For reprint orders, please contact: reprints@futuremedicine.com

Clinical and neuropsychiatric correlates of lumbar spinal surgery in older adults: results of a pilot study

Jordan F Karp^{*1,2}, Jonathan McGovern³, Megan M Marron¹, Peter Gerszten⁴,
Debra K Weiner^{1,2,5}, David Okonkwo⁴ & Adam S Kanter⁴

Summary points

- In late life, low back pain with and without leg pain is frequently associated with functional disability, psychosocial impairment, poor sleep quality and depression.
- A substantial body of literature has identified comorbidities that predict suboptimal spine surgery outcome, including musculoskeletal conditions, impaired gait, cardiovascular disease, and mood and anxiety disorders.
- We observed that mild cognitive impairment and the presence of widespread pain may be two potential predictors of satisfaction and disability following lumbar surgery. Given the relatively high frequency at which these two conditions occur in older adults in clinical settings, future projects are warranted to understand their potential impact on surgical outcome, functioning and satisfaction.
- Patients with at least a 30% improvement in disability had better physical health-related quality of life and were less likely to report widespread pain before surgery.
- Depression and anxiety both improved at the 3-month follow-up with moderate effect sizes for both.

Aim: To improve selection of older lumbar surgical candidates, we surveyed correlates of functioning and satisfaction with surgery. **Materials & methods:** Prospective sample at lumbar spine surgery clinic. Patients ($n = 48$) were evaluated before surgery and after 3 months. Dependent variables were functioning and surgical satisfaction. **Results:** Baseline variables associated with disability at 3 months included cognitive status and widespread pain. There was clinically significant improvement with moderate effects sizes for anxiety and depression at follow-up. Patients with at least a 30% improvement in disability had better physical health-related quality of life and were less likely to report widespread pain before surgery. **Conclusion:** Although preliminary, two novel potential predictors of lumbar surgery outcome include diminished cognitive functioning and widespread pain. Further study of these variables on post-surgical functioning and satisfaction may improve patient selection.

First draft submitted: 12 October 2015; Accepted for publication: 1 April 2016; Published online: 22 April 2016

¹Department of Psychiatry, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA

²Geriatric Research Education & Clinical Center (GRECC) VA Pittsburgh Healthcare System, Pittsburgh, PA, USA

³Department of Radiology, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA

⁴Department of Neurological Surgery, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA

⁵Department of Medicine, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA

*Author for correspondence: Tel.: +1 412 246 6048; Fax: +1 412 246 6030; karpjf@upmc.edu

KEYWORDS

- aging • complications
- lumbar spine • predictors
- psychiatric • spinal stenosis

In late life, low back pain with and without leg pain is frequently associated with functional disability, psychosocial impairment, poor sleep quality and depression [1]. While low back pain with and without radiculopathy results from a variety of conditions including but not limited to intervertebral disc disease, scoliosis, hip joint arthritis, and vertebral fracture, degenerative lumbar spinal stenosis is among the most common pain generators in older adults and is the most common indication for lumbar spine surgery in adults older than 65 years [2]. Although the SPORT trial suggested that surgical intervention for lumbar spinal stenosis and spondylolisthesis [3] is moderately more effective in treating symptoms than nonoperative management, a substantial number of those who undergo lumbar spine surgery continue to experience persistent pain and disability [4]. Published failure rates range from 30 to 46% for vertebral fusion, 19–25% for microdiscectomy and approximately 35% for lumbar decompressive surgery [4]. Additionally, complications are common in older adults undergoing lumbar spine surgery, with incidences ranging from 6.9 to 35.2% for decompression and 37–80% for fusion [5].

Given this relatively high potential for poor outcome and complications, improving candidate selection for lumbar spine surgery is critical. Currently, selection of candidates for lumbar spinal stenosis surgery is a clinical judgment typically based on symptom severity, functional deficit, physical examination and radiographic evidence of canal stenosis or vertebral displacement. This process is complicated by the fact that as many as 80% of individuals over the age of 70 years have radiographic spinal stenosis [6], of whom a significant proportion are relatively asymptomatic [7]. A substantial body of literature has identified comorbidities that predict suboptimal spine surgery outcome, including musculoskeletal conditions [8], impaired gait [9], cardiovascular disease [10], and mood and anxiety disorders [11]. In addition, nonrestorative sleep [12] and cognitive impairment [13,14] may be associated with more severe pain and a greater likelihood of treatment failure. These neuropsychiatric covariates of treatment outcome have not been systematically assessed in an older cohort of lumbar spine surgery patients.

Despite identification of a number of neuropsychiatric and psychosocial predictors of surgical outcome, evidence is still lacking that selecting patients based on these factors improves functional

outcome and satisfaction with surgery [11]. The goal of this pilot project was to collect neuropsychiatric and psychosocial data prior to and 3 months after surgery to estimate relationships between these presurgical variables and outcomes of great significance to patients – back-related disability and satisfaction with surgery.

Materials & methods**• Patient population**

Patients aged 60 years or older presenting to an academic neurological surgery clinic for evaluation for low back pain with or without radiculopathy were recruited immediately after the decision to proceed with surgery. The selection of surgical candidates was based on identification of neurological signs and symptoms which, in conjunction with radiographic findings, indicated degenerative spinal stenosis and/or spondylolisthesis as the putative primary pain generator. Patients provided written informed consent to participate, and the study was approved and monitored by the institutional review board at the University of Pittsburgh.

• Initial assessment

The baseline assessment was administered at the time of the initial surgical consultation. Measures assessing low back pain-related disability included the Roland Morris Disability Questionnaire (RMDQ) [15] on which a higher score indicates greater low-back pain-related disability, and a modified Swiss Spinal Stenosis Questionnaire (SSSQ; satisfaction subscale omitted) [16] on which a higher score indicates more severe spinal stenosis symptoms. Although the RMDQ does not capture information about radiculopathy or leg symptoms, the items reflect many of the functional impairments reported by our patients, supporting its use with this population. The MOS-12, comprised of both a Physical Health Component (PHC) and Mental Health Component, is a measure on which a higher score indicates better quality of life [17]. Gait speed was assessed by recording the faster of two 4-meter trials in which subjects were asked to walk at their usual pace. Widespread pain was assessed with the question, ‘do you often feel like you hurt all over?’, on which a ‘yes’ response suggests a high likelihood of fibromyalgia [18,19]. Psychiatric comorbidity was assessed with the Patient Health Questionnaire (PHQ-9) [20] and the Generalized Anxiety Disorder 7-item scale (GAD-7) [21]. Sleep quality was assessed by

asking Item 6 of the Pittsburgh Sleep Quality Index (PSQI): ‘During the past month, how would you rate your sleep quality overall?’ on which a higher score indicates worse sleep quality [22]. Medical comorbidity was rated with the Cumulative Illness Rating Scale for Geriatrics (CIRS-G) [23] and by summing the total number of analgesic and nonanalgesic medications [24]. Cognitive status was assessed with the Mini-Mental State Examination (MMSE) [25].

• Outcome measures

Outcome assessments were collected 3 months postoperatively. 3-month follow-up was selected as 3 months is usually the last visit a patient has with their surgeon following surgery for lumbar spinal stenosis. Payment for follow-ups up to 3 months is bundled into the cost of the surgery. Our spine surgical practice is located in a tertiary referral center with a large geographic catchment area. Because of the financial cost and challenges of long-distance travel for many older adults, it is our center’s practice for the last clinic visit to be at 3 months if no further neurosurgical care is warranted. The primary outcomes were the RMDQ and the complete SSSQ, which includes a subscale assessing satisfaction with treatment (SSSQ_{satisfaction}; higher score means more satisfied). We also readministered the MOS-12, PHQ-9, GAD-7, PSQI-Item 6, and reassessed total analgesic and nonanalgesic medication use.

• Statistical analysis

Descriptive statistics (mean [$\pm$ standard deviation] or % [n]) were used to describe baseline and post-operative demographic and clinical characteristics. Distributions were examined prior to analyses and transformed if non-normal. If distributions did not improve with a transformation then nonparametric tests were used. We tested changes in variables that were measured at baseline and at 3-month follow-up using a paired t-test for continuous measures and a chi-square test or a Fisher’s exact test for categorical measures. Cohen’s D and phi coefficient were used to describe the effect size of continuous and categorical measures, respectively. We used Pearson correlations to examine relationships between preoperative variables and percentage improvement in RMDQ. Preoperative variables that were correlated ($p \leq 0.10$) with percentage improvement in RMDQ were considered for multivariable linear regression models. Stepwise regression was used to obtain a model predicting

percentage improvement in RMDQ. We used both forward and backward stepwise in order to determine that the final model reported was stable. We used the same process to obtain a model for postoperative SSSQ_{satisfaction}. Pearson correlations were also used to examine the relationship between post-operative variables and percentage improvement in RMDQ and SSSQ_{satisfaction}. Because this project is hypothesis-generating and not confirmatory, we did not correct for multiple comparisons.

To further describe the subset of subjects who had clinically meaningful reduction in low-back pain-related disability, descriptive statistics were used to characterize those with $\geq 30\%$ improvement on RMDQ and those with $< 30\%$ improvement. A 30% reduction in RMDQ has been shown to be the minimal clinically important improvement [26]. The groups were compared using a t-test or Wilcoxon test for continuous measures and a Chi-squared test or Fisher’s exact test for categorical measures.

Results

• Subject recruitment

A prospective cohort of 61 patients aged 60 years or older who were scheduled to have elective lumbar spine surgery for spinal stenosis with or without spondylolisthesis (both with and without radiculopathy) were recruited. This was a convenience sample from the lumbar spine surgery clinics of P Gerszten, D Okonkwo and AS Kanter. No approached patients refused to participate. Four patients completed baseline assessments and underwent surgery, but withdrew from the study before completing the 3-month assessment; eight patients completed the baseline assessment but were removed from the study after electing to cancel surgery; and one patient died 2 months postoperatively as a result of pneumonia. The remaining 48 patients were included in the study that had at least one post-surgery measure.

• Surgery & complications

The surgeries performed on this cohort were overall of a similar impact, namely an open decompressive laminectomy with or without instrumentation. None of the surgeries were performed in a ‘minimally invasive fashion’. Therefore, we expected all of the patients to have a similar recovery and comparable outcome measures at the 3-month follow-up time point. It is our experience that at 3 months, patients should have

similar recoveries of function whether or not they received spinal fusion. The procedures included instrumented fusion (62.5%; *n* = 30), noninstrumented fusion (25%; *n* = 12), dynamic stabilization (8.3%; *n* = 4) and spinal decompression including microdiscectomy and laminectomy (4.2%; *n* = 2). The only intraoperative complications were unintentional dural tears (*n* = 5), which were closed primarily. One of these patients developed a cerebrospinal leak postoperatively, requiring revision of durotomy closure. A second patient developed a seroma in the postoperative period, requiring evacuation. Several patients developed complications within the 3-month postoperative period, including: hematoma requiring evacuation (*n* = 1), wound dehiscence requiring revision (*n* = 1), atrial fibrillation (*n* = 2), delirium (*n* = 2), wound infection requiring debridement (*n* = 2), superficial wound infection requiring antibiotics alone (*n* = 1), deep vein thrombosis (*n* = 2), and pneumonia (*n* = 3). One patient who developed pneumonia died 2 months postoperatively. Overall, 15 patients (31.3%) experienced at least one intra- or post-operative complication in the 3 months following surgery.

• Baseline & postoperative assessments

Baseline measures are summarized in Table 1. Subjects were predominantly Caucasian

(93.8%) and male (54.2%) with a mean age of 71.4 (±8.0) years. They completed an average of 14.4 (±2.3) years of education and more than a quarter of the sample were employed at least part time. Subjects were being treated by a physician for approximately three medical conditions (mean CIRS-G total and count = 5.96 [±2.5] and 2.98 [±1.3], respectively) and 20.8% reported the presence of widespread pain. While we did not adjust the MMSE scores as a function of educational level, given the relatively high educational level of the sample, the average MMSE score of 26.0 (±3.0) [27] may be consistent with some impairment in cognitive functioning.

Variables that were assessed in clinic at baseline and three months post-surgery are described in Table 2. Overall, there was an improvement in sleep quality from baseline to 3-month follow-up. Average GAD-7 and PHQ-9 scores at baseline were suggestive of mild anxiety and depression, respectively [28,29]. There was improvement in both the GAD-7 and PHQ-9 scores at the 3-month follow-up with moderate effect sizes for both (GAD-7: -0.69, PHQ-9: -0.44). The RMDQ at baseline (mean: 14.9 [±5.6]) was similar in severity to another study of back-related disability among patients treated at a hospital clinic for radiculopathy [30]. The average RMDQ at 3 months was 10.6 (±7.1), with an estimated effect size for this change of -0.67 and the percentage improvement for the RMDQ of 31.9 (±42.5). There was neither a clinically or statistically significant reduction in the use of ambulatory assistive devices at 3-month follow-up.

There was clinically meaningful improvement for the SSSQ total score (omitting the satisfaction subscale) following surgery (presurgery: mean = 35.3 (±7.1); post-surgery: mean = 26.8 (±8.9); effect size = -1.1). Clinically significant improvements were also observed for both the RAND-12 physical health component score (presurgery: mean = 28.0 (±6.5); post-surgery: mean = 34.8 (±10.8); effect size = 0.76) and mental health component score (presurgery: mean = 40.1 (±11.1); post-surgery: mean = 45.1 (±12.7); effect size = 0.42). The average number of prescribed medications decreased from 7.29 (±4.2) to 5.56 (±3.1); effect size = -0.47. There was also a statistically and clinically significant decrease in the use of over-the-counter medications (Table 2). However, there was no statistical or clinically significant change in opioid use at

Table 1. Baseline demographic and clinical measures (n = 48).	
Variable	Mean (SD) or % (n) [n if reduced sample]
Age (years)	71.4 (8.0)
Education (years)	14.4 (2.3) [n = 47]
Female (%)	45.8% [n = 22]
Caucasian (%)	93.8% [n = 45]
Married (%)	56.3% [n = 27]
Employed (full/part-time) (%)	27.1% [n = 13]
CIRS-G:	
– Total	5.96 (2.5)
– Count	2.98 (1.3)
MMSE (0–30 scale)	26.0 (3.0) [n = 44]
4-meter gait speed (m/s)	0.80 (0.22) [n = 43]
Endorsing widespread pain (%)	20.8% [n = 10]
Alcohol:	
– Never drink (%)	67.4% [n = 31/46]
– 1–7 drinks/week (%)	30.4% [n = 14/46]
– 8–21 drinks/week (%)	2.17% [n = 1/46]
Smoking (responded):	
– ‘Yes, I smoke’ (%)	16.7% [n = 8]
– ‘Yes, I use smokeless tobacco’ (%)	2.08% [n = 1]
– ‘No, I do not smoke’ (%)	81.3% [n = 39]

CIRS-G: Cumulative Illness Rating Scale – Geriatrics; MMSE: Mini-Mental State Examination.

Table 2. Comparison between baseline and 3 months post-operative clinical measures (n = 48).

Variable	Baseline, mean (SD) or % (n) [n or denominator listed if reduced sample]	3 months post-operative, mean (SD) or % (n) [n or denominator listed if reduced sample]	Statistical test comparing baseline and 3 months after surgery	Effect size
PSQI-Item 6 (theoretical range: 0–3, higher is worse sleep)	1.52 (1.0)	1.30 (0.89) [n = 46]	t(45) = 2.4; p = 0.02	-0.23
GAD-7 (theoretical range: 0–21, higher more severe)	6.25 (6.0)	2.65 (4.4)	t(47) = 5.2; p < 0.0001	-0.69
RMDQ (theoretical range 0–24, higher more severe)	14.9 (5.6)	10.6 (7.1) [n = 46]	t(45) = 4.9; p < 0.0001	-0.67
Percentage improvement in RMDQ	31.9 (42.5) [n = 46]		–	–
PHQ-9 [†] (theoretical range 0–27, higher more severe)	8.33 (6.4) [n = 45]	5.60 (6.0) [n = 47]	t(43) = 4.2; p = 0.0001	-0.44
RAND-12:				
– Physical Health Component (theoretical range 0–100, higher is better functioning)	28.0 (6.5) [n = 41]	34.8 (10.8) [n = 46]	t(39) = -5.2; p < 0.0001	0.76
– Mental Health Component (theoretical range 0–100, higher is better functioning)	40.1 (11.1) [n = 41]	45.1 (12.7) [n = 44]	t(38) = -2.9; p = 0.007	0.42
Spinal Stenosis Questionnaire [‡] (theoretical range: 12–55, higher is more pain and disability)	35.3 (7.1) [n = 46]	26.8 (8.9) [n = 46]	t(43) = 7.6; p < 0.0001	-1.1
Satisfaction subscale (theoretical range: 6–24, higher means more satisfaction)	–	18.5 (5.3) [n = 46]	–	–
Number of prescribed medications	7.29 (4.2)	5.56 (3.1)	t(47) = 3.7; p = 0.0005	-0.47
Antidepressants:			Fisher's Exact p = 0.30	0.15
– Never (%)	54.2% [n = 26]	66.7% [n = 32]		
– Intermittent (%)	2.08% [n = 1]	0		
– Daily (%)	43.8% [n = 21]	33.3% [n = 16]		
Ambulatory assistive device (%)	28.6% [n = 10/35]	20.8% [n = 10]	Chi-sq(1) = 0.66; p = 0.42	-0.09
Involved in a lawsuit (%)	2.08% [n = 1]	6.3% [n = 3]	Fisher's exact p = 0.62	0.10
Muscle relaxers:			Chi-sq(2) = 6.0; p = 0.05	0.25
– Never (%)	87.5% [n = 42]	66.7% [n = 32]		
– Intermittent (%)	6.25% [n = 3]	18.8% [n = 9]		
– Daily (%)	6.25% [n = 3]	14.6% [n = 7]		
Opioid analgesics:			Chi-sq(2) = 0.84; p = 0.66	0.09
– Never (%)	45.8% [n = 22]	54.2% [n = 26]		
– Intermittent (%)	22.9% [n = 11]	16.7% [n = 8]		
– Daily (%)	31.3% [n = 15]	29.2% [n = 14]		
Over the counter medications:			Chi-sq(2) = 10.2; p = 0.006	0.33
– Never (%)	21.3% [n = 10/47]	43.8% [n = 21]		
– Intermittent (%)	10.6% [n = 5/47]	20.8% [n = 10]		
– Daily (%)	68.1% [n = 32/47]	35.4% [n = 17]		

[†]Log(X) transformation used for analyses. Means and standard deviations reported in original units.

[‡]Spinal Stenosis Questionnaire Score Minus the Satisfaction Subscale.

PSQI Item 6: Pittsburgh Sleep Quality Index item assessing: "During the past month, how would you rate your sleep quality overall?"; RMDQ: Roland Morris Disability Questionnaire.

3-month follow-up, and there was a trend for increased use of muscle relaxants at 3-month follow-up (Table 2).

• Baseline correlations with surgical outcome

Pearson correlations of baseline variables with the primary outcome measures, percentage

improvement in RMDQ score and SSSQ_{satisfaction}, are presented in Table 3. Being employed and general cognitive functioning as assessed with the MMSE were significantly correlated with a greater percentage improvement on the RMDQ 3 months following surgery. Worse sleep quality on the PSQI-item 6, greater depressive and anxiety symptoms on the PHQ-9, and the presence

Table 3. Pearson correlations of SSSQ_{satisfaction} and Roland Morris Disability Questionnaire with baseline variables.

Variable	Pearson correlation coefficients (p-value) [n if reduced sample]	
	% improvement in RMDQ (n = 46 [†])	Spinal Stenosis Questionnaire Satisfaction Subscale (n = 46 [†])
Age	-0.059 (p = 0.70)	-0.296 (p = 0.05)
Education	0.209 (p = 0.17) [n = 45]	0.155 (p = 0.31) [n = 45]
Female	-0.030 (p = 0.84)	0.158 (p = 0.29)
Married	0.025 (p = 0.87)	-0.125 (p = 0.41)
Employed (full/part-time)	0.322 (p = 0.03)	0.477 (p = 0.008)
CIRS-G:		
– Total	-0.179 (p = 0.26)	-0.259 (p = 0.08)
– Count	-0.170 (p = 0.26)	-0.259 (p = 0.08)
MMSE	0.399 (p = 0.008) [n = 43]	0.400 (p = 0.008) [n = 43]
PSQI-Item 6 (sleep quality)	-0.393 (p = 0.007)	-0.096 (p = 0.53)
4-meter gait speed	0.004 (p = 0.98) [n = 41]	0.119 (p = 0.46) [n = 41]
GAD-7 (anxiety)	-0.298 (p = 0.04)	0.013 (p = 0.93)
PHQ-9 [‡] (depression)	-0.323 (p = 0.03) [n = 43]	-0.100 (p = 0.52) [n = 43]
Rand-12:		
– Physical health component	0.215 (p = 0.18) [n = 40]	0.294 (p = 0.07) [n = 39]
– Mental health component	0.118 (p = 0.47) [n = 40]	0.084 (p = 0.61) [n = 39]
Number of prescribed medications	-0.137 (p = 0.36)	-0.089 (p = 0.56)
Endorsing widespread pain at baseline	-0.304 (p = 0.04)	-0.045 (p = 0.77)

[†]Two subjects were missing one of the outcomes.

[‡]Log transformation.

GAD-7: Generalized Anxiety Disorder 7-item scale; MMSE: Mini-Mental State Examination; PHQ-9: Patient Health Questionnaire 9-item scale; PSQI Item 6: Pittsburgh Sleep Quality Index item assessing: "During the past month, how would you rate your sleep quality overall?"; RMDQ: Roland Morris Disability Questionnaire; SSSQ_{satisfaction}: Satisfaction subscale of the Swiss spinal stenosis questionnaire.

of widespread pain at baseline were all associated with less percentage improvement measured with the RMDQ 3 months postoperatively. Older age was significantly correlated with less satisfaction with surgical outcome, while being employed and higher MMSE score were all significantly correlated with greater satisfaction with surgery.

• Linear regression models

Variables that were considered for inclusion in a multivariable regression model for percentage improvement in RMDQ ($p \leq 0.10$) included employment, MMSE, PSQI-item 6, GAD-7, PHQ-9 and widespread pain. When considering multicollinearity and performing stepwise regression, being employed (beta = 31.4 [standard error = 11.9]; $p = 0.01$), better sleep as measured with the PSQI-Item 6 (-14.7 [± 5.5]; $p = 0.01$), and not having widespread pain (-27.9 [± 13.7]; $p = 0.05$) remained associated with percentage improvement in RMDQ ($F[3, 42] = 6.7$; $p = 0.0008$; $R^2 = 0.32$).

Variables that were considered for the multivariable regression model for SSSQ_{satisfaction} ($p \leq 0.10$) included age, employment, number of medical conditions, MMSE and RAND-12 PHC. MMSE (0.43 [± 0.22]; $p = 0.06$) and being

employed (4.7 (± 1.5); $p = 0.003$) remained in the model predicting SSSQ_{satisfaction} ($F[2, 40] = 10.0$; $p = 0.0003$; $R^2 = 0.33$). While MMSE was not statistically significant, the stability of the model improved when it was retained as a predictor.

• Postoperative measures correlated with surgical outcome

Pearson correlations of postoperative measures with percentage improvement in RMDQ score and SSSQ_{satisfaction} are presented in Table 4. Worse sleep quality as measured by item 6 of the PSQI, greater anxiety on the GAD-7, greater depressive symptoms on the PHQ-9 and less improvement in symptoms specific for spinal stenosis were all significantly correlated with a smaller percentage improvement on the RMDQ as well as a lesser degree of satisfaction with surgical outcome. Higher scores on the RAND-12 PHC and Mental Health Component were associated with both a greater improvement on the RMDQ and greater satisfaction with surgery.

• Correlates of at least 30% improvement on RMDQ

There were 22 subjects who had an improvement in RMDQ that was at least 30% and 24 subjects

who had an improvement in RMDQ less than 30%. Subjects with at least a 30% improvement in RMDQ had better physical health quality of life (assessed with the RAND-12 PHC; $t[38] = -2.2$; $p = 0.03$) and less widespread pain (Fisher's Exact Test, $p = 0.02$).

Discussion

This hypothesis-generating pilot study examined clinical and neuropsychiatric comorbidities as predictors of improvement of disability and satisfaction with lumbar spine surgery in a prospective cohort of 48 older adults treated at a tertiary medical center neurological surgery clinic. At baseline, subjects were mildly depressed and anxious, exhibited mildly diminished cognitive functioning, and a significant proportion endorsed widespread pain. Nearly every assessment measured 3 months after surgery indicated improvement from baseline. Subjects reported improved sleep quality, less anxiety and depression, better physical health and mental health quality of life, fewer spinal stenosis symptoms, less low-back pain-related disability, and were taking fewer prescription and over the counter medications. They continued to use opioid medications at about the same rate postoperatively as they did preoperatively, and there was no change in the use of ambulatory assistive devices. The use of muscle relaxers increased 3 months after surgery. These observations about medication use were not expected. Although the number of prescribed and over the counter medications decreased, it is troubling that 3 months after surgery there were not significant decreases in the use of opioid analgesics and a trend for increase in the use of muscle relaxants.

Several baseline variables were found to be significantly associated with functional improvement and satisfaction with surgery 3 months postoperatively. Better cognitive function, as measured by the MMSE, was associated with both greater functional improvement and higher satisfaction following surgery. While the MMSE is only a screen for cognitive impairment, is susceptible to both ceiling and floor effects, and does not relay information about specific domains of cognitive functioning such as memory, executive functioning or information processing speed, to our knowledge, this is the first study to specifically assess cognitive status in older adults as a correlate of outcome for lumbar spinal stenosis surgery. The association of employment with both greater improvement in functioning and satisfaction with surgery may reflect that employment serves as a multidimensional proxy for an individual's general state of health, being influenced by factors such as age, medical comorbidity, cognitive status and functional capacity. Similarly, greater physical health-related quality of life prior to surgery was marginally associated with increased satisfaction. Conversely, older patients were less likely to be satisfied with surgical outcome. The presence of widespread pain also predicted less functional improvement. This is consistent with research describing that those with low back pain as a component of chronic widespread pain had more severe pain for a greater length of time, leading to greater functional disability [31].

Psychiatric symptoms at baseline were also correlated with surgical outcome at 3 months. Greater burdens of depression and anxiety were associated with less functional improvement. This is consistent with a large body of literature

Table 4. Pearson correlations of SSSQ_{satisfaction} and percentage improvement on Roland Morris Disability Questionnaire with 3-month postoperative measures.

Variable	Pearson correlation coefficients (p-value) [n if reduced sample]	
	% improvement in RMDQ (n = 46 [†])	SSSQ _{satisfaction} at T2 (n = 46 [†])
Overall sleep quality for past month at T2	-0.621 (p < 0.0001) [n = 45]	-0.382 (p = 0.01) [n = 44]
GAD-7 (anxiety) at T2	-0.606 (p < 0.0001)	-0.330 (p = 0.03)
PHQ-9 [‡] (depression) at T2	-0.636 (p < 0.0001)	-0.517 (p = 0.0003) [n = 45]
Rand-12 Physical Health Component at T2	0.693 (p < 0.0001) [n = 44]	0.493 (p = 0.0009) [n = 44]
Rand-12 Mental Health Component at T2	0.632 (p < 0.0001) [n = 43]	0.493 (p = 0.0009) [n = 42]
Spinal Stenosis Questionnaire Difference [§] (T2 - T1)	-0.508 (p = 0.0005) [n = 43]	-0.547 (p = 0.0002) [n = 42]

[†]Two subjects were missing one of the outcomes.

[‡]Log transformation.

[§]Spinal stenosis questionnaire score minus the satisfaction subscale.

GAD-7: Generalized anxiety disorder 7-item scale; PHQ-9: Patient health questionnaire 9-item scale; RMDQ: Roland Morris Disability Questionnaire; SSSQ_{satisfaction}: Satisfaction subscale of the Swiss spinal stenosis questionnaire.

suggesting that baseline mood and anxiety disorders prognosticate poor surgical outcome [11], with even mild depressive symptoms predicting poor functional outcomes 5 years after surgery [32]. In addition, self-reported poor sleep quality was correlated with less improvement on the RMDQ. This relationship may be explained by the fact that pain has a bidirectional relationship with sleep quality, in particular insomnia [33], and that poor sleep quality is a subsequent risk factor for decreased pain tolerance [34].

We were surprised to discover a lack of correlation between gait speed and either functional improvement or satisfaction, since self-reported better walking capacity has been described as a positive predictor of satisfaction with lumbar spine surgery [35]. We included gait speed as a neuropsychiatric correlate of functioning and satisfaction with surgery since gait speed reflects overall physical functioning [36] as well as cognitive status [37–39]. The mean gait speed of 0.80 m/s (SD = 0.22) was slower than the accepted comfortable gait speed for healthy community-dwelling women aged between 70 and 79 years of 1.13 m/s and for men 1.26 m/s [40]. For women and men aged 80–99 years the values are 0.94 m/s and 0.97 m/s, respectively [40]. A recent systematic review suggested that a gait speed of 0.80 m/s is a predictor of poor clinical outcomes and 0.60 m/s as a threshold to predict further functional decline in those older adults already impaired [38]. The average gait speed we observed (0.80 m/s) suggests that these patients may be at risk of poor clinical outcomes and may be supported by our observation that while there was clinically significant improvement in functioning and many were satisfied with the surgery, there was no change in the use of opioids or reduction of use of ambulatory assistive devices over the course of 3 months. A possible reason why gait speed was not a significant correlate of either function or satisfaction could be because we did not ask participants to walk at their fastest possible gait. This more provocative test of functioning may have revealed a statistically and clinically significant association with our outcomes of interest. In future work with these patients, we plan to assess both ‘average/comfortable’ gait speed and ‘fastest’ gait speed.

The linear regression models found that being employed, having better sleep, and less widespread pain was associated with improvement

of functional disability, and being employed was associated with greater satisfaction after surgery. Although these variables all make good clinical sense, given the limited sample size, these models should be interpreted with caution.

Although this project was not focused on surgically-related complications, we felt it was important to include the rates of complications, since cognitive impairment [41], depression and anxiety [42], and age may all be risks for an increased incidence of complications. Nearly a third of our sample experienced at least one complication, either intraoperatively, or in the 3-month postoperative period. While the majority of these adverse events were relatively minor and easily managed, such as incidental durotomies and superficial infections, several patients required a return to the operating room to manage infection or for drainage of fluid collections, with one patient dying from pneumonia contracted in the recovery period. While this incidence of complications in our sample was consistent with that reported in the literature [5], this serves as a reminder that lumbar surgery in even relatively healthy older adults is not without risk. We plan to pursue a larger, appropriately powered longitudinal study (guided by the results of this pilot project), in which we explore which baseline characteristics predict intra- and postoperative complications, and if complications of varying type and severity affect functioning and satisfaction outcomes.

Conclusion

The goal of this study was to detect potential covariates of surgical outcome in older adults undergoing surgery for lumbar spinal stenosis that may serve as targets for future intervention studies. Despite being limited by a small sample size, lack of ethnic diversity, inclusion of subjects with both lumbar stenosis and spondylolisthesis, recruitment from only one urban, academic neurological surgery clinic, and only 3 months of follow-up, several interesting potential predictors emerged. Greater baseline functioning, as measured by being employed and a smaller burden of medical and psychological comorbidities, may predict better surgical outcome at 3 months after surgery. Two potential predictors that to our knowledge have not been studied in relation to satisfaction with and disability following lumbar surgery include diminished cognitive function and the presence of widespread pain. Given the relatively high frequency at which

these two conditions occur in older adults in clinical settings, future projects are warranted to understand their potential impact on surgical outcome, functioning and satisfaction.

Financial & competing interests disclosure

JF Karp has received medication supplies from Pfizer and Invidior for investigator initiated trials. This study was supported in part by NIH grant number AG033575. The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter

or materials discussed in the manuscript apart from those disclosed.

No writing assistance was utilized in the production of this manuscript.

Ethical conduct of research

The authors state that they have obtained appropriate institutional review board approval or have followed the principles outlined in the Declaration of Helsinki for all human or animal experimental investigations. In addition, for investigations involving human subjects, informed consent has been obtained from the participants involved.

References

Papers of special note have been highlighted as:
• of interest; •• of considerable interest

- 1 Ferrell BA. Pain management in elderly people. *J. Am. Geriatr. Soc.* 39(1), 64–73 (1991).
- 2 Weinstein JN, Lurie JD, Tosteson TD *et al.* Surgical versus nonsurgical treatment for lumbar degenerative spondylolisthesis. *N. Engl. J. Med.* 356(22), 2257–2270 (2007).
- 3 Pearson A, Lurie J, Tosteson T, Zhao W, Abdu W, Weinstein JN. Who should have surgery for spinal stenosis? Treatment effect predictors in SPORT. *Spine (Phila Pa 1976)* 37(21), 1791–1802 (2012).
- 4 Chan CW, Peng P. Failed back surgery syndrome. *Pain Med.* 12(4), 577–606 (2011).
- 5 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.* 56(7), 1318–1327 (2008).
- 6 Sasaki K. Magnetic resonance imaging findings of the lumbar root pathway in patients over 50 years old. *Eur. Spine J.* 4(2), 71–76 (1995).
- 7 Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. *J. Bone Joint Surg. Am.* 72(3), 403–408 (1990).
- 8 Zheng F, Sandhu HS, Cammisa FP Jr, Girardi FP, Khan SN. Predictors of functional outcome in elderly patients undergoing posterior lumbar spine surgery. *J. Spinal Disord.* 14(6), 518–521 (2001).
- Predictors of unfavorable outcome after surgery include coexistence of other bone and joint degenerative disorders, history of heart disease and previous lumbar surgery.
- 9 Jonsson B, Annertz M, Sjöberg C, Stromqvist B. A prospective and consecutive study of surgically treated lumbar spinal stenosis. Part II: five-year follow-up by an independent observer. *Spine (Phila. Pa 1976)* 22(24), 2938–2944 (1997).
- 10 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)* 24(21), 2229–2233 (1999).
- 11 Celestin J, Edwards RR, Jamison RN. Pretreatment psychosocial variables as predictors of outcomes following lumbar surgery and spinal cord stimulation: a systematic review and literature synthesis. *Pain Med.* 10(4), 639–653 (2009).
- 12 Casten RJ, Parmelee PA, Kleban MH, Lawton MP, Katz IR. The relationships among anxiety, depression, and pain in a geriatric institutionalized sample. *Pain* 61(2), 271–276 (1995).
- 13 Karp JF, Reynolds CF 3rd, Butters MA *et al.* The relationship between pain and mental flexibility in older adult pain clinic patients. *Pain Med.* 7(5), 444–452 (2006).
- 14 Weiner DK, Rudy TE, Morrow L, Slaboda J, Lieber S. The relationship between pain, neuropsychological performance, and physical function in community-dwelling older adults with chronic low back pain. *Pain Med.* 7(1), 60–70 (2006).
- In older adults with chronic low back pain, pain severity is inversely correlated with neurocognitive performance, and neurocognitive performance mediates the relationship between pain and physical performance.
- 15 Roland M, Morris R. A study of the natural history of back pain. Part I: development of a reliable and sensitive measure of disability in low-back pain. *Spine (Phila. Pa 1976)* 8(2), 141–144 (1983).
- 16 Stucki G, Daltroy L, Liang MH, Lipson SJ, Fossel AH, Katz JN. Measurement properties of a self-administered outcome measure in lumbar spinal stenosis. *Spine (Phila. Pa 1976)* 21(7), 796–803 (1996).
- 17 Stewart AL, Hays RD, Ware JE Jr. The MOS short-form general health survey. Reliability and validity in a patient population. *Med. Care* 26(7), 724–735 (1988).
- 18 Wolfe F, Smythe HA, Yunus MB *et al.* The American College of Rheumatology 1990 Criteria for the Classification of Fibromyalgia. Report of the Multicenter Criteria Committee. *Arthritis Rheum.* 33(2), 160–172 (1990).
- 19 Jochum JR, Begley AE, Dew MA, Weiner DK, Karp JF. Advancing the screening of fibromyalgia in late-life depression: practical implications for psychiatric settings. *Int. Psychogeriatr.* 27(9), 1513–1521 (2015).
- The simple screener, ‘Do you often feel like you hurt all over?’ may be a sensitive screener for fibromyalgia among older adults with low back pain and depression.
- 20 Spitzer RL, Kroenke K, Williams JB. Validation and utility of a self-report version of PRIME-MD: the PHQ primary care study. Primary care evaluation of mental disorders. Patient health questionnaire. *JAMA* 282(18), 1737–1744 (1999).
- 21 Spitzer RL, Kroenke K, Williams JB, Lowe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch. Intern. Med.* 166(10), 1092–1097 (2006).
- 22 Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res.* 28(2), 193–213 (1989).
- 23 Miller MD, Paradis CF, Houck PR *et al.* Rating chronic medical illness burden in geropsychiatric practice and research: application of the Cumulative Illness Rating Scale. *Psychiatry Res.* 41(3), 237–248 (1992).

- 24 Mulsant BH, Ganguli M, Seaberg EC. The relationship between self-rated health and depressive symptoms in an epidemiological sample of community-dwelling older adults. *J. Am. Geriatr. Soc.* 45(8), 954–958 (1997).
- 25 Folstein MF, Folstein SE, McHugh PR. “Mini-mental state”. A practical method for grading the cognitive state of patients for the clinician. *J. Psychiatr. Res.* 12(3), 189–198 (1975).
- 26 Jordan K, Dunn KM, Lewis M, Croft P. A minimal clinically important difference was derived for the Roland-Morris Disability Questionnaire for low back pain. *J. Clin. Epidemiol.* 59(1), 45–52 (2006).
- 27 Crum RM, Anthony JC, Bassett SS, Folstein MF. Population-based norms for the Mini-Mental State Examination by age and educational level.[see comment]. *JAMA* 269(18), 2386–2391 (1993).
- 28 Kroenke K, Spitzer R, Williams J, Monahan P, Lowe B. Anxiety disorders in primary care: prevalence, impairment, comorbidity, and detection. *Ann. Intern. Med.* 146(5), 317–325 (2007).
- 29 Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J. Gen. Intern. Med.* 16(9), 606–613 (2001).
- 30 Leclaire R, Blier F, Fortin L, Proulx R. A cross-sectional study comparing the Oswestry and Roland-Morris Functional Disability scales in two populations of patients with low back pain of different levels of severity. *Spine (Phila. Pa 1976)* 22(1), 68–71 (1997).
- 31 Natvig B, Bruusgaard D, Eriksen W. Localized low back pain and low back pain as part of widespread musculoskeletal pain: two different disorders? A cross-sectional population study. *J. Rehabil. Med.* 33(1), 21–25 (2001).
- 32 Pakarinen M, Vanhanen S, Sinikallio S *et al.* Depressive burden is associated with a poorer surgical outcome among lumbar spinal stenosis patients: a 5 year follow-up study. *Spine J.* 14(10), 2392–2396 (2004).
- 33 Fishbain DA, Cole B, Lewis JE, Gao J. What is the evidence for chronic pain being etiologically associated with the DSM-IV category of sleep disorder due to a general medical condition? A structured evidence-based review. *Pain Med.* 11(2), 158–179 (2010).
- 34 Smith MT, Wickwire EM, Grace EG *et al.* Sleep disorders and their association with laboratory pain sensitivity in temporomandibular joint disorder. *Sleep* 32(6), 779–790 (2009).
- 35 Aalto TJ, Malmivaara A, Kovacs F *et al.* Preoperative predictors for postoperative clinical outcome in lumbar spinal stenosis: systematic review. *Spine (Phila. Pa 1976)* 31(18), E648–663 (2006).
- **Although the predictive values may be outcome specific, depression, cardiovascular comorbidity, disorders affecting walking ability, and scoliosis predicts subjective outcome after lumbar spinal stenosis surgery in older adults.**
- 36 Purser JL, Weinberger M, Cohen HJ *et al.* Walking speed predicts health status and hospital costs for frail elderly male veterans. *J. Rehabil. Res. Dev.* 42(4), 535–546 (2005).
- 37 Fitzpatrick AL, Buchanan CK, Nahin RL *et al.* Associations of gait speed and other measures of physical function with cognition in a healthy cohort of elderly persons. *J. Gerontol. A Biol. Sci. Med. Sci.* 62(11), 1244–1251 (2007).
- 38 Abellan Van Kan G, Rolland Y, Andrieu S *et al.* Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people an International Academy on Nutrition and Aging (IANA) Task Force. *J. Nutr. Health Aging* 13(10), 881–889 (2009).
- 39 Graham JE, Ostir GV, Fisher SR, Ottenbacher KJ. Assessing walking speed in clinical research: a systematic review. *J. Eval. Clin. Pract.* 14(4), 552–562 (2008).
- 40 Peel NM, Kuys SS, Klein K. Gait speed as a measure in geriatric assessment in clinical settings: a systematic review. *J. Gerontol. A Biol. Sci. Med. Sci.* 68(1), 39–46 (2013).
- 41 Robinson TN, Wu DS, Pointer L, Dunn CL, Cleveland JC Jr, Moss M. Simple frailty score predicts postoperative complications across surgical specialties. *Am. J. Surg.* 206(4), 544–550 (2013).
- 42 Tully PJ, Baker RA, Knight JL. Anxiety and depression as risk factors for mortality after coronary artery bypass surgery. *J. Psychosom. Res.* 64(3), 285–290 (2008).