) need discectomy **(Table 3)**.

Table (3): Clinical examination and radiological findings of patients amongboth groups:

Examination	**Group**		**Chi-value**	**P-value**
	Group A 15(100%)	Group B 15 (100%)		
Motor power				
Not affected	11(73.3)	14(93.3)	5.36	0.252
Affected	4(26.6)	1(6.7)		
Sensory nerve affection				
Not affected	11(73.3)	13(86.7)	1.16	0.558
Affected	4(26.6)	2(12.4)		
Straight leg raising				
Normal	13(86.7)	10(66.7)	0.000	0.195

Affected	2(13.3)	5(33.3)		
Radiological findings				
Stenotic level				
L3-4	8	5	0.85	0.632
L4-5	15	14		
L5-S1	5	3		

Figure (1) showed that there was no statistically significant difference between both groups regarding the need for discectomy as there were 2 (13.3%) and 5 (33.3%) cases who needed discectomy (P-value =0.195 and chi-value=1.8).

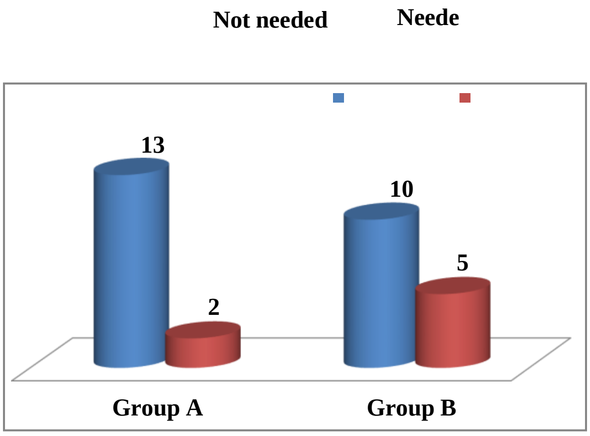


Figure (1): Comparison between both groups regarding the need fordiscectomy during the operation.

The estimated blood loss was significantly higher among group A than in group B (P-value=0.033), contrary to the surgical time that was significantly higher in group B than in group A (P-value=0.009). the follow-up period was higher among group A than group B (P-value <0.001). The follow-up period was significantly higher among group A than in group B (9.9±1.5 vs. 6.1±3.2 months) (P-value <0.001). **Table (4).**

Table (4): Comparison between both groups regarding the operationcircumstances and follow-up period:

Circumstances		**Mean±SD**	**P-value**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**
				Lower Bound	Upper Bound		
Estimated blood loss	Group A	174.7±42.9	0.002*	150.9059	198.4274	90	220
	Group B	128.7±35.4		109.0466	148.2868	80	200
Length of operation	Group A	83±22.9	0.011*	70.3	95.7	50	130
	Group B	102.8±16.5		93.7	111.9	80	140
Follow Up period (months)	Group A	9.9±1.5	<0.001 **	9	10.6	8	12
	Group B	6.1±3.2		4.3	7.9	1	11

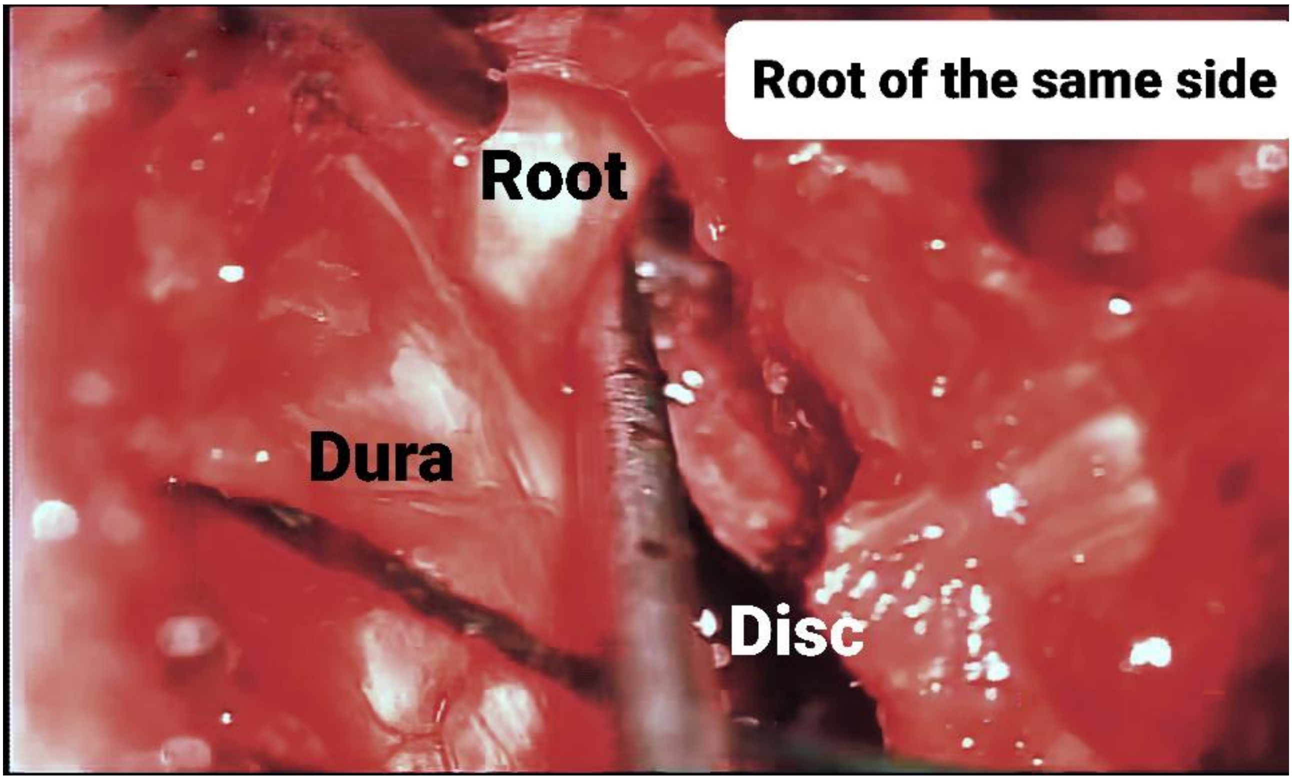
There was no statistically significant difference between both groups regarding the visual pain analog scale (VAS) pre and post-operative, neurogenic claudication outcome score (NCOS) pre and post-operative, and patient satisfaction (P-value≥0.05).VAS improved in both groups up to 7 and 9 points for groups A, B respectively. There was no statistically significant difference between both groups regarding the complications as there were no complications in 13 (86.7%) in group A and 14 (93.3%) in group B but there were only 2 cases (13.3%) complicated with dural tear group A versus 1 case (6.7%) complicated with a dural tear in group B. (P-value =0.475 and chi-value=1.5).**Table (5).**

Table (5): Comparison between both groups regarding the effect of the operation on the VAS, NCOS, and patient satisfaction:

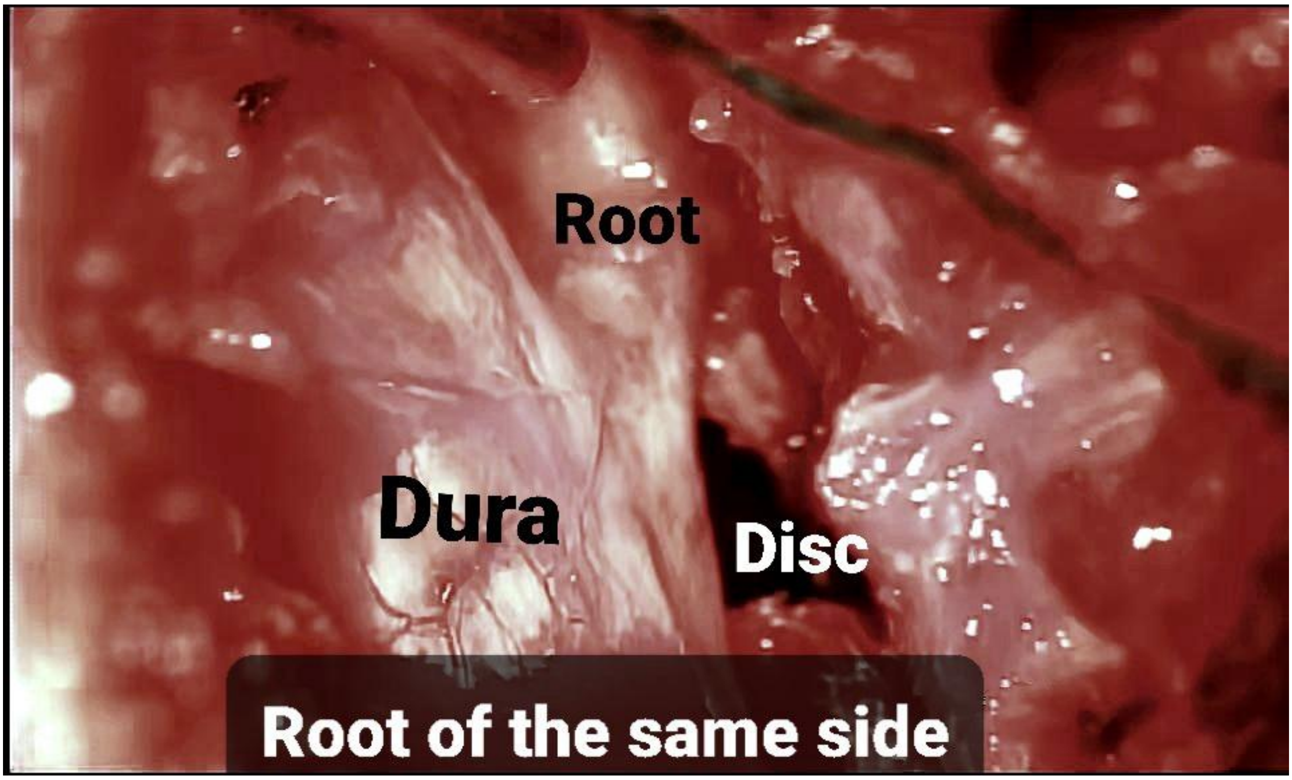
Scores		**Mean ± SD**	**P-value**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**
				Lower Bound	**Upper Bound**		
VAS Pre-operative	Group A	7.2±0.9	0.935	6.7	7.7	6	9
	Group B	7.2±1.01		6.6	7.8	6	9

VAS Post-operative	Group A	1.3±0.8	0.653	0.9	1.8	0	3
	Group B	1.5±0.9		1.02	2	0	4
NCOS Pre-operative	Group A	25±13.7	0.050	17.4	32.6	0	42
	Group B	34.5±8.02		30.1	38.9	21	48
NCOS Post-operative	Group A	62.6±21.8	0.775	44.4	80.8	0	90
	Group B	75.6±8.2		71.1	80.1	61	90
Patient satisfaction	Group A	1.7±0.8	0.389	1.3	2.2	1	4
	Group B	1.5±0.6		1.1	1.8	1	3

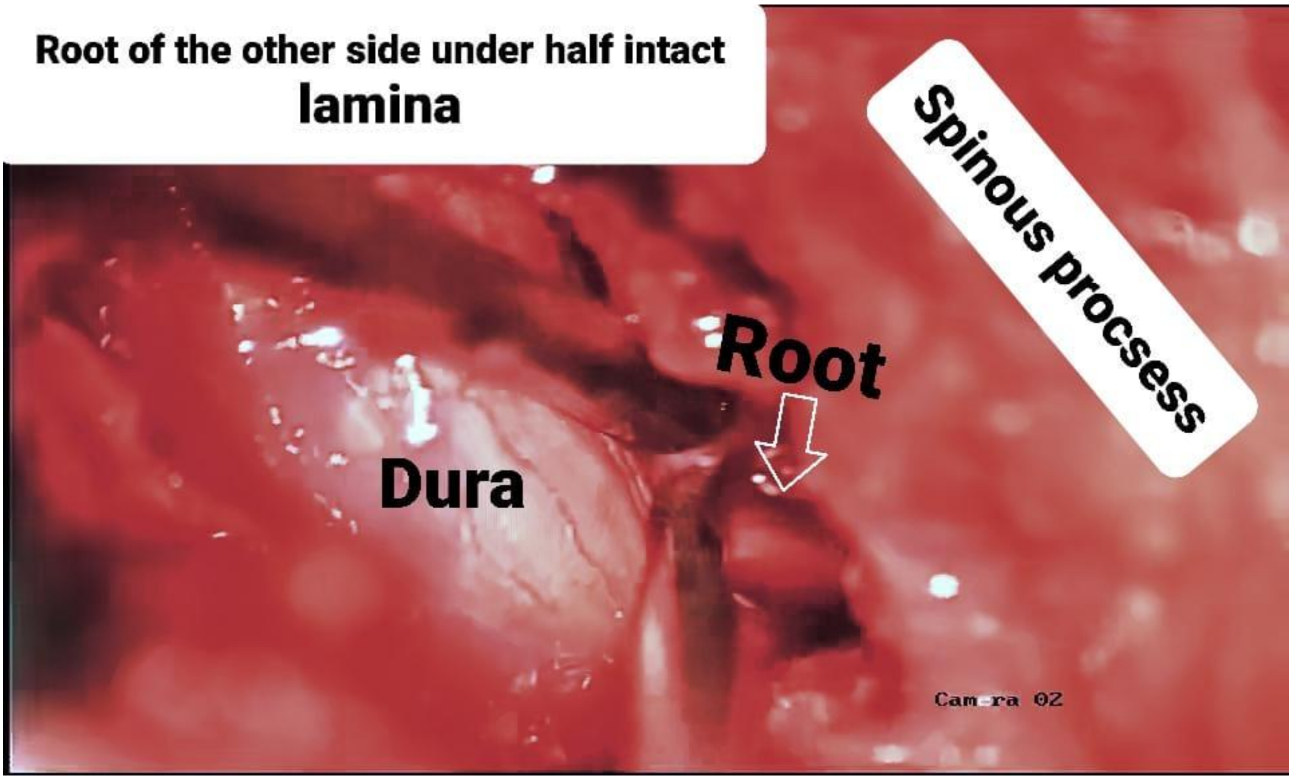
Data presented as mean ±SD *P-value is significant at <0.05



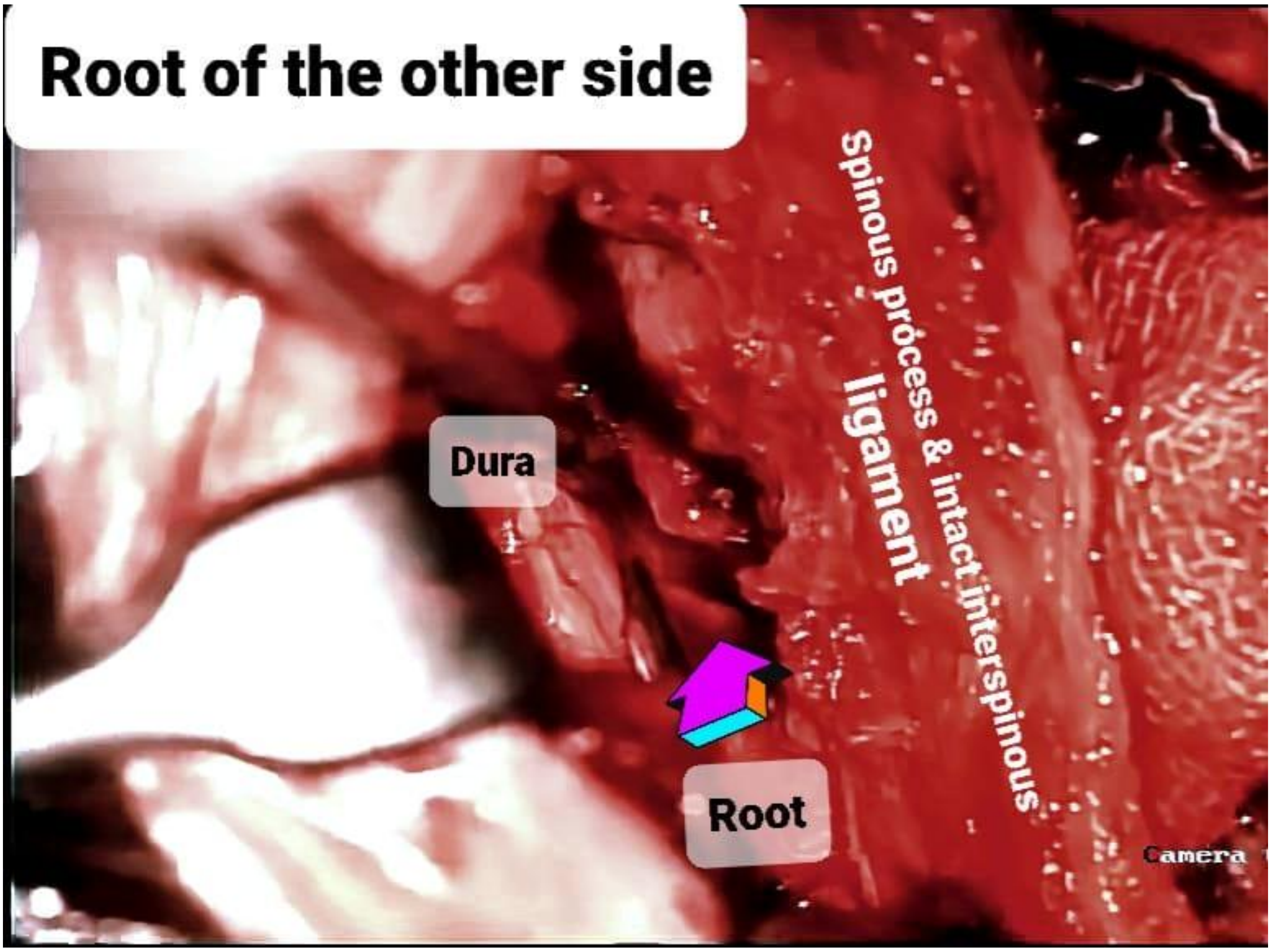
Figer (1) showing root and disc space on the same side



Figer (2) showing root and disc space on the same side



Figer (3) showing root of the other side



Figer (4) showing root of the other side

4. Discussion:

Acquired lumbar canal stenosis is the most common indication for surgery in elderly patients the outcome is almost improve due to increases in life expectancy and preoperative management [8].

Patients usually complain from backache and lower extremity pain. Non-operative management includes rest , physiotherapy, and the usage of NSAID for patients with mild symptoms. Surgical treatment may be appropriate for patients who failed non-operative management or showed more severe symptoms. More frequent cases of multiple-level involvement of lumbar spine degenerative disease are present due to the recent increase in numbers of the elderly population. However, few reports have described in LSS patients, the clinical results of compression at multiple-level [9].

Patients characteristics:

In our study, low back pain and neurogenic claudication were the main symptoms in both groups, (13.3%) versus (33.3) of patients who complained of sciatica.

Operative data

In our study 14 patients (46.7%) decompressed at one Level, 10 patients

(33.3%) decompressed at two Levels, and 6 patients decompressed at three Levels. The total number was 50 decompressed , L4-5 was the more level affected (58%) then L3-4 (26%) and L5-S1 (16%). 7 patients (23.3%) need discectomy.

In ELmorshidy, et aL series, (36.8%) patients were decompressed at one Level, (39.6%) patients at two Levels, (19.8%) patients at three Levels, and four (3.8%) patients at four Levels. In 17 patients, an associated disc herniation was removed (16%). The most common affected Level was L4–L5 (82.1%) [10]. In ALimi et aL series, the most common affected level was L4–5 (50.3% of cases). Then L3–4 (29%) and L5–S1,(11.2%) ; and L2–3, (9.5%) [11]

The time taken during surgery was significantly higher in group B (102.8 min/level) than in group A (83 min/level) (P-value=0.009) similar to Khoo and Fessler who reported the duration of the operation was109 minutes in cases of single-level micro-endoscopic unilateral laminotomy and 88 minutes in cases of open laminectomy [12]. Other authors have reported shorter operative times for laminectomies [13]. Sasai, et al reported 191 min/level for microsurgical decompression of spinal degenerative stenotic group [14]

Contrary to Rahman et al, the unilateral approach in bilateral spinal canal decompression of lumbar spinal stenosis involves a shorter operative time than open techniques [15]

The estimated blood loss was significantly higher among group A (174.7±42.9 c.c/ level) than in group B (128.7±35.4c.c/level) (P-value=0.033) similar but a lesser amount than the results described by Thomé, et al were estimated blood loss in laminectomy group more than microscopic laminotomy group: (227 ± 154 c.c/level) versus (212 ± 147 c.c/level) respectively)[16]

The follow-up period was significantly higher among group A than in group B (9.9±1.5 vs. 6.1±3.2 months) (P-value <0.001) that was similar but shorter than described by Mobbs et al where the mean duration of follow-up was higher in the conventional laminectomy than in the ULBD group (44.3 vs. 36.9 months) [17]

Preoperative complication

The primary step in assessing a new technique consists of analyzing its safety compared with the current standard of care. This step is obligatory in cases of assessment of a new surgical method of treatment of a disease, like lumbar stenosis which is predominant in an elderly population and is thought to be prone to perioperative morbidity [13].

An increase in radiculopathy postoperatively was observed in few laminectomy cases, whereas this complication is rarely reported since Postacchini, et al. reported an increase in postoperative radiculopathy in one case (1.3%) of 32 patients following laminectomy compared with three cases (11.5%) of 26 patients following laminotomy[18], nerve root actual injury did not occur, Intraoperative manipulation and/or compression of nerve roots, though, it may incite radicular deficit, patients with these deficits suffered from long-lasting diabetes complicated by polyneuropathy and they suffer from sensorimotor deficit preoperatively [16]. None of our patients in both groups developed an increase in radicular pain postoperatively.

The wound infection about 2% of all spinal surgery cases (Truumees E. et al 2001) and this complication was also rare Thomé et al series (0.8%). we have no reported cases of infection in our study.

Another concern during spinal decompressive surgery is unintended durotomy, although there is no association with long-term sequelae has been detected. [16]

Total, durotomy rates for laminectomy ranged from 5 to 15% and ranged from 3.5–12% in cases of unilateral laminotomy with contra lateral decompression.[19]

But microscope surgery incidence was 17.6% (three of 17 patients) (Palmer S. et al 2002)

In our study, there were no complications in 13 (86.7%) in group A and 14 (93.3%) in group B but there were only 2 cases (13.3%) complicated with a dural tear in group A versus 1 case (6.7%) complicated with a dural tear in group B.

These cases were treated by primary suturing of the dura, and watertight closure of lumbar fascia without the use of a suction drain. All patients were not noticeably associated with postoperative morbidity except one patient (group A) who developed urinary retention and bilateral lower limb weakness (dorsiflexion G2-3), MRI showed disc fragment, and reoperation is required.

In our study, no reported cases of reoperation nor instability in both groups during the follow-up period which is short duration, [10]

Dohzono, et al did not find a correlation between the postoperative increase in percent slip and bone regrowth. In this procedure, there was no relationship between the postoperative bone regrowth and the clinical outcomes or the postoperative segmental spinal instability [20]

Mobbs reported one patient in the group of ULBD and 3 patients in the open surgery needed a reoperation because there was a failure of relief of symptoms. Reoperations included a new lumbar level decompression, repeat decompression of the nerve root due to entrapment by the postoperative scar and repeat the laminectomy due to residual or recurrent stenosis. Between groups, there was no significant difference in reoperation rates. [16]

Outcome assessment

Preoperative to postoperative (NCOS), (VAS), and (PSI) changes were documented in our study. , NCOS increased from 41 to 61 points in group A and 33 to 51 for group B. similar to Weiner et al. 40% of patients in group A versus 60% of patients in group B. Surgery meets their expectations. VAS improved in both groups up to 7 and 9 points for groups A, B respectively .53.3% of patient group A versus 33.3 % patient group B. surgery didn't meet their expectation but they would undertake the same operation for the same results. Papavero, et al reported that The Neurogenic claudication outcome score (NCOS) improved in 95% of patients soon after ULBD and become much better by 90% of patients 1 year later after surgery [21]

Weiner et al. reported after ULBD, NCOS increased from 32 to 67 points (approximately double), and 87% of patients reported a high rate of satisfaction[22]. On the other hand, in Sasai, et al degenerative stenosis group, the NCOS increased from an average of 30 to 71 points [14]. Both approaches resulted in significant improvements in function and leg pain (VAS score) with no obvious differences in between. Contrary to Mobbs, et al., study where the minimally invasive technique g a give significantly good outcome regarding leg pain (VAS score) than did the open approach [17]

Takayuki Awaya, et al., reported that ULBD less recurrent rate, and less blood loss.[24]

Patients in the ULBD group give good satisfaction and also decrease in visual analog score (VAS) leg symptoms[23]. There was no relation between postoperative functional disability, patient satisfaction or leg symptoms with the type of surgical technique [1]. Overall, There was no statistically significant difference between both groups regarding the visual pain analog scale (VAS) pre and post-operative, neurogenic claudication outcome score (NCOS) pre and post-operative, and patient satisfaction.

5. Conclusion:

This study aimed to compare the outcomes following the minimally invasive unilateral laminectomy for bilateral decompression (ULBD) to the standard open laminectomy for LCS. This study demonstrated the feasibility of spinal canal decompressing by unilateral approach. Considerable experience is required to adequately decompress the neural structures. Microscopic techniques do involve a steep learning curve that must be diligently overcome. ULBD is effective as laminectomy in the treatment of LCS with the benefit of respecting the integrity of the neural elements with a little amount of blood loss.

Additional benefits of the ULBD approach include shorter postoperative hospital recovery time and time to mobilization.

6. References:

1. Phan K, Teng I, Schultz K, Mobbs RJ. Treatment of Lumbar Spinal Stenosis by Microscopic Unilateral Laminectomy for Bilateral Decompression: A Technical Note. Orthop Surg. 2017;9(2):241-246.
2. Ammendolia C. Degenerative lumbar spinal stenosis and its imposters: three case studies. J Can Chiropr Assoc. 2014;58(3):312-319.
3. Koc Z, Ozcakir S, Sivrioglu K, Gurbet A, Kucukoglu S. Effectiveness of physical therapy and epidural steroid injections in lumbar spinal stenosis. Spine (Phila Pa

1976). May 1 2009;34(10):985-989.

4. Amundsen T, Weber H, Nordal HJ, Magnaes B, Abdelnoor M, Lilleås F. Lumbar spinal stenosis: conservative or surgical management?: A prospective 10-year study. Spine. 2000;25(11):1424-1436.
5. Ciol MA, Deyo RA, Howell E, Kreif S. An assessment of surgery for spinal stenosis: time trends, geographic variations, complications, and reoperations. Journal of the American Geriatrics Society. 1996;44(3):285-290.
6. Joaquim AF, Milano JB, Ghizoni E, Patel AA. Is There a Role for Decompression Alone for Treating Symptomatic Degenerative Lumbar Spondylolisthesis?: A Systematic Review? Clinical spine surgery. Jun 2016;29(5):191-202.
7. Azimi P, Mohammadi HR, Montazeri A. An outcome measure of functionality in patients with lumbar spinal stenosis: a validation study of the Iranian version of Neurogenic Claudication Outcome Score (NCOS). BMC Neurol. 2012;12:101-101.
8. Kalff R, Ewald C, Waschke A, Gobisch L, Hopf C. Degenerative lumbar spinal stenosis in older people: current treatment options. Dtsch Arztebl Int. 2013;110(37):613-624.
9. Lurie J, Tomkins-Lane C. Management of lumbar spinal stenosis. BMJ (Clinical research ed.). 2016;352:h6234-h6234.
10. Elmorshidy E, Ali H, Khalifa Y, El-Kady H, Siepe C, Mayer M. Microscopic decompression for lumbar spinal canal stenosis. The Egyptian Orthopaedic Journal. April 1, 2016 2016;51(2):158-164.
11. Alimi TO, Fuller DO, Qualls WA, et al. Predicting potential ranges of primary malaria vectors and malaria in northern South America based on projected changes in climate, land cover, and human population. Parasites & Vectors. 2015/08/20 2015;8(1):431.
12. Khoo LT, Fessler RG. Microendoscopic decompressive laminotomy for the treatment of lumbar stenosis. Neurosurgery. Nov 2002;51(5 Suppl):S146-154.
13. Friedman JA, Ecker RD, Piepgras DG, Duke DA. Cerebellar Hemorrhage after Spinal Surgery: Report of Two Cases and Literature Review. Neurosurgery. 2002;50(6):1361-1364.
14. Sasai K, Umeda M, Maruyama T, Wakabayashi E, Iida H. Microsurgical bilateral decompression via a unilateral approach for lumbar spinal canal stenosis including degenerative spondylolisthesis: Clinical article. Journal of Neurosurgery: Spine SPI. 01 Dec. 2008 2008;9(6):554-559.
15. Rahman M, Summers LE, Richter B, Mimran RI, Jacob RP. Comparison of techniques for decompressive lumbar laminectomy: the minimally invasive versus the "classic" open approach. Minimally invasive neurosurgery: MIN. Apr 2008;51(2):100-105.
16. Thomé C, Zevgaridis D, Leheta O, et al. Outcome after less-invasive decompression of lumbar spinal stenosis: a randomized comparison of unilateral laminotomy,

bilateral laminotomy, and laminectomy. Journal of Neurosurgery: Spine. 2005;3(2):129-141.

17. Mobbs RJ, Sivabalan P, Li J. Minimally invasive surgery compared to open spinal fusion for the treatment of degenerative lumbar spine pathologies. Journal of clinical neuroscience: official journal of the Neurosurgical Society of Australasia. Jun 2012;19(6):829-835.
18. Postacchini F, Cinotti G, Perugia D, Gumina S. The surgical treatment of central lumbar stenosis. Multiple laminotomy compared with total laminectomy. The Journal of bone and joint surgery. British volume. May 1993;75(3):386-392.
19. da C Menezes Costa L, Maher CG, Hancock MJ, McAuley JH, Herbert RD, Costa LOP. The prognosis of acute and persistent low-back pain: a meta-analysis. CMAJ. 2012;184(11):E613-E624.
20. Dohzono S, Toyoda H, Matsumura A, Terai H, Suzuki A, Nakamura H. Clinical and Radiological Outcomes after Microscopic Bilateral Decompression via a Unilateral Approach for Degenerative Lumbar Disease: Minimum 5-Year Follow-Up. Asian Spine J. 2017;11(2):285-293.
21. Papavero L, Thiel M, Fritzsche E, Kunze C, Westphal M, Kothe R. Lumbar spinal stenosis: prognostic factors for bilateral microsurgical decompression using a unilateral approach. Neurosurgery. Dec 2009;65(6 Suppl):182-187; discussion187.
22. Weiner DK, Kim YS, Bonino P, Wang T. Low back pain in older adults: are we utilizing healthcare resources wisely? Pain medicine (Malden, Mass.). Mar-Apr 2006;7(2):143-150.
23. Zanoli G, Strömqvist B, Jönsson B. Visual analog scales for interpretation of back and leg pain intensity in patients operated for degenerative lumbar spine disorders. Spine (Phila Pa 1976). Nov 1 2001;26(21):2375-2380.
24. Takayuki Awaya, Yusuke, Nishimura, Kaoru Eguchi, Yoshitaka Nagashima, Ryo Ando, Sho Akahori, Satoshi Yoshikawa, Shoichi Haimoto, Masahito Hara, Masakazu Takayasu, Ryuta Saito. Radiological Analysis of Minimally Invasive Microscopic Laminectomy for Lumbar Canal Stenosis with a Focus on Multilevel Stenosis and Spondylolisthesis World Neurosurgery, 2022.