

Outcome and Complications in Surgical Treatment of Lumbar Stenosis or Spondylolisthesis in Geriatric Patients

Jin-Young Lee¹, Seong-Hwan Moon², Bo-Kyung Suh³, Myung Ho Yang³, and Moon Soo Park³

¹Department of Orthopaedic Surgery, Kangdong Sacred Heart Hospital, Medical College of Hallym University, Seoul;

²Department of Orthopaedic Surgery, Yonsei University College of Medicine, Seoul;

³Department of Orthopaedic Surgery, Hallym University Sacred Heart Hospital, Medical College of Hallym University, Anyang, Korea.

Development of anesthesiology and improvement of surgical instruments enabled aggressive surgical treatment even in elderly patients, who require more active physical activities than they were in the past. However, there are controversies about the clinical outcome of spinal surgery in elderly patients with spinal stenosis or spondylolisthesis. The purpose of this study is to review the clinical outcome of spinal surgery in elderly patients with spinal stenosis or spondylolisthesis. MEDLINE search on English-language articles was performed. There were 39685 articles from 1967 to 2013 regarding spinal disease, among which 70 dealt with geriatric lumbar surgery. Eighteen out of 70 articles dealt with geriatric lumbar surgery under the diagnosis of spinal stenosis or spondylolisthesis. One was non-randomized prospective, and other seventeen reports were retrospective. One non-randomized prospective and twelve out of seventeen retrospective studies showed that old ages did not affect the clinical outcomes. One non-randomized prospective and ten of seventeen retrospective studies elucidated postoperative complications: some reports showed that postoperative complications increased in elderly patients, whereas the other reports showed that they did not increase. Nevertheless, most complications were minor. There were two retrospective studies regarding the mortality. Mortality which was unrelated to surgical procedure increased, but surgical procedure-related mortality did not increase. Surgery as a treatment option in the elderly patients with the spinal stenosis or spondylolisthesis may be reasonable. However, there is insufficient evidence to make strong recommendations regarding spinal surgery for geriatric patients with spinal stenosis and spondylolisthesis.

Key Words: Spinal surgery, geriatric patient, spinal stenosis, spondylolisthesis

INTRODUCTION

As the elderly population increase, the incidence of degenerative spinal disease and its surgical treatment also increase, because development of anesthesiology and improvement of surgical instruments enabled aggressive surgical treatment in

geriatric patients. However, there are controversies about clinical outcome, complication rates and mortality rates of geriatric patients after spinal surgery with the spinal problem.¹⁻¹⁸ To our knowledge, there has been only one review article on the surgical outcome for geriatric patients in a geriatric journal,¹⁹ and no review article from the viewpoints of spine experts in the journal for spinal pathology.

Therefore, the purpose of the present study is to review the literature on the clinical outcome of surgical treatment in the geriatric patients with the diagnoses of lumbar stenosis or spondylolisthesis which are most commonly encountered in clinical practice of spinal surgeon.

STUDIES ABOUT THE TOPIC

A detailed computerized literature search using the MEDLINE

Received: March 6, 2015 **Revised:** April 26, 2015

Accepted: May 14, 2015

Corresponding author: Dr. Moon Soo Park, Department of Orthopaedic Surgery, Hallym University Sacred Heart Hospital, Medical College of Hallym University, 22 Gwanpyeong-ro 170beon-gil, Dongan-gu, Anyang 431-796, Korea.
Tel: 82-31-380-6000, Fax: 82-31-380-6008, E-mail: amhangpark@gmail.com

•The authors have no financial conflicts of interest.

© Copyright: Yonsei University College of Medicine 2015

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

search engine was employed using medical subject terms of “lumbar vertebrae”, “surgery”, and “geriatric”. This database consists of literature published from January 1967 through December 2013. We included English language articles regarding clinical outcome, complication, or mortality after surgical treatment for geriatric patients older than 65 years old with spinal stenosis or spondylolisthesis. Articles regarding the surgical treatment for the geriatric patients with the diagnoses of disc herniation, scoliosis, fractures or infection were excluded. Review articles or case reports with less than ten patients were excluded. All full-text articles were read by two reviewers independently; each article was read by both the first author and one of the coauthors. In case of inconsistencies between two reviewers, the consensus was established through a discussion between them. We then categorized the articles as randomized clinical trial, non-randomized prospective study, and retrospective study for overall quality of the article. Finally, to focus on the most recent evidence, we limited our review to those published on or after 1986. We identified 39685 articles regarding lumbar surgery, among which 70 articles were about geriatric lumbar surgery and 21 dealt with geriatric lumbar surgery for spinal stenosis or spondylolisthesis. One article was excluded because it did not provide specific information about their diagnosis and age of study population,²⁰ one other article was excluded because it dealt with patients younger than 65 years old,²¹ and another article was excluded because it included patients with heterogenous spinal diseases such as spinal stenosis, spondylolisthesis, herniated nucleus pulposus, instabil-

ity, and scoliosis into the study population.²² Finally, we found one non-randomized prospective and seventeen retrospective studies that met the study criteria (Table 1-4). However, there was no randomized clinical trial that met the study criteria.

CLINICAL OUTCOME

One non-randomized prospective and twelve retrospective studies dealt with clinical outcomes (Table 1).¹⁻¹³ The quality of the data appears to be poor except one non-randomized prospective study. The retrospective studies contained four case-control and eight case-series. Only eight studies used standard outcome measures in their study designs and this number is reduced to five if the visual analog scale (VAS) or neurologic function is not included.

Glassman, et al.¹ investigated clinical outcomes of 224 patients following lumbar decompression and arthrodesis for spinal stenosis. Patients were divided into two groups according to ages; over (n=50) or below 65 years old (n=174).¹ The health-related quality-of-life measures (HRQOL) including Oswestry Disability Index (ODI), the Medical Outcomes Study Short Form-36 (SF-36), back pain VAS, and leg pain VAS were evaluated for the mean follow-up of two years.¹ There was no difference in the postoperative clinical outcomes.¹ They performed another study on postoperative clinical outcomes of 178 patients following lumbar decompression and arthrodesis for spinal stenosis or spondylolisthesis.² Patients were divided into

Table 1. Clinical Studies Examining Clinical Outcome after Lumbar Surgery in Geriatric Patients

Source	Age of study group (yrs)	Patient number (study/control)	Mean follow-up (months)	Disease entity	Operative procedures	Outcome measures
Glassman, et al. ¹	65 to 86	50/174	24	Spinal stenosis	Decompression & fusion	HRQOL
Glassman, et al. ²	65 to 85	85/93	33	Spinal stenosis or spondylolisthesis	Decompression & fusion	HRQOL
Okuda, et al. ³	70 to 79	31/70	50	Spondylolisthesis	Decompression & fusion	JOA score
Arinzo, et al. ⁴	75 to 90	83/152	42	Spinal stenosis	Decompression	Satisfaction
Rihn, et al. ⁵	80 to ?	58/742	48	Spinal stenosis or spondylolisthesis	Decompression or decompression & fusion	HRQOL
Crawford, et al. ⁶	75 to 85	35	24	Spinal stenosis or spondylolisthesis	Decompression & fusion	HRQOL
Shabat, et al. ⁷	80 to 91	39	36	Spinal stenosis	Decompression	VAS, satisfaction
Fredman, et al. ⁸	75 to 89	122	45	Spinal stenosis	Decompression	VAS
Tokuhashi, et al. ⁹	70 to 85	81	96	Spinal stenosis or spondylolisthesis	Decompression & fusion	Independence
Vitaz, et al. ¹⁰	75 to ?	65	Unknown	Spinal stenosis	Decompression or decompression & fusion	Neurologic function
Ragab, et al. ¹¹	70 to 101	118	84	Spinal stenosis or spondylolisthesis	Decompression or decompression & fusion	Satisfaction
Sanderson and Wood ¹²	65 to 81	31	42	Spinal stenosis or spondylolisthesis	Decompression	Satisfaction
Jönsson and Strömquist ¹³	70 to 84	50	24	Spinal stenosis	Decompression	Satisfaction

HRQOL, health-related quality-of-life measures; JOA score, Japanese Orthopaedic Association score; VAS, visual analog scale.

two groups according to ages; over (n=85) or below 65 years old (n=93).² There was no difference in the clinical outcomes with the mean follow-up of 33 months, evaluated with the same HRQOL.²

Okuda, et al.³ investigated clinical outcomes after lumbar decompression and fusion in 101 patients with spondylolisthesis. Patients were divided into two groups according to ages; over (n=31) or below 70 years old (n=70),³ and Japanese Orthopaedic Association score (JOA score) was evaluated at the mean follow-up of 50 months.³ The result indicated that the recovery rates in each group were 63% and 70%, respectively, showing no statistical difference.³

Arinzon, et al.⁴ performed the case-control study for the clinical outcomes after decompression in 235 patients with spinal stenosis. The authors included 83 patients over 75 years old in the study group and 152 patients between 65 and 75 years old in the control group.⁴ Clinical outcome was measured by patients' satisfaction at the mean follow-up of 42 months.⁴ Patients who were "not satisfied" were 10% in the study group and 15% in the control group, respectively, showing no difference.⁴

Rihn, et al.⁵ performed non-randomized prospective study on the clinical outcomes after decompression and fusion in patients with spinal stenosis or degenerative spondylolisthesis. The authors included 58 patients over 80 years old in the study group and 742 patients younger than 80 years old in the control group.⁵ The HRQOL outcomes including ODI, SF-36, stenosis bothersome index, low back pain bothersome scale, patient satisfaction, and patient self-reported improvement were measured at the final follow-up of 48 months.⁵ All HRQOL measures were similar between the study and control groups except the SF-36 bodily pain domain.⁵ The authors initially had the designs of both randomized cohort and observational cohort study. However, they found extensive cross-over in the randomized cohort,⁵ so that they combined the randomized and observational cohorts into an "as-treated"

analysis.⁵ In the present study, therefore, we classified it as the non-randomized prospective study.

Crawford, et al.⁶ performed the case series study for the clinical outcomes after decompression and fusion in patients over 75 years old with lumbar stenosis or spondylolisthesis. They included 35 patients over 75 years old in the study cohort.⁶ The HRQOL outcomes including ODI, SF-36, back pain VAS, and leg pain VAS were measured at the mean follow-up of 24 months.⁶ All HRQOL measures were found to improve until 2 years after operation.⁶

The other seven studies were the case series study, evaluated with non-standard outcome measures of VAS, satisfaction, independence and neurologic functions.⁷⁻¹³ All of them showed that surgery favored the clinical outcome in geriatric patients with spinal stenosis or spondylolisthesis.⁷⁻¹³

In summary, clinical outcome after spine surgery was satisfactory in geriatric patients with age between 65 and 101 after 2 to 8 years of follow-up period.¹⁻¹³ Addition of arthrodesis had no negative effect on the clinical outcomes.^{1-3,6,9,10}

COMPLICATION RATES

Complication was defined as any event for which the patient required a specific intervention. There was no randomized clinical trial regarding complications after spine surgery in geriatric patients. However, one non-randomized prospective study and ten retrospective studies on the complications were found, which can be considered as options (Table 2).^{3-5,7,10-16} The quality of the data is poor except one non-randomized prospective study. The retrospective studies had three case-control and seven series studies.

One non-randomized prospective study and three case-control studies showed no statistical difference in complication rate after lumbar fusion in geriatric patients.^{3-5,15} Four out of

Table 2. Clinical Studies Dealing with Complications after Lumbar Surgery in Geriatric Patients

Source	Age of study group (yrs)	Patient number (study/control)	Mean follow-up (months)	Disease entity	Operative procedures
Okuda, et al. ³	70 to 79	31/70	50	Spondylolisthesis	Decompression & fusion
Arinzon, et al. ⁴	75 to 90	83/152	42	Spinal stenosis	Decompression
Rihn, et al. ⁵	80 to ?	58/742	48	Spinal stenosis or spondylolisthesis	Decompression or decompression & fusion
Kilincer, et al. ¹⁵	65 to 91	43/85	11	Spinal stenosis or spondylolisthesis	Decompression or decompression & fusion
Vitaz, et al. ¹⁰	75 to ?	65	Unknown	Spinal stenosis	Decompression or decompression & fusion
Ragab, et al. ¹¹	70 to 101	118	84	Spinal stenosis or spondylolisthesis	Decompression or decompression & fusion
Sanderson and Wood ¹²	65 to 81	31	42	Spinal stenosis or spondylolisthesis	Decompression
Jönsson and Strömqvist ¹³	70 to 84	50	24	Spinal stenosis	Decompression
Carreon, et al. ¹⁴	65 to 84	98	Unknown	Spinal stenosis	Decompression or decompression & fusion
Shabat, et al. ⁷	80 to 91	39	36	Spinal stenosis	Decompression
Raffo and Lauerman ¹⁶	80 to ?	20	30	Spinal stenosis or spondylolisthesis	Decompression or decompression & fusion

seven case series studies found that advanced age did not increase operation-associated complication,¹⁰⁻¹³ however, three out of seven case series studies found contrary results, showing the complication ranging from 52% to 70% (Table 2).^{7,14,16}

Postoperative complication was divided into minor and major complication (Table 3).¹⁴ Minor complications included urinary tract infection (UTI) and ileus which do not affect clinical outcome, whereas major complications included deep wound infection, pneumonia, and renal failure, which affect clinical outcome.¹⁴ Carreon, et al.¹⁴ found that 21% of geriatric patients had at least one major complication and 70% of them had at least one minor complication (Table 3).¹⁴ The major complication was found in 49% of the patients older than 75 years old.¹⁴ Shabat, et al.⁷ showed that 52% of the patients had complication.⁷ Most of them were minor (Table 3).⁷ However, Raffo and Lauerman¹⁶ found that major complications occurred in 7 out

of 20 patients (35%).

In summary of the complications, there was no increasing tendency after spinal surgery in geriatric patients in one non-randomized prospective, three case-control and four case series studies.^{3-5,10-13,15} However, postoperative complications increased in three case series studies, especially in patients over 80 years old.^{7,14,16} Fortunately, most postoperative complications after spine surgery in elderly patients were minor (Table 3).^{7,10-12,14}

MORTALITY RATES

There was no randomized clinical trial or non-randomized prospective study in regard to mortality in spine surgery of elderly patients. The quality of the data is poor. There were two

Table 3. Minor and Major Complications after Lumbar Surgery in Geriatric Patients

Source	Number of complication (minor/major)	Minor complications	Major complications
Okuda, et al. ³	5 (3/2)	Delirium (2) Adjacent segmental degeneration (1)	Neurologic deficit (1) Brain infarction (1)
Vitaz, et al. ¹⁰	31 (23/8)	UTI (12) Delirium (7) Atrial fibrillation (2) CHF (1) COPD (1)	Wound infection (5) Pulmonary embolus (3)
Ragab, et al. ¹¹	20 (17/3)	Confusion (5) Urinary retention (2) Ileus (1) Pseudogout (1) Dural tear (8)	Wound infection (3)
Sanderson and Wood ¹²	3 (3/0)	Deep venous thromboses (2) Confusion (1)	
Jönsson and Strömqvist ¹³	3 (1/2)	Dural tear (1)	Wound infection (1) Neurologic deficit (1)
Carreon, et al. ¹⁴	158 (128/30)	UTI (33) Anemia (26) Confusion (26) Others (43)	Wound infection (10) Pneumonia (5) Others (15)
Shabat, et al. ⁷	23 (21/2)	Urinary retention (6) UTI (5) Others (10)	Wound infection (2)

UTI, urinary tract infection; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease.

Table 4. Studies Dealing with Lumbar Surgery-Related Mortality in Geriatric Patients

Author	Age range	Study design	Patient number	Mean follow-up (months)	Diagnosis	Procedures
Oldridge, et al. ¹⁷	65 to 85	Cohort study	34418	12	Spinal stenosis or spondylolisthesis	Decompression or decompression & fusion
Kim, et al. ¹⁸	50 to 85	Cases series	846	120	Spinal stenosis	Decompression or decompression & fusion

retrospective studies on the mortality (Table 4).^{17,18} Oldridge, et al.¹⁷ compared postoperative mortality in 34418 elderly patients, who underwent lumbar surgery under the diagnosis of spinal stenosis or spondylolisthesis, with age-matched healthy group. Relative risk of expected mortality was lower than 1, which indicates that mortality was not increased by surgery.¹⁷ Kim, et al.¹⁸ investigated 10-year survival of elderly patients who underwent spinal surgery under the diagnosis of spinal stenosis and compared them with age- and gender-matched controls of general population. The standardized mortality ratios were 0.45 in patients aged 70 to 85 who underwent spinal surgery, showing lower mortality rate in the surgery group.¹⁸ To summarize the mortality data, more than 3500 elderly patients over 65 years old who underwent lumbar surgery were followed up for 1 to 10 years, and the result showed that mortality did not increase in elderly patients compared with age-adjusted control group who did not undergo spinal surgery.^{17,18}

KEY POINTS ABOUT THE TOPIC

Because of controversies on the clinical outcome, complication and mortality of spinal surgery in geriatric patients with the spinal stenosis or spondylolisthesis, we herein reviewed the literature about spinal surgery for geriatric patients, focusing on the diagnosis of spinal stenosis and spondylolisthesis which are most commonly encountered in a clinical practice of spinal surgeon.

Although it is generally known that spine surgery in elderly patients could deteriorate postoperative clinical outcomes, it does not affect surgical results.¹⁻¹³ It is not too far different from the clinical outcome of surgery for the deformity in the geriatric patients.²³

There are some reports to suggest that postoperative complications are increased in elderly patients,^{7,14,16,20} whereas the others report that complications are not increased.^{3-5,10-13,15} Nev-

ertheless, most of them were minor complications,^{7,10-12,14} and did not increase the mortality associated with the operation.^{17,18} It is the same with the complications of surgery for the deformity in the geriatric patients.^{23,24} The retrospective study of minimal 5-level spinal deformity surgery in 21 patients older than 75 years old showed that the overall complication was 62% and major complication was 38%.²⁴ It is similar with the complications after surgery for the heterogenous spinal diseases in geriatric patients. Benz, et al.²² investigated the complication after decompression in 68 patients over 70 years old with heterogenous spinal diseases such as spinal stenosis, spondylolisthesis, herniated nucleus pulposus, instability, and scoliosis. The total complication rate was 40%, and major complications occurred only in 12% of patients.²²

Generally, elderly patients have more comorbidities. As the number of preoperative comorbidities increase, more complications develop.^{16,24} Mortality not related to surgical procedure increased, whereas mortality related to surgical procedure did not increase.^{17,18} It is also same with the mortality after surgery for the deformity in geriatric patients.²⁴ The correlation of preoperative morbidity with postoperative complication or mortality was investigated in elderly patients.^{11,16} Raffo and Lauerman¹⁶ reported that patients over 80 years old develop postoperative complications 9.20 fold more because they had more preoperative morbidities. On the other hand, Ragab, et al.¹¹ found that preoperative morbidity did not cause postoperative complications and advanced age did not increase the morbidity associated with the operation.

As in any study, the present investigation has several limitations. First, all the literatures reviewed are all retrospective except one non-randomized prospective study. There have been five randomized controlled studies comparing the clinical results of surgical and conservative treatment for spinal stenosis of patients with all ages (Table 5).^{21,25-28} During 1 to 4 years of short-term follow-up, patients treated operatively had better clinical results with radicular and low back pain. During long-

Table 5. Randomized Controlled Studies Comparing Clinical Results of Surgical and Conservative Treatment for Spinal Stenosis

Author	Number of patients*	Mean F/U [†]	Procedures	Outcome measures	Results
Atlas, et al. ²⁵	81/67	1	Decompression	VAS, satisfaction, stenosis index, SF-36, modified Roland Scale	Surgery had better improvement for all measurements
Atlas, et al. ²⁶	67/52	4	Decompression	Same as above	Same as above
Atlas, et al. ²⁷	53/38	10	Decompression	Same as above	Surgery had better improvement for leg pain. No difference for back pain, satisfaction
Amundsen, et al. ²⁸	22/68	10	Decompression	VAS, satisfaction, claudication distance	No difference for claudication, back pain
Chang, et al. ²¹	51/35	10	Decompression	Symptom index, satisfaction, SF-36, modified Roland Scale	Surgery had better improvement for leg pain, functional status. No difference for satisfaction, back pain. However, during the follow up of 1-5 years surgery had better improvement for all measurements.

VAS, visual analog scale; SF-36, Short Form-36.

*Expressed as the number of patients treated with surgery/with conservative treatment, [†]Follow-up period with years.

term follow-up such as 10 years, there were no significant differences in clinical results between surgery and conservative management for low back pain, because it is due to degenerative changes, although the patients treated operatively had better outcomes with radicular pain.^{21,25-28} Second, there is no data on patients who were lost to follow-up. Third, the operative procedures of decompression or decompression & fusion were different among the studies mentioned. Fourth, surgery-related complications, such as hardware failure, fracture, progression of spinal deformity due to osteoporosis, and degenerative polyneuropathy, were not addressed. Fifth, our study could be improved by the methodology of meta-analysis. Unfortunately, we have only one prospective and five case-control studies, which might be insufficient to make a conclusion with meta-analysis. Additionally, outcome measurements were not consistent among available studies. Despite these shortcomings, to our knowledge, this is the first review on the surgical outcome of geriatric patients in the journal of spinal pathology.

In conclusion, there was no difference in clinical outcome, postoperative complication and mortality rates between geriatric and non-geriatric patients. However, there is insufficient evidence to make strong recommendations with regard to spinal surgery for geriatric patients with lumbar stenosis and spondylolisthesis. High-quality, prospective randomized studies on the spinal surgery for geriatric patients with lumbar stenosis and spondylolisthesis are needed.

REFERENCES

1. Glassman SD, Polly DW, Bono CM, Burkus K, Dimar JR. Outcome of lumbar arthrodesis in patients sixty-five years of age or older. *J Bone Joint Surg Am* 2009;91:783-90.
2. Glassman SD, Carreon LY, Dimar JR, Campbell MJ, Puno RM, Johnson JR. Clinical outcomes in older patients after posterolateral lumbar fusion. *Spine J* 2007;7:547-51.
3. Okuda S, Oda T, Miyauchi A, Haku T, Yamamoto T, Iwasaki M. Surgical outcomes of posterior lumbar interbody fusion in elderly patients. *J Bone Joint Surg Am* 2006;88:2714-20.
4. 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;36:273-9.
5. Rihn JA, Hilibrand AS, Zhao W, Lurie JD, Vaccaro AR, Albert TJ, et al. Effectiveness of surgery for lumbar stenosis and degenerative spondylolisthesis in the octogenarian population: analysis of the Spine Patient Outcomes Research Trial (SPORT) data. *J Bone Joint Surg Am* 2015;97:177-85.
6. Crawford CH 3rd, Smail J, Carreon LY, Glassman SD. Health-related quality of life after posterolateral lumbar arthrodesis in patients seventy-five years of age and older. *Spine (Phila Pa 1976)* 2011;36:1065-8.
7. Shabat S, Arinzon Z, Folman Y, Leitner J, David R, Pevzner E, et al. Long-term outcome of decompressive surgery for lumbar spinal stenosis in octogenarians. *Eur Spine J* 2008;17:193-8.
8. Fredman B, Arinzon Z, Zohar E, Shabat S, Jedeikin R, Fidelman ZG, et al. Observations on the safety and efficacy of surgical decompression for lumbar spinal stenosis in geriatric patients. *Eur Spine J* 2002;11:571-4.
9. Tokuhashi Y, Ajiro Y, Umezawa N. Outcomes of posterior fusion using pedicle screw fixation in patients >or=70 years with lumbar spinal canal stenosis. *Orthopedics* 2008;31:1096.
10. Vitaz TW, Raque GH, Shields CB, Glassman SD. Surgical treatment of lumbar spinal stenosis in patients older than 75 years of age. *J Neurosurg* 1999;91(2 Suppl):181-5.
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;28:348-53.
12. Sanderson PL, Wood PL. Surgery for lumbar spinal stenosis in old people. *J Bone Joint Surg Br* 1993;75:393-7.
13. Jönsson B, Strömquist B. Lumbar spine surgery in the elderly. Complications and surgical results. *Spine (Phila Pa 1976)* 1994;19:1431-5.
14. Carreon LY, Puno RM, Dimar JR 2nd, Glassman SD, Johnson JR. Perioperative complications of posterior lumbar decompression and arthrodesis in older adults. *J Bone Joint Surg Am* 2003;85-A:2089-92.
15. Kilincer C, Steinmetz MP, Sohn MJ, Benzel EC, Bingaman W. Effects of age on the perioperative characteristics and short-term outcome of posterior lumbar fusion surgery. *J Neurosurg Spine* 2005;3:34-9.
16. Raffo CS, Lauerma WC. Predicting morbidity and mortality of lumbar spine arthrodesis in patients in their ninth decade. *Spine (Phila Pa 1976)* 2006;31:99-103.
17. Oldridge NB, Yuan Z, Stoll JE, Rimm AR. Lumbar spine surgery and mortality among Medicare beneficiaries, 1986. *Am J Public Health* 1994;84:1292-8.
18. Kim HJ, Lee HM, Kim HS, Moon ES, Park JO, Lee KJ, et al. Life expectancy after lumbar spine surgery: one- to eleven-year follow-up of 1015 patients. *Spine (Phila Pa 1976)* 2008;33:2116-21.
19. Cloyd JM, Acosta FL Jr, Ames CP. Complications and outcomes of lumbar spine surgery in elderly people: a review of the literature. *J Am Geriatr Soc* 2008;56:1318-27.
20. 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;74:536-43.
21. Chang Y, Singer DE, Wu YA, Keller RB, Atlas SJ. The effect of surgical and nonsurgical treatment on longitudinal outcomes of lumbar spinal stenosis over 10 years. *J Am Geriatr Soc* 2005;53:785-92.
22. Benz RJ, Ibrahim ZG, Afshar P, Garfin SR. Predicting complications in elderly patients undergoing lumbar decompression. *Clin Orthop Relat Res* 2001;116-21.
23. Daubs MD, Lenke LG, Cheh G, Stobbs G, Bridwell KH. Adult spinal deformity surgery: complications and outcomes in patients over age 60. *Spine (Phila Pa 1976)* 2007;32:2238-44.
24. Acosta FL Jr, McClendon J Jr, O'Shaughnessy BA, Koller H, Neal CJ, Meier O, et al. Morbidity and mortality after spinal deformity surgery in patients 75 years and older: complications and predictive factors. *J Neurosurg Spine* 2011;15:667-74.
25. Atlas SJ, Deyo RA, Keller RB, Chapin AM, Patrick DL, Long JM, et al. The Maine Lumbar Spine Study, Part III. 1-year outcomes of surgical and nonsurgical management of lumbar spinal stenosis. *Spine (Phila Pa 1976)* 1996;21:1787-94.
26. Atlas SJ, Keller RB, Robson D, Deyo RA, Singer DE. Surgical and nonsurgical management of lumbar spinal stenosis: four-year outcomes from the maine lumbar spine study. *Spine (Phila Pa 1976)* 2000;25:556-62.
27. Atlas SJ, Keller RB, Wu YA, Deyo RA, Singer DE. Long-term outcomes of surgical and nonsurgical management of lumbar spinal stenosis: 8 to 10 year results from the maine lumbar spine study.

- Spine (Phila Pa 1976) 2005;30:936-43.
28. 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 (Phila Pa 1976) 2000;25:1424-35.