Minimally Invasive Spinal Decompression in Patients Older Than 75 Years of Age: Perioperative Risks, Complications, and Clinical Outcomes Compared with Patients Younger Than 45 Years of Age

Morsi Khashan[1,2], Zvi Lidar[1], Khalil Salame[1], Laurence Mangel[1], Ran Lador[1,2], Michael Drexler[2], Eilat Sapirstein[1], Gilad J. Regev[1,2]

■ OBJECTIVE: **Minimally invasive spinal decompression for the treatment of spinal stenosis or disk herniation is often indicated if conservative management fails. However, the influence of old age on the risk of postoperative complications and clinical outcome is not well understood. We therefore sought to compare complication rates and outcomes after minimally invasive surgery decompression and discectomy in elderly patients with a cohort of younger patients undergoing similar procedures.**

■ METHODS: **We evaluated medical records of 61 patients older than 75 years and 69 patients younger than 45 years that underwent minimally invasive lumbar decompression between April 2009 and July 2013 at our institute. Medical history, American Society of Anesthesiologists score, perioperative mortality, complications, and revision surgery rates were analyzed. Patient outcomes included visual analog scale and EuroQol-5 Dimension scores.**

■ RESULTS: **The average age was 78.66 ± 4.42 years in the elderly group and 33.59 ± 6.7 years in the younger group. No major postoperative complications were recorded in either group, and all recruited patients were still alive at the time of the last follow-up. No statistically significant difference existed in the surgical revision rate between the groups. Both groups showed significant improvement in their outcome scores after surgery.**

■ CONCLUSIONS: **Our results indicate that minimally invasive decompressive surgery is a safe and effective treatment for elderly patients and does not pose an increased risk of complications. Future prospective studies are necessary to validate the specific advantages of the minimally invasive techniques in the elderly population.**

INTRODUCTION

The Western population has aged steadily over the last decades, and today one in nine persons in the United States is above the age of 65 years.[1] By 2050 this proportion is expected to rise to 20%,[1] along with an increase in the prevalence of age-related disorders. Aging of the spine results in degenerative changes, such as spinal stenosis[1] and deformity, and is one of the leading causes of pain, functional impairment, and decline in the quality of life of the geriatric population.

Degenerative lumbar spinal stenosis is the most common indication for spinal surgery in patients older than 65 years of age.[2,3] Surgical decompression for this condition was found to be an effective treatment that results in a low complication rate and excellent long-term clinical outcomes.[4,5] However, many geriatric patients are reluctant to undergo such surgeries, based on the belief that old patients are at high risk for serious surgical complications, poor outcome, and even mortality. The tendency to avoid surgical intervention for elderly patients is also encountered among primary care physicians, who recommend that patients continue conservative treatment even in cases where the latter was proven ineffective.

Key words
- Clinical outcomes
- Complications
- Elderly patients
- Minimally invasive
- Spinal decompression

Abbreviations and Acronyms
ASA: American Society of Anesthesiologists
EQ-5D: EuroQol-5 dimension
MIS: Minimally invasive surgery
VAS: Visual analog scale

From the Departments of [1]Neurosurgery and [2]Orthopaedic Surgery, The Spine Surgery Unit, Tel-Aviv Sourasky Medical Center, Tel-Aviv, Israel

To whom correspondence should be addressed: Gilad J. Regev, M.D. [E-mail: gregev@gmail.com]

Morsi Khashan and Zvi Lidar are co–first authors.

Citation: World Neurosurg. (2016) 89:337-342. http://dx.doi.org/10.1016/j.wneu.2016.02.018

*Journal homepage: **www.WORLDNEUROSURGERY.org***

*Available online: **www.sciencedirect.com***

Geriatric patients pose a surgical challenge because of their physical, psychologic, and social frailty. Although the effect of age as an independent risk factor is not well understood, it has been related to an increased risk of morbidity after open spine surgery.[6,7] However, this finding might be confounded by the high prevalence of multiple medical comorbidities in this age group.[8,9] In addition, other studies have found comparable morbidity and complication rates after spine surgery in older adults compared with younger patients.[10-12]

Minimally invasive surgery (MIS) of the spine has gained increased popularity in recent years. This approach significantly reduces soft tissue injury[13] and intraoperative bleeding.[14] As a result, patients experience less postoperative pain[14] and can usually be mobilized and discharged early.[15] Previous studies have shown comparable long-term outcomes of MIS and traditional open spinal decompression procedures.[16,17]

We hypothesize that the MIS procedures along with its inherent advantages will be particularly safe and beneficial to the geriatric population. Therefore, the aim of the present study was to compare complication rates and outcomes after MIS decompression and discectomy in elderly patients with a cohort of younger patients undergoing similar procedures.

MATERIALS AND METHODS

After approval from our local institutional review board, we retrospectively collected medical records of patients who underwent 1 or 2 levels of lumbar decompression surgery between April 2009 and July 2013. Inclusion criteria included patients older than 75 years of age for group A and between the ages of 18–45 years for group B. Exclusion criteria included patients undergoing surgeries at more than 2 spinal levels and procedures that included spinal instrumentation, fusion, resection of tumor, spinal infection, or revision surgery.

The study cohort included a total of 129 patients: 61 patients in group A and 68 in group B. Demographic data and preoperative data, including medical history, medical comorbidities, and American Society of Anesthesiologists (ASA) score, were recorded. To simplify the presentation of the medical history data, we classified patients' comorbidities into 10 categories: cardiac, vascular, endocrine, metabolic, neoplastic, gastrointestinal, neurological, pulmonary, renal, and connective tissue diseases. Operative data included type of surgery (discectomy, laminoforaminotomy, or both), number of operated spinal level, and incidence of intraoperative complications.

Measured clinical outcomes included hospital length of stay, early postsurgical complications, revision surgery, and mortality. Patient-reported outcomes were collected for a subgroup of 37 patients in group A and 43 patients in group B using telephone interviews. Reported outcomes included the health-related quality of life EuroQol-5 Dimension (EQ-5D) instrument[18] and the visual analog scale (VAS) for pain, before surgery, and at the time of data collection. The EQ-5D questionnaire consists of 5 dimensions, including mobility, self-care, usual activities, pain, and anxiety/depression. Each domain is rated according to 3 levels of severity: no problems (1 point), some or moderate problems (2 points), and severe problems (3 points).

MIS Surgical Technique

All procedures were performed in a single medical center by 2 senior spinal surgeons who are well experienced in MIS surgeries. MIS decompression procedures were done routinely under general anesthesia using an 18- or 20-mm tubular retractor system (METRx [Medtronic Sofamor Danek, Memphis, TN, USA]) and a surgical microscope. Surgery was performed using a unilateral approach, with either an ipsilateral or bilateral canal decompression as described previously.[19]

Statistical Analysis

The statistical analysis was performed using SPSS version 19 (IBM Corp., Armonk, NY). Significant differences between groups were determined using independent samples t tests, the χ^2 test, and Fisher exact test to evaluate categorical variables' independence. Preoperative to postoperative EQ-5D changes within each group were analyzed with paired t tests. A P value <0.05 was considered statistically significant.

RESULTS

The average age in group A was 78.66 ± 4.42 years and 33.59 ± 6.7 years in group B. The male/female ratio was similar for both groups ($P = 0.258$). The follow-up period was similar between groups: 31.19 ± 12.85 months for group A and 32.15 ± 11.12 months for group B ($P = 0.45$).

Thirty-one patients in group A were diagnosed with spinal canal stenosis and therefore underwent an MIS bilateral spinal canal decompression (laminectomy). The remaining 30 patients were diagnosed with lumbar disk herniation and underwent an MIS discectomy. All of the patients in group B were diagnosed with lumbar disk herniation and underwent MIS discectomy. Forty-five patients in group A presented with motor weakness in one or more of the lower-limbs muscles compared with 37 patients in group B.

Operated levels in group A included mainly L3-4 ($n = 27$) and L4-5 ($n = 45$) compared with L4-5 ($n = 30$) and L5-S1 ($n = 35$) in group B. Seven patients in group A underwent a 2-level procedure compared with only 1 patient in group B.

Patients in group A had an average number of 1.95 ± 1.43 medical comorbidities and an average ASA score of 2.64 ± 0.82. Patients in group B were generally healthy with no systemic comorbidities (0.06 ± 0.38, $P < 0.01$) and with an average ASA score of 1 ± 0.41 (Table 1).

The distribution of the grouped comorbidities within the groups is shown in Table 2.

The most prevalent comorbidities were of the cardiovascular system. Fifty-four percent of patients in group A were diagnosed with hypertension, and 43% were diagnosed with ischemic heart disease. The second most prevalent group included endocrine and metabolic disorders, such as diabetes (36%) and dyslipidemia (23%). In group B, only 1 patient was found with hypertension, 1 patient was found with diabetes, 1 patient was found with dyslipidemia, and none had ischemic heart disease.

In group A, 12 patients (20%) had no comorbidities, 10 patients (16%) had 1 comorbidity, 20 patients had 2 comorbidities (33%), and 19 patients (31%) had 3 or more comorbidities. In group B,

Table 1. Demographic Data and Basic Health Status in Both Groups

Demographic	Group A (>75 years; n = 61)	Group B (<45 years; n = 68)	P Value
Age (years)	78.66 ± 4.42	33.59 ± 6.70	0.006
Male	28 (46)	38 (56)	0.258
Comorbidities	1.95 ± 1.43	0.06 ± 0.38	<0.01
ASA score	2.64 ± 0.82	1.16 ± 0.41	<0.01
Follow-up (months)	31.19 ± 12.85	32.15 ± 11.12	0.452

Values are mean ± SD, number (%), or as otherwise indicated.
ASA, American Society of Anesthesiologists.

these figures were 66 (97%), 1 (1%), and 1 (1%), respectively (Table 2).

The mean length of hospital stay was longer in the geriatric group: 3.62 ± 5.14 days versus 1.82 ± 3.51 days ($P = 0.001$). The rate of accidental durotomy was <2% and was similar for both groups ($P = 0.938$). Two minor systemic complications were recorded in 2 patients in group A. One patient developed rapid atrial fibrillation that was treated by antiarrhythmic agent. Bradycardia was diagnosed in the other patient and resolved spontaneously. No major postoperative infection or pulmonary or cerebrovascular complications were recorded in either group, and all recruited patients were still alive at the time of the last follow-up.

No statistically significant difference existed in the surgical revision rate between the groups ($P = 0.631$). In group A, 4 patients underwent revision surgeries. The indication was adjacent-level stenosis in 3 cases and recurrent disk protrusion in 1 case. The indication for revision surgery in group B consisted of same-level recurrent disk herniation in all 6 cases (Table 3). No fusion was performed in group A or group B. Overall, VAS and EQ-5D scores significantly improved in both groups after surgery. The VAS score improved from 8.25 ± 2.63 to 5.27 ± 3.57 in group A and from 9.16 ± 1.43 to 2.66 ± 2.8 in group B ($P < 0.05$). The EQ-5D scores improved from 1.98 ± 0.08 to 1.66 ±0 .08 in group A and from 2.19 ± 0.42 to 1.32 ± 0.22 in group B ($P < 0.05$). However, the EQ-5D scores for anxiety and daily activities failed to show a statistically significant improvement in group A (Figure 1). When comparing the 2 groups, we found that postoperative EQ-5D and VAS scores were significantly higher in group A and that the average improvement in group A was significantly inferior to group B (Figure 1).

Table 2. Comorbidities Distribution in the 2 Age Groups

Comorbidity	Group A	Group B	P Value
Cardiovascular	59 (97)	1 (1)	<0.00
Metabolic and endocrine	36 (59)	3 (4)	<0.01
Neoplastic	19 (31)	0 (0)	<0.01
Gastrointestinal	5 (8)	0 (0)	0.022
Neurologic	12 (20)	0 (0)	<0.01
Pulmonary	5 (8)	0 (0)	0.022
Connective tissue	5 (8)	0 (0)	0.022
Renal	2 (3)	0 (0)	0.22

Data are number (%) or as otherwise indicated.

DISCUSSION

This study compares 2 patient groups that largely differ in age, medical comorbidities, and surgical risk, but are similar in sex distribution. We have used a double threshold and excluded patients between 45 and 74 years old in contrast with a previously published study.[20] As expected, significant differences were found in the average ASA score, the number of medical comorbidities, and the surgical risk for perioperative complications and mortality. The modified ASA score assesses the patient's physical status before surgery and encompasses 5 grades of increasing severity.[18,21] Class 1 indicates a healthy patient, and class 5 indicates a moribund patient not expected to survive 24 hours with or without surgery. This classification has been shown to predict postoperative outcomes.[22,23]

Moreover, approximately 50% of the patients in group A suffered from spinal canal stenosis, and 11% were diagnosed with 2-level stenosis, which required a relatively more extensive, long, and complicated procedure than the 1-level discectomy that was performed in group B patients.

Despite the increased risk of complications and surgical failure in the geriatric population, our results did not show any statistically significant rise in intraoperative complications, such as durotomy, which was found to be more prevalent in previous studies.[24,25] A possible explanation for this finding could be that in contrast with open surgeries, the MIS technique requires the use of an intraoperative microscope and that all surgeries were performed by well-experienced senior spine surgeons. The rate for surgical revisions was also found to be similar in both groups; however, the causes for repeated interventions in 50% of the geriatric patients group were because of adjacent-level pathologies. This finding is expected because elderly patients are usually presenting with multilevel spondylotic changes in contrast with the younger population. The higher rate of disk herniation in the younger group is explained by the fact that the most patients in this group underwent discectomy, whereas about half of the patients in the older group underwent laminectomy and foraminotomy. The overall incidence of recurrent disk herniation in our study was 5.4%. This is consistent with previous studies that reported a rate of 5%–15%.[26-28]

No cases of infection were found in our study, and postoperative infections are common after open spine surgery, with a reported incidence of 1%–14%.[29] Multiple studies reported a significantly low risk of infection after minimally invasive procedures.[30] O'toole et al.[31] reported an infection rate of 0.22% after MIS decompression surgery in a cohort of 1,274 patients, which is consistent with our results for both groups A and B. Aleem and Rampersaud reported a similar risk of infection between patients aged older or younger than 70 who underwent

Table 3. Postoperative Complications, Revisions, and Mortality in Both Groups

	Group A	Group B	*P* Value
Systemic complications	2 (3)	0 (0)	0.22
Infection	0 (0)	0 (0)	
Revision	4 (6.5)	6 (9)	0.631
Mortality	0 (0)	0 (0)	

Data are number (%) or as otherwise indicated.

MIS decompression with or without fusion.[20] Our results support their findings for an even older population (mean age, 78 years) of patients compared with a much younger cohort (mean age, 33 years).

On average, the geriatric patients were hospitalized 1.8 days longer than the younger patients largely because of differences in required medical preparation and longer recovery period. Still, hospital length of stay for both groups was found to be shorter than the average hospitalization length after open spine surgeries as reported in previous studies.[15,16,32]

Patient-reported health-related quality of life and VAS scores showed significant improvement after surgeries in both groups.

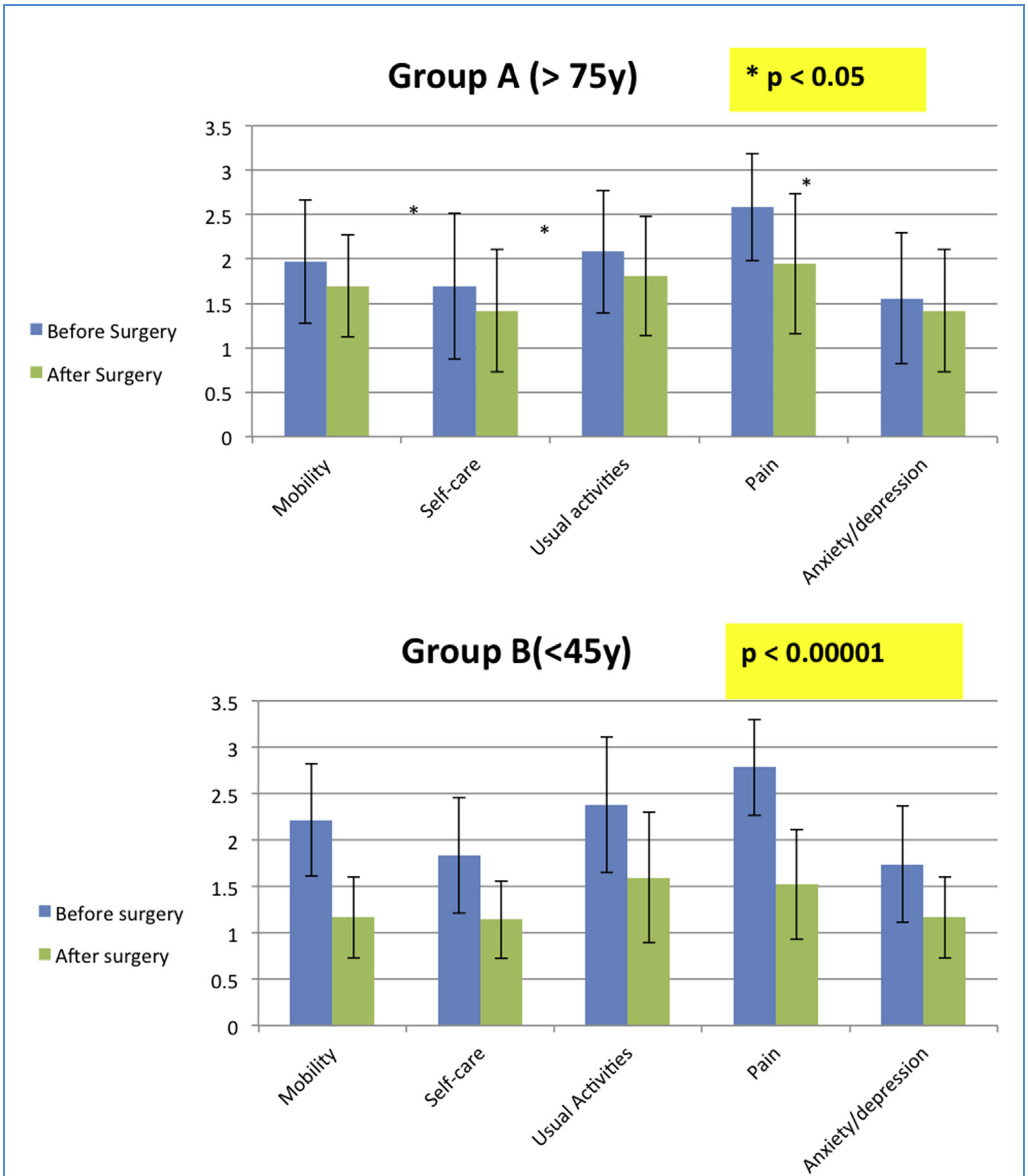

Figure 1. Changes in EuroQol-5 Dimensions within each group.

However, the geriatric patients' improvement was significantly inferior to that of the younger patients. These results are consistent with reports from previous studies.[15,20] Of the 5 dimensions of the EQ-5D questionnaire, anxiety, depression, and daily activities failed to improve significantly in the elderly patients group. We attribute this observation to the general physical status and disability of this group and to the accompanied psychologic and mental changes of aging. These processes are complex and multifactorial. Previous studies reported that increasing age is associated with less improvement after spinal stenosis surgery.[7,33] Katz et al.[7] found that after decompressive laminectomy, coexisting illness was associated with poor outcomes. In addition, patients with greater medical comorbidity and functional disability were significantly less satisfied with the results of surgery.[34]

We speculate that the excellent safety and good outcomes of the minimally invasive approach, even in the elderly patients, result from several inherent advantages of the MIS technique. MIS results in less paraspinal soft tissue trauma, therefore reducing the inflammatory and stress response after surgery. Postsurgical stress response was found to contribute to imbalance in autonomic, endocrine, and immune systems. It was also found to promote hypertension, cardiac dysrhythmias, and myocardial infarctions in the immediate perioperative period.[32,35,36] Elderly frail patients suffering from multiple medical comorbidities and limited physiologic reserve are vulnerable to stress and may therefore especially benefit from MIS procedures that minimize these risks.

Another advantage of MIS surgery is the reduced blood loss.[14,16] The cardiovascular and pulmonary compensatory mechanisms are of limited capacity in older patients because age decreases the contractility and increases the stiffness of the left ventricle.[37-39] These alterations may impair the patient from tolerating large volume shifts, which can lead to life-threating complications in this age group.

Reduction in postoperative pain after the MIS approach, compared with open spinal surgeries, reduces the risks of delirium, enables early mobilization, allows for a shorter hospital stay, and facilitates early rehabilitation.[14,40] Perioperative pain and the use of narcotic analgesics in elderly patients has been found to increase the risk for delirium and falls.[41,42] MIS procedures usually require relatively little analgesia that can consist of nonsteroidal anti-inflammatory drugs or acetaminophen starting immediately after surgery.

Aging and a comorbid condition, such as vasculopathy, can lead to delayed wound healing that may jeopardize patient outcomes either by direct influence on spinal muscle rehabilitation or by increasing the risk of wound infection.[43,44] MIS surgery results in smaller skin incisions that facilitate wound healing and decrease the risk of wound complications in this patient population. Finally, MIS procedures are associated with shorter postoperative hospitalization,[15,16,40] which result in lower rates of nosocomial infections and promote faster rehabilitation.

In conclusion, our results indicate that MIS decompressive surgery is a safe and effective treatment for elderly patients and does not pose an increased risk of complications. Future prospective studies are necessary to validate the specific advantages of the minimally invasive techniques in the elderly population.

REFERENCES

1. Garfin SR, Herkowitz HN, Mirkovic S. Spinal stenosis. *Instr Course Lect*. 2000;49:361-374.

2. Katz JN, Stucki G, Lipson SJ, Fossel AH, Grobler LJ, Weinstein JN. Predictors of surgical outcome in degenerative lumbar spinal stenosis. *Spine (Phila Pa 1976)*. 1999;24:2229-2233.

3. Szpalski M, Gunzburg R. Lumbar spinal stenosis in the elderly: an overview. *Eur Spine J*. 2003; 12(suppl 2):S170-S175.

4. Weinstein JN, Lurie JD, Tosteson TD, Hanscom B, Tosteson AN, Blood EA, et al. Surgical versus nonsurgical treatment for lumbar degenerative spondylolisthesis. *N Engl J Med*. 2007;356: 2257-2270.

5. Weinstein JN, Tosteson TD, Lurie JD, Tosteson AN, Blood E, Hanscom B, et al. Surgical versus nonsurgical therapy for lumbar spinal stenosis. *N Engl J Med*. 2008;358:794-810.

6. Deyo RA, Cherkin DC, Loeser JD, Bigos SJ, Ciol MA. Morbidity and mortality in association with operations on the lumbar spine. The influence of age, diagnosis, and procedure. *J Bone Joint Surg Am*. 1992;74:536-543.

7. Katz JN, Lipson SJ, Brick GW, Grobler LJ, Weinstein JN, Fossel AH, et al. Clinical correlates of patient satisfaction after laminectomy for degenerative lumbar spinal stenosis. *Spine (Phila Pa 1976)*. 1995;20:1155-1160.

8. Arinzon ZH, Fredman B, Zohar E, Shabat S, Feldman JS, Jedeikin R, et al. Surgical management of spinal stenosis: a comparison of immediate and long term outcome in two geriatric patient populations. *Arch Gerontol Geriatr*. 2003;36: 273-279.

9. Raffo CS, Lauerman WC. Predicting morbidity and mortality of lumbar spine arthrodesis in patients in their ninth decade. *Spine (Phila Pa 1976)*. 2006;31:99-103.

10. Severn A. Anaesthesia and the preparation and management of elderly patients undergoing surgery. *Eur J Cancer*. 2007;43:2231-2234.

11. Ragab AA, Fye MA, Bohlman HH. Surgery of the lumbar spine for spinal stenosis in 118 patients 70 years of age or older. *Spine (Phila Pa 1976)*. 2003;28: 348-353.

12. Thornes E, Ikonomou N, Grotle M. Prognosis of surgical treatment for degenerative lumbar spinal stenosis: a prospective cohort study of clinical outcomes and health-related quality of life across gender and age groups. *Open Orthop J*. 2011;5: 372-378.

13. Stevens KJ, Spenciner DB, Griffiths KL, Kim KD, Zwienenberg-Lee M, Alamin T, et al. Comparison of minimally invasive and conventional open posterolateral lumbar fusion using magnetic resonance imaging and retraction pressure studies. *J Spinal Disord Tech*. 2006;19:77-86.

14. 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. *Minim Invasive Neurosurg*. 2008;51:100-105.

15. Mobbs RJ, Li J, Sivabalan P, Raley D, Rao PJ. 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*. 2014;21:179-186.

16. Goldstein CL, Macwan K, Sundararajan K, Rampersaud YR. Comparative outcomes of minimally invasive surgery for posterior lumbar fusion: a systematic review. *Clin Orthop Relat Res*. 2014;472: 1727-1737.

17. Sidhu GS, Henkelman E, Vaccaro AR, Albert TJ, Hilibrand A, Anderson DG, et al. Minimally invasive versus open posterior lumbar interbody fusion: a systematic review. *Clin Orthop Relat Res*. 2014;472:1792-1799.

18. Euroqol G. EuroQol—a new facility for the measurement of health-related quality of life. *Health Policy*. 1990;16:199-208.

19. Khoo LT, Fessler RG. Microendoscopic decompressive laminotomy for the treatment of lumbar stenosis. *Neurosurgery*. 2002;51(5 suppl):S146-S154.

20. Aleem IS, Rampersaud YR. Elderly patients have similar outcomes compared to younger patients after minimally invasive surgery for spinal stenosis. *Clin Orthop Relat Res*. 2014;472:1824-1830.

21. Dripps RD, Lamont A, Eckenhoff JE. The role of anesthesia in surgical mortality. *JAMA*. 1961;178: 261-266.

22. Wolters U, Wolf T, Stützer H, Schröder T. ASA classification and perioperative variables as predictors of postoperative outcome. *Br J Anaesth*. 1996;77:217-222.

23. Farrow SC, Fowkes FG, Lunn JN, Robertson IB, Samuel P. Epidemiology in anaesthesia. II: Factors affecting mortality in hospital. *Br J Anaesth*. 1982; 54:811-817.

24. Du JY, Aichmair A, Kueper J, Lam C, Nguyen JT, Cammisa FP, et al. Incidental durotomy during spinal surgery: a multivariate analysis for risk factors. *Spine (Phila Pa 1976)*. 2014;39:E1339-E1345.

25. Wang JC, Bohlman HH, Riew KD. Dural tears secondary to operations on the lumbar spine. Management and results after a two-year-minimum follow-up of eighty-eight patients. *J Bone Joint Surg Am*. 1998;80:1728-1732.

26. Swartz KR, Trost GR. Recurrent lumbar disc herniation. *Neurosurg Focus*. 2003;15:E10.

27. 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;85:102-108.

28. Suk KS, Lee HM, Moon SH, Kim NH. Recurrent lumbar disc herniation: results of operative management. *Spine (Phila Pa 1976)*. 2001;26:672-676.

29. Radcliff KE, Neusner AD, Millhouse PW, Harrop JD, Kepler CK, Rasouli MR, et al. What is new in the diagnosis and prevention of spine surgical site infections. *Spine J*. 2015;15:336-347.

30. McGirt MJ, Parker SL, Lerner J, Engelhart L, Knight T, Wang MY. Comparative analysis of perioperative surgical site infection after minimally invasive versus open posterior/transforaminal lumbar interbody fusion: analysis of hospital billing and discharge data from 5170 patients. *J Neurosurg Spine*. 2011;14:771-778.

31. O'toole JE, Eichholz KM, Fessler RG. Surgical site infection rates after minimally invasive spinal surgery. *J Neurosurg Spine*. 2009;11:471-476.

32. Burton D, Nicholson G, Hall G. Endocrine and metabolic response to surgery. *Contin Educ Anaesth Crit Care Pain*. 2004;4:144-147.

33. Yamashita K, Ohzono K, Hiroshima K. Five-year outcomes of surgical treatment for degenerative lumbar spinal stenosis: a prospective observational study of symptom severity at standard intervals after surgery. *Spine (Phila Pa 1976)*. 2006;31: 1484-1490.

34. Katz JN, Lipson SJ, Larson MG, McInnes JM, Fossel AH, Liang MH. The outcome of decompressive laminectomy for degenerative lumbar stenosis. *J Bone Joint Surg Am*. 1991;73:809-816.

35. Kim S, Brooks AK, Groban L. Preoperative assessment of the older surgical patient: honing in on geriatric syndromes. *Clin Interv Aging*. 2015;10: 13-27.

36. Wilmore DW. From Cuthbertson to fast-track surgery: 70 years of progress in reducing stress in surgical patients. *Ann Surg*. 2002;236:643-648.

37. Ramly E, Kaafarani HM, Velmahos GC. The effect of aging on pulmonary function: implications for monitoring and support of the surgical and trauma patient. *Surg Clin North Am*. 2015;95:53-69.

38. Scandrett KG, Zuckerbraun BS, Peitzman AB. Operative risk stratification in the older adult. *Surg Clin North Am*. 2015;95:149-172.

39. Olivetti G, Melissari M, Capasso JM, Anversa P. Cardiomyopathy of the aging human heart. Myocyte loss and reactive cellular hypertrophy. *Circ Res*. 1991;68:1560-1568.

40. Asgarzadie F, Khoo LT. Minimally invasive operative management for lumbar spinal stenosis: overview of early and long-term outcomes. *Orthop Clin North Am*. 2007;38:387-399. abstract vi-vii.

41. Kosar CM, Tabloski PA, Travison TG, Jones RN, Schmitt EM, Puelle MR, et al. Effect of preoperative pain and depressive symptoms on the development of postoperative delirium. *Lancet Psychiatry*. 2014;1:431-436.

42. Wildes TM, Dua P, Fowler SA, Miller JP, Carpenter CR, Avidan MS, et al. Systematic review of falls in older adults with cancer. *J Geriatr Oncol*. 2015;6:70-83.

43. Lober CW, Fenske NA. Cutaneous aging: effect of intrinsic changes on surgical considerations. *South Med J*. 1991;84:1444-1446.

44. McGarry SA, Engemann JJ, Schmader K, Sexton DJ, Kaye KS. Surgical-site infection due to Staphylococcus aureus among elderly patients: mortality, duration of hospitalization, and cost. *Infect Control Hosp Epidemiol*. 2004;25:461-467.

Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received 21 November 2015; accepted 3 February 2016

Citation: World Neurosurg. (2016) 89:337-342.
http://dx.doi.org/10.1016/j.wneu.2016.02.018

Journal homepage: ***www.WORLDNEUROSURGERY.org***

Available online: ***www.sciencedirect.com***

1878-8750/$ - see front matter