Outcomes after Spinal Stenosis Surgery by Type of Surgery among Adults Age 60 Years and Older

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Abstract

Background: Mobility disability due to spinal stenosis is common in the senior population. We assessed the recovery timeline and compared outcomes among seniors undergoing spinal stenosis surgery by type of surgery.

Methods: We investigated 451 patients (77.4 ± 10.9 years, 58% women) of a consecutive cohort prior to spinal stenosis surgery and at 3 or 6-month and at 12-month follow-up. At each visit, pain, neurological dysfunction, and disability were assessed using the North American Spine Society questionnaire. Repeated-measures analysis compared outcomes by type of surgery adjusting for baseline symptoms, gender, age, comorbidities, center, and year of surgery.

Results: Most improvement occurred within the first 3 to 6 months with little or no improvement up to 12 months. Over 12 months and in adjusted models, patients receiving one-segment versus multi-segment decompression experienced greater reduction of pain (-46.0% vs. -41.0%; $p = 0.05$), neurological dysfunction (-36.4% vs. -26.1%; $p < 0.001$), and disability (-30.5% vs. -26.7%; $p = 0.06$). Moreover, reduction in pain and neurological function did not differ with or without additional stabilization and extend of decompression. However, patients who received one-segment (-26.7%) or multi-segment (-27.5%) stabilization experienced significantly less reduction in disability after surgery compared with those who were not stabilized (-31.6%; $p < 0.05$).

Conclusions: Among seniors undergoing spinal stenosis surgery, recovery was largely complete by 3 to 6 months after surgery, and differed little by type of surgery independent of symptoms prior to surgery and other covariates. However, particularly neurological dysfunction and disability may improve more with less invasive surgery.

Introduction

Mobility disability due to spinal stenosis is common in the senior population; including a wide range of symptoms such as pain in the lower back and buttocks, thighs, and sometime calves provoked by walking or longer standing. Prevalence of symptomatic spinal stenosis among seniors age 60 to 69 was found to be 19.4% in the Framingham Study, increasing further with age [1]. Similar data were presented from a population-based study in Japan [2]. Lumbar spinal stenosis is caused by progressive degeneration of intervertebral discs, facet joints, and ligaments resulting in decreased vertebral height causing a narrowing the neural foramina and the spinal canal. This is further enhanced by age-related secondary osteoarthritis of the intervertebral joints. Degenerative instability with the development of spondylolisthesis and chronic degenerative slippage is a frequent sign of progressive disease [3].

Symptoms of spinal stenosis include low back pain as well as pain and weakness in the legs, reduced walking distance and increased frequency of falls [1,4]. While for mild symptoms, conservative treatment is recommended (pain medication, physiotherapy and steroid injection), for patients with severe symptoms and neurological dysfunction surgery is warranted [5-7]. Notably, in patients age 65 and older lumbar spinal stenosis is the most common indication for spinal surgery [8]; and similar to patient-reported outcome research findings in total joint replacement due to

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osteoarthritis of the hip, [9] it has been suggested that the prevalence of comorbid diseases rather than age, contribute to worse outcomes [10].

Another source of outcome variability in seniors undergoing spinal stenosis surgery may be the extent of decompression and the need for additional stabilization. While current guidelines recommend stabilization surgery in patients with spinal stenosis and additional instability due to degenerative spondylolisthesis, outcomes depending on type of surgery are not well studied [11]. Notably, as senior patients often present with a progressed disease stage of spinal stenosis, degenerative spondylolisthesis is highly prevalent. Further, as stabilization in addition to decompression increases surgery time and therefore may carry extra risks in senior patients (i.e. infections, bleeding), outcome variation due to surgery technique carry great clinical significance [12].

The aim of the present study was to investigate the timeline of patient-reported recovery in the first year after spinal stenosis surgery and outcome variation by the extent of decompression and the need for additional stabilization among senior patients age 60 years and older. To compare outcomes in the best possible way, our study adjusted, among others, for symptoms prior to surgery as well as for comorbid status, age, and gender.

Methods

Study design and participants

We enrolled 524 consecutive patients age 60 years and older (mean age 77.1 ± 11.2 years, 56% women) who were scheduled for surgery to treat spinal stenosis in two large hospital centers in Switzerland (Basel University Hospital and Triemli City Hospital, Zurich) in a 2-center prospective cohort study between January 2002 and December 2009. All of the 524 patients enrolled underwent baseline assessments prior to surgery. Post-surgical assessments of pain, neurological dysfunction, and disability were performed at two time points: the first measurement was performed either at 3 months ($n = 277$) or 6 months ($n = 189$) depending on the center and the second measurement at 12 months after the surgery ($n = 451$). Among 73 patients, we had only incomplete follow-up data; these patients were therefore excluded from the statistical analysis (Table 1).

The protocol of the study was in accordance with the standards for the use of human subjects in research as outlined in the World Medical Association Declaration of Helsinki and was approved by the local Ethics Committee of the Triemli City Hospital in Zurich (approval number: KEK 2004-15), Switzerland. All participants gave their written informed consent to the study.

Type of spinal stenosis surgery

Type of surgery performed on each patient with spinal stenosis was recorded and, as pre-defined for the purposes of this study, categorized according to two parameters: segmental decompression (one vs. multiple) and segmental stabilization (none, one, and multiple). Type of surgery was defined by the spinal surgeons based on radiology findings and their clinical examination of each of their patients.

Assessment of pain, neurological dysfunction, and disability

At baseline (before surgery) as well as at 3 or 6 months (depending on the center) and at 12 months, all participants were interviewed by a study nurse in a standardized way with respect to their levels of back pain, neurological dysfunction, and disability based on three subscales of the North American Spine Society (NASS) Lumbar Spine Outcome Assessment questionnaire [13,14]. The NASS questionnaire assesses these characteristics as a score (0-100) on a scale from 0 (total absence of pain, no neurological dysfunction or disability) to 100 (maximum level of pain, neurological dysfunction or disability).

Assessment of covariates

At the baseline assessments, age, gender, year of the surgery, and the clinical center where the surgery was performed were recorded. Baseline levels of pain, neurological dysfunction, or disability were assessed using the NASS questionnaire, and the presence of comorbid conditions (score: 0-3, 4-7, and 8+) before surgery was assessed using the Sangha comorbidity index (score range 0-12) [15].

Statistical analysis

Baseline characteristics were compared by using a χ^2 test for categorical variables and a Student's *t* test for continuous variables. In the primary analysis, overall differences in the impact of different types of decompression or stabilization strategies on the repeatedly assessed NASS outcomes (change values of level of pain, neurological dysfunction, or disability compared to baseline) over the total period of 12 months after spinal stenosis surgery were analyzed using multivariable repeated-measures linear mixed effects ANCOVA models. Models included time, the main surgery strategies (decompression and stabilization), and the interaction terms of these variables as indicator variables and were further adjusted for gender, age, comorbidities (Sangha score: 0-3, 4-7, and 8+), center, year of the surgery, and the baseline value of the respective outcome variable (pain, neurological dysfunction, or disability). For graphical presentation of the timeline of recovery (Figure 1), the same repeated-measures analysis was conducted, however, with absolute (instead of change) values for the NASS outcomes and not adjusting for the baseline values of pain, neurological dysfunction, or disability, respectively.

To investigate the timeline of recovery as well as for a sensitivity analysis to compare the impact of segment decompression and stabilization on NASS outcomes at each time point separately, differences in the NASS outcomes (change values of level of pain, neurological dysfunction, or disability compared to baseline) between different types of decompression or stabilization strategies were analyzed at each time point (3 or 6 months, and 12 months) after spinal stenosis surgery using multivariable linear ANCOVA models. Models included the main surgery strategies (decompression and stabilization) and the interaction term of these strategies as indicator variables and were further adjusted for gender, age, comorbidities (Sangha score: 0-3, 4-7, and 8+), center, year of the surgery, and the baseline value of the respective outcome variable (pain, neurological dysfunction, or disability).

Statistical significance was set at $p < 0.05$. All analyses were performed with SAS version 9.4.

Results

Characteristics of the study population

Baseline age of the 451 patients included in the prospective analysis was 74.4 (10.9) years, 58% were women, and the Sangha comorbidity index was 6.1 (2.9) (Table 1). The pre-surgery NASS scores were 80.0(16.6) for pain, 55.7 (27.8) for neurological dysfunction, and

57.0 (19.0) for disability. Of the included patients, 68% required decompression of multiple segments and 51% required stabilization of at least one segment (28% needed one segment stabilized and 23% required stabilization of multiple segments). Except for the center where the surgery was performed and year of the surgery, there were no significant differences in baseline characteristics between participants with complete follow-up data (n = 451; 86%) and the 73 excluded participants.

Table 1: Baseline characteristics of the study population.

Characteristic	Participants included in the prospective analyses		p	Entire population (N = 524)
	Yes (n = 451)	No (n = 73)		
Gender [n (%)]				
Men	191 (42%)	37 (51%)	0.18	228 (44%)
Women	260 (58%)	36 (49%)		296 (56%)
Age (y)	77.4 (10.9)	75.4 (12.6)	0.17	77.1 (11.2)
Decompressed segments [n(%)]				
One	145 (32%)	25 (34%)	0.72	170 (32%)
Multiple	306 (68%)	48 (66%)		354 (68%)
Stabilized segments [n (%)]				
No	224 (50%)	34 (47%)	0.84	258 (49%)
One	123 (27%)	20 (27%)		143 (27%)
Multiple	104 (23%)	19 (26%)		123 (24%)
Surgery Type [n (%)]				
One-segment decompression	56 (12%)	10 (13%)	0.90	66 (12%)
One-segment decompression and stabilization	71 (16%)	13 (19%)		84 (16%)
One-segment decompression, multi-segment stabilization	18 (4%)	2 (3%)		20 (4%)
Multi-segment decompression	168 (37%)	24 (33%)		192 (37%)
Multi-segment decompression, one-segment stabilization	52 (12%)	7 (9%)		59 (11%)
Multi-segment decompression and stabilization	86 (19%)	17 (23%)		103 (20%)
Center [n (%)]				
Basel	246 (55%)	21 (29%)	<0.0001	267 (51%)
Zurich	205 (45%)	52 (71%)		257 (49%)
Year of the surgery [n (%)]				
2002/3	41 (9%)	15 (21%)	0.02	56 (11%)
2004	98 (22%)	13 (19%)		111 (21%)
2005	123 (27%)	12 (17%)		135 (26%)
2006	66 (15%)	11 (16%)		77 (15%)
2007-9	123 (27%)	19 (27%)		142 (27%)
Sangha comorbidity index (score 0-12)	6.1 (2.9)	7.7 (2.5)	0.35	6.3 (2.8)
Pre- surgery pain (score 0-100) ^a	80.0 (16.6)	83.3 (11.7)	0.19	80.2 (16.4)
Pre-surgery neurological dysfunction(score 0-100) ^a	55.7 (27.8)	64.4 (30.5)	0.12	56.2 (28.0)
Pre-surgery disability (score 0-100) ^a	57.0 (19.0)	62.6 (16.9)	0.14	57.3 (18.9)

Data are means (SD) or n (%) for the total study population as well as for the participants included or excluded from the prospective analyses due to missing follow-up data. Differences between participants included or excluded were assessed by using Student's t test for continuous variables and a χ^2 test for categorical variables. P values are two-sided. Statistical significance was set at $p < 0.05$. NASS, North American Spine Society.

^aNASS scoring: 0-100; 0 = total absence and 100 = maximum of pain, neurological dysfunction, or disability.

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Timeline of recovery after spinal stenosis surgery by type of surgery

Investigating the timeline of recovery after spinal stenosis surgery by type of surgery for all outcomes and independent of symptoms prior to surgery, type of surgery, age, gender, comorbidity, year of surgery, and center, most improvement was achieved at 3 or 6 months with minimal or no further improvement at 12 months (Table 2). Notably, the timeline of recovery for all three outcomes looked very similar regardless of surgery type (Figure 1).

Overall change in repeated NASS outcomes over 12 months after spinal stenosis surgery by type of surgery

Regarding the overall impact of type of surgery in the first year after spinal stenosis surgery over 12 months (Table 3), in adjusted analysis, patients who received one-segment decompression experienced greater reduction of pain (-46.0% vs. -41.0%; $p = 0.05$), neurological dysfunction (-36.4% vs. -26.1%; $p < 0.001$), and disability (-30.5% vs. -26.7%; $p = 0.06$) during the first year compared with those who required decompression of multiple segments, independent of symptoms prior to surgery, extend of stabilization, and other covariates.

Concerning additional segment stabilization, in adjusted analysis, reduction in pain and neurological dysfunction did not differ with or without stabilization, independent of symptoms prior to surgery; extend of decompression and other covariates (Table 3). However, patients who received one-segment (-26.7% reduction) or multi-segment (-27.5% reduction) stabilization experienced significantly less reduction in disability compared with those who were not stabilized (-31.6% reduction; $p = 0.05$) (Table 3).

Moreover, pre-surgery levels of pain, neurological dysfunction, and disability were important predictors of improvement after surgery independent of type of surgery and other covariates (Table 3). Notably, per 10% stronger symptoms prior to surgery, patients had on average 7% additional reduction in pain, 8% greater reduction in neurological dysfunction, and 6% greater reduction in disability after spinal stenosis surgery ($p < 0.0001$) (Table 3).

Sensitivity analysis

The results of the sensitivity analysis comparing the impact of type of surgery on pain, neurological dysfunction, and disability at each time point separately were similar to those of the primary repeated-measures analysis (Table 2). In adjusted analysis, patients who had decompression of only one segment experienced consistently greater improvement in all three outcomes compared to those who had multi-segment decompression independent of symptoms prior to surgery, extend of stabilization, and other covariates. For pain ($p = 0.02$) and disability ($p = 0.04$) reduction, these differences were only significant at 12 months after surgery, whereas the differences in neurological dysfunction were significant at 3 months ($p = 0.02$), 6 months ($p = 0.04$), and 12 months ($p < 0.0001$). Moreover, the estimated effect sizes were very similar to those obtained in the primary analysis. Additional segment stabilization did not improve the results of decompression with respect to pain or neurological dysfunction independent of symptoms prior to surgery; extend of decompression, and other covariates. Patients who had segment stabilization tended to have significantly worse results with respect to reduction in disability compared to those who did not have this procedure ($p < 0.05$) (Table 2).

Table 2: Change in NASS outcomes in the first year after spinal stenosis surgery by time point.

Difference in NASS outcome scores (0-100) compared to baseline ^a	Number of decompressed segments		p	Number of stabilized segments			p
	One	Multiple		None	One	Multiple	
	Mean (SE)	Mean (SE)		Mean (SE)	Mean (SE)	Mean (SE)	
Pain ^b							
Δ (3 months - BL)	-46.6 (3.7)	-41.7 (3.1)	0.24	-48.6 (3.7)	-44.0 (3.9)	-40.0 (4.4)	0.24
Δ (6 months - BL)	-41.3 (5.6)	-39.6 (3.4)	0.74	-39.2 (4.3)	-39.2 (4.3)	-43.0 (6.8)	0.86
Δ (12 months - BL)	-48.5 (2.4)	-41.6 (1.7)	0.02	-45.9 (2.0)	-44.7 (2.3)	-44.6 (3.3)	0.91
Neurological dysfunction ^b							
Δ (3 months - BL)	-34.7 (3.7)	-24.9 (3.0)	0.02	-34.0 (3.6)	-26.4 (3.8)	-29.1 (4.4)	0.29
Δ (6 months - BL)	-41.7 (5.7)	-30.7 (3.5)	0.04	-30.4 (4.5)	-30.8 (4.4)	-47.5 (7.2)	0.06
Δ (12 months - BL)	-37.5 (2.3)	-26.3 (1.6)	<0.0001	-32.7 (1.9)	-28.8 (2.2)	-34.2 (3.1)	0.24
Disability ^b							
Δ (3 months - BL)	-29.9 (2.6)	-24.5 (2.2)	0.07	-32.2 (2.6)	-22.5 (2.8)	-26.8 (3.2)	0.02
Δ (6 months - B)	-28.7 (4.2)	-27.0 (2.6)	0.66	-29.5 (3.3)	-26.8 (3.3)	-27.1 (5.3)	0.71
Δ (12 months - BL)	-32.8 (1.9)	-28.2 (1.3)	0.04	-34.1 (1.5)	-29.0 (1.8)	-28.5 (2.6)	0.045

Data are mean differences (SE) compared to baseline (pre-surgery) in NASS outcomes at 3 months ($n=277$) or 6 months ($n=189$) and at 12 months ($n=451$) after spinal stenosis surgery based on ANOCVA models. Models included time, the main surgery strategies (decompression and stabilization), and the interaction terms of these variables as indicator variables and were further adjusted for gender, age, comorbidities (Sangha score), center, year of the surgery, and baseline levels of pain, neurological dysfunction, or disability. P values are two-sided. Statistical significance was set at $p < 0.05$. BL, baseline; NASS, North American Spine Society.

^aNASS scoring: 0-100; 0 = total absence and 100 = maximum of pain, neurological dysfunction, or disability.

^bPost-surgical assessments of NASS outcomes were performed at two time points: the first at 3 months or 6 months depending on the center, and the second at 12 months.

Figure 1: Timeline of recovery after spinal stenosis surgery by type of surgery. (A) NASS pain scores, (B) NASS neurological dysfunction scores, and (C) NASS disability scores over time and by surgery type. Data (n = 451) are means (SE) of absolute values of NASS outcomes prior to the surgery (month "0") and at 3, 6, and 12-month follow-up after spinal stenosis surgery based on repeated-measures linear mixed effects ANCOVA models.

Table 3: Overall change in repeated NASS outcomes over 12 months after spinal stenosis surgery by type of surgery and other covariates.

Parameter	Mean differences in NASS scores (0-100) compared to baseline ^a					
	Pain	p	Neurological dysfunction	p	Disability	p
Decompression						
One-segment	-46.0 (2.2)	0.05	-36.4 (2.1)	<0.001	-30.5 (1.7)	0.06
Multi-segment	-41.0 (1.5)		-26.1 (1.4)		-26.7 (1.2)	
Stabilization						
None	-44.8 (1.8)	0.73	-32.1 (1.7)	0.23	-31.6 (1.4)	0.047
One-segment	-43.3 (2.1)		-28.4 (2.0)		-26.7 (1.6)	
Multi-segment	-42.3 (2.9)		-33.2 (2.8)		-27.5 (2.3)	
Gender						
Men	-44.9 (1.9)	0.22	-31.8 (1.9)	0.59	-29.6 (1.4)	0.25
Women	-42.1 (1.6)		-30.7 (1.5)		-27.6 (1.4)	
Age (5 years increase) ^b	-0.4 (0.5)	0.39	0.3 (0.5)	0.56	0.03 (0.4)	0.94
Sangha score (0-12)						
0–3	-44.0 (2.3)	0.56	-31.2 (2.2)	0.99	-28.6 (1.8)	0.30
4–7	-44.5 (1.6)		-31.4 (1.6)		-30.1 (1.3)	
8+	-41.9 (2.2)		-31.2 (2.1)		-27.2 (1.7)	
Baseline pain (10-unit increase) ^b	-6.8 (0.6)	<0.0001	--		--	
Baseline neurological dysfunction (10-unit increase) ^b	--		-7.9 (0.4)	<0.0001	--	
Baseline disability (10-unit increase) ^b	--		--		-5.9 (0.4)	<0.0001

Data (n = 451) are least-square mean differences (SE) for categorical variables or slopes for continuous variables compared to baseline (pre-surgery) in NASS outcomes after spinal stenosis surgery over 12 months by type of surgery (decompression and stabilization), gender, 5-year age increase, and comorbidities (Sangha score) based on repeated-measures mixed-linear ANCOVA models. Models included time, the main surgery strategies (decompression and stabilization), and the interaction terms of these variables as indicator variables and were further adjusted (except in the respective strata) for gender, age, comorbidities (Sangha score), center, year of the surgery, and baseline levels of pain, neurological dysfunction, or disability. P values are two-sided; statistical significance was set at $p < 0.05$. NASS, North American Spine Society.

^aNegative numbers reflect a decrease in NASS scores (scoring 0-100; 0 = total absence and 100 = maximum of pain, neurological dysfunction, or disability).

^bNegative slopes indicate a greater decrease in pain, neurological dysfunction, or disability compared to pre-surgery levels.

Discussion

To our knowledge, our study is the first cohort study to compare prospectively if and to what extent one-segment versus multi-segment decompression is associated with outcome in patients with spinal stenosis. We assessed 524 consecutive patients age 60 years and older prior to surgery due to degenerative spinal stenosis, and were able to follow and investigate 451 (86%) of them at 3 or 6 plus 12-month follow-up. Our results suggest that for pain, neurological dysfunction, and disability most improvements after spinal stenosis surgery were achieved within the first 3 or 6 months after surgery. Notably, independent of symptoms prior to surgery and other covariates such as age, gender, and comorbid conditions, we found little variation in outcome by type of surgery. However, there was a signal that neurological dysfunction and disability may improve more with less invasive surgery. Further, relevant to clinical care and outcome prediction after spinal stenosis surgery in senior patients, we found that benefits from surgery were most pronounced among patients with more severe symptoms prior to surgery.

While long-term outcomes at 5 to 12 years after spinal stenosis have been addressed in several studies [16-19] showing favorable results, limited data is available on the timeline of early recovery in

the first year after spinal stenosis surgery. The timeline of recovery after spinal stenosis surgery observed for improvement in pain, neurological dysfunction, and disability in our study suggests that most benefits to be expected in the first 12 months after surgery are achieved at 3 to 6-month follow-up. We found little or no further improvement for all three symptoms thereafter. Thus, the timeline of recovery after spinal stenosis surgery is similar to what has been described in senior patients undergoing total hip replacement [20].

In a systematic review by Martin et al., [21] among 578 patients (253 enrolled in 4 RCTs and 325 included in 9 observational studies), a greater benefit for clinical outcome was reported for spinal stenosis surgery with additional stabilization in comparison with decompression alone (relative risk was 1.40; 95% CI: 1.04 to 1.89). Notably, however, the authors stated that the individual study quality was low with sample sizes ranging from 19 to 102 patients. Alternatively, as suggested by our study among 451 senior patients followed for 1 year with standardized assessments prior and after surgery, additional stabilization may not contribute to greater pain reduction and improvements in neurological function, independent of symptoms prior to surgery, extent of decompression, and the other covariates. In fact, our study provides a signal that, in the first year after surgery, patients who received one-segment or multi-

segment stabilization experienced significantly less improvement in disability after surgery compared with those who were treated with decompression alone. This finding is supported by data from the National Swedish Register for Spine Surgery (Swespine) among a total of 5,390 patients [22]. At two years follow-up, the authors found no significant difference in patient satisfaction between the decompression surgery for spinal stenosis with or without stabilization for any of the outcomes and regardless of the presence of a pre-operative spondylolisthesis [22].

We found that independent of symptoms prior to surgery, age, gender, and additional stabilization, the average improvement in neurological dysfunction was significantly better for one-segment decompression with 36% improvement compared with 26% improvement for multi-segment decompression ($p < 0.001$). A similar pattern became apparent for reduction of pain and improvement in disability. A possible explanation may be that patients undergoing multi-segment decompression had more extended degenerative changes over multiple segments than patients undergoing one-segment decompression, and therefore their outcome is expected to be worse. However, our analyses adjusted for symptoms prior to surgery as well as age, gender and comorbidity, which could be considered a good measure of disease severity and risk profile prior to surgery. Moreover, our analyses suggest that worse symptoms prior to surgery are associated with significantly greater improvements after surgery for all three outcomes assessed in our study.

Notably, surgeons may choose more extensive surgery techniques in order to decline the possibility of repeat surgery. While this question could not be addressed in our study, a study by Martin et al., [23] among 24,882 adults undergoing any spine surgery, provides mixed findings over a 11 year follow-up. While patients with spondylolisthesis of any age had a lower incidence of reoperation after stabilization compared with decompression alone (17.1% vs. 28.0%, $p = 0.002$), for all other diagnoses, the incidence of reoperation was higher with stabilization compared with decompression alone (21.5% vs. 18.8%, $p = 0.008$). Supporting our findings that less invasive surgery may be more advantageous for clinical outcomes in senior patients with spinal stenosis, Deyo et al., [24] documented that among 32,152 medicare recipients undergoing spinal stenosis surgery, life-threatening complications occurred in 2.3% of patients with decompression alone compared with in 5.6% among those with additional stabilization. This may in part be explained by the longer operating time associated with more extensive surgery.

Our study has several strengths. We followed a large number of consecutive patients undergoing spinal stenosis surgery from two large hospital centers. Also the same outcome assessment (NASS) was applied in a standardized way prior to surgery, and at 3 or 6 months, as well as 12 months follow-up. Finally, a predefined surgery protocol was used to classify type of surgery in all patients. A limitation of our study is the observational design rather than a random allocation of type of surgery. Also, no data was collected on the prevalence of radiological spondylolisthesis prior to surgery. However, our assumption was that patients who received stabilization in addition to decompression were likely selected based on prevalent instability in addition to spinal stenosis. Another limitation of our study may be the lack of long-term follow-up beyond one year and thereby missing information on patients who required repeat surgery depending on type of surgery.

In summary, based on patient-reported outcomes prior and after surgery, our findings suggest that the timeline of recovery after spinal stenosis surgery is largely complete by 3 to 6 months after surgery, and differs little by type of surgery, independent of baseline symptoms, gender, age and number of comorbidities. However, our data does provide a signal that for improvement in neurological dysfunction and disability less invasive surgery may be more advantageous in patient's age 60 years and older, independent of symptoms prior to surgery.

Conclusion

Among seniors undergoing spinal stenosis surgery, recovery may be largely complete by 3 to 6 months after surgery and differs little by the type of surgery. However, particularly neurological dysfunction and disability may improve more with less invasive surgery. Therefore, when surgery is considered, least invasive procedures may be warranted independent of pre-surgery symptoms.

Contributions of Authors

Authors' roles: Study design: HBF, RT; Study conduct: HBF; Data analysis: PCB; Figures KF; Data interpretation: TD, KF, HBF; Drafting manuscript: TD, KF, HBF; Review of final version: all authors. HBF takes responsibility for the integrity of the data analysis.

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References

1. Kalichman L, Cole R, Kim DH, Li L, Suri P, Guermazi A, et al. Spinal stenosis prevalence and association with symptoms: the Framingham Study. *Spine J*. 2009; 9: 545-550.
2. Ishimoto Y, Yoshimura N, Muraki S, Yamada H, Nagata K, Hashizume H, et al. Prevalence of symptomatic lumbar spinal stenosis and its association with physical performance in a population-based cohort in Japan: the Wakayama Spine Study. *Osteoarthritis Cartilage*. 2012; 20: 1103-110877 .
3. Fraser JF, Huang RC, Girardi FP, Cammisa FP. Pathogenesis, presentation, and treatment of lumbar spinal stenosis associated with coronal or sagittal spinal deformities. *Neurosurg Focus*. 2003; 14: e6.
4. Kim HJ, Chun HJ, Han CD, Moon SH, Kang KT, Kim HS, et al. The risk assessment of a fall in patients with lumbar spinal stenosis. *Spine*. 2011; 36: E588-592.
5. Lee JH, Sung E. The effects of aquatic walking and jogging program on physical function and fall efficacy in patients with degenerative lumbar spinal stenosis. *J Exerc Rehabil*. 2015; 11: 272-275.
6. Chou R, Hashimoto R, Friedly J, Fu R, Bougatsos C, Dana T, et al. Epidural Corticosteroid Injections for Radiculopathy and Spinal Stenosis: A Systematic Review and Meta-analysis. *Ann Intern Med*. 2015; 163: 373-381.
7. Friedly JL, Comstock BA, Turner JA, Heagerty PJ, Deyo RA, Sullivan SD, et al. A randomized trial of epidural glucocorticoid injections for spinal stenosis. *N Engl J Med*. 2014; 371: 11-21.
8. Spinal stenosis. Severity determines treatment plan. *Mayo Clin Health Lett*. 2001; 19: 1-3.

9. Bischoff-Ferrari HA, Lingard EA, Losina E, Baron JA, Roos EM, Phillips CB, et al. Psychosocial and geriatric correlates of functional status after total hip replacement. *Arthritis Rheum.* 2004; 51: 829-835.
10. Sobottke R, Herren C, Siewe J, Mannion AF, Roder C, Aghayev E. Predictors of improvement in quality of life and pain relief in lumbar spinal stenosis relative to patient age: a study based on the Spine Tango registry. *Eur Spine J.* 2015.
11. North American Spine S. Diagnosis and treatment of degenerative spinal stenosis.
12. 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: 181-185.
13. Daltroy LH, Cats-Baril WL, Katz JN, Fossel AH, Liang MH. The North American spine society lumbar spine outcome assessment Instrument: reliability and validity tests. *Spine.* 1996; 21: 741-749.
14. Schaeren S, Bischoff-Ferrari HA, Knupp M, Dick W, Huber JF, Theiler R. A computer touch-screen version of the North American Spine Society outcome assessment instrument for the lumbar spine. *J Bone Joint Surg Br.* 2005; 87: 201-204.
15. Sangha O, Stucki G, Liang MH, Fossel AH, Katz JN. The Self-Administered Comorbidity Questionnaire: a new method to assess comorbidity for clinical and health services research. *Arthritis Rheum.* 2003; 49: 156-163.
16. Micankova Adamova B, Vohanka S, Dusek L, Jarkovsky J, Bednarik J. Prediction of long-term clinical outcome in patients with lumbar spinal stenosis. *Eur Spine J.* 2012; 21: 2611-2619.
17. Galiano K, Obwegeser AA, Gabl MV, Bauer R, Twerdy K. Long-term outcome of laminectomy for spinal stenosis in octogenarians. *Spine (Phila Pa 1976).* 2005; 30: 332-335.
18. Hurri H, Slati P, Soini J, Tallroth K, Alaranta H, Laine T, et al. Lumbar spinal stenosis: assessment of long-term outcome 12 years after operative and conservative treatment. *J Spinal Disord.* 1998; 11: 110-115.
19. 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: 193-198.
20. Bachmeier CJ, March LM, Cross MJ, Lapsley HM, Tribe KL, Courtenay BG, et al. A comparison of outcomes in osteoarthritis patients undergoing total hip and knee replacement surgery. *Osteoarthritis Cartilage.* 2001; 9: 137-146.
21. Martin CR, Gruszczynski AT, Braunsfurth HA, Fallatah SM, O'Neil J, Wai EK. The surgical management of degenerative lumbar spondylolisthesis: a systematic review. *Spine (Phila Pa 1976).* 2007; 32: 1791-1798.
22. Forsth P, Michaelsson K, Sanden B. Does fusion improve the outcome after decompressive surgery for lumbar spinal stenosis?: A two-year follow-up study involving 5390 patients. *Bone Joint J.* 2013; 95-B: 960-965.
23. Martin BI, Mirza SK, Comstock BA, Gray DT, Kreuter W, Deyo RA. Reoperation rates following lumbar spine surgery and the influence of spinal fusion procedures. *Spine (Phila Pa 1976).* 2007; 32: 382-387.
24. Deyo RA, Mirza SK, Martin BI, Kreuter W, Goodman DC, Jarvik JG. Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. *JAMA.* 2010; 303: 1259-1265.