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ORIGINAL ARTICLE

The association between lumbar lordosis preoperatively and changes in PROMs for lumbar spinal stenosis patients 2 years after spinal surgery: radiological and clinical results from the NORDSTEN-spinal stenosis trial

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Abstract

Background Patients with lumbar spinal stenosis (LSS) sometimes have lower lumbar lordosis (LL), and the incidence of LSS correlates closely with the loss of LL. The few studies that have evaluated the association between LL and clinical outcomes after non-instrumented surgery for LSS show conflicting results. This study investigates the association between preoperative LL and changes in PROMs 2 years after decompressive surgery.

Method This prospective cohort study obtained preoperative and postoperative data for 401 patients from the multicenter randomized controlled spinal stenosis trial as part of the NORwegian degenerative spondylolisthesis and spinal STENosis (NORDSTEN) study. Before surgery, the radiological sagittal alignment parameter LL was measured using standing X-rays. The association between LL and 2-year postoperative changes was analyzed using the oswestry disability index (ODI), a numeric rating scale (NRS) for low back and leg pain, the Zurich claudication questionnaire (ZCQ), and the global perceived effect (GPE) score. The changes in PROMs 2 years after surgery for quintiles of lumbar lordosis were adjusted for the respective baseline PROMs: age, sex, smoking, and BMI. The Schizas index and the Pfirrmann index were used to analyze multiple regressions for changes in PROMs.

Results There were no associations in the adjusted and unadjusted analyses between preoperative LL and changes in ODI, ZCQ, GPE, and NRS for back and leg pain 2 years after surgery.

Conclusion LL before surgery was not associated with changes in PROMs 2 years after surgery. Lumbar lordosis should not be a factor when considering decompressive surgery for LSS.

Keywords Lumbar lordosis · Lumbar spinal stenosis · Lumbar spine surgery · Patient-related outcome measures

Introduction

Degenerative changes in the lumbar spine such as bulging of the intervertebral disk and hypertrophy of the facet joints and ligaments can result in narrowing of the spinal canal and lumbar spinal stenosis (LSS). The clinical presentation of patients with LSS is generally leg pain and numbness when walking, so-called neurogenic claudication [1]. Leaning forward often relieves the symptoms as the cross-sectional area of the spinal canal increases and the compression of the neurovascular structures decreases [2]. In addition, degenerative changes in the lumbar spine result in closer contact with the spinal processes; if there is a direct contact with the spinal processes, the lordosis in that segment will decrease [3]. Changes in posture activate compensatory mechanisms such as the retroversion of the pelvis, the extension of the hips, reduction of lumbar lordosis (LL), bending of the knees, and increase of the sagittal vertical axis (SVA) [4]. Patients with lumbar spinal stenosis have been reported to have lower LL compared to a control group (i.e., no lumbar spinal stenosis symptoms) [5]. The incidence of LSS correlates closely with the loss of LL, which may be related to both adaptive pain-relieving forward leaning and degenerative spinal changes such as degeneration and

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reduction of disk heights and age-related muscle atrophy [6]. Some studies have found an association between LL before and outcomes after decompressive surgery for lumbar spinal stenosis [7]. However, most previous studies have included few patients and do not adjust for the association between lumbar lordosis and outcomes for other variables that may impact outcomes after surgery. Thus, little is known about the association between LL and clinical outcomes after non-instrumented surgery for lumbar spinal stenosis. This study investigates the association between LL before surgery and changes in patient-related outcome measures 2 years after minimally invasive surgery for lumbar spinal stenosis.

Materials and methods

Study population

This prospective cohort study is based on data from a multicenter randomized controlled spinal stenosis trial (SST) from the NORwegian degenerative spondylolisthesis and spinal STENosis (NORDSTEN) study, which included patients with LSS without degenerative spondylolisthesis. The inclusion and exclusion criteria for the NORDSTEN-SST are presented in Table 1. The patients underwent non-instrumented decompression spinal surgery with minimally invasive surgical procedures, i.e., unilateral laminotomy with crossover (UL), bilateral laminotomy (BL), or spinous process osteotomy (SPO). The NORDSTEN-SST is well described in previous publications [1, 8–10] and registered in ClinicalTrials.gov under the identifier NCT02007083. A flow chart of the study cohort is presented in Fig. 1. At baseline, information about age, gender, body mass index (BMI), and smoking as well as Schizas scores, Pfirrmann scores, ODI, ZCQ, and NRS for leg and back pain was collected.

Preoperative and postoperative radiological imaging

LL was measured using standing lateral X-rays of the lumbar region at the intersection between the line ending from the upper endplate of L1 and the other extending from the upper endplate of S1 (Fig. 2). All radiological images were imported and stored in a picture and archiving system (PACS), Sectra IDS7 Sweden, and the integrated software tools for angle measurements were used.

Outcome assessment and patient-reported outcome measures

Patient-reported outcome measures (PROMs) used in this study were self-administered at admission for surgery (baseline) and 2 years after surgery. The primary outcome was changed in pain-related physical function and assessed by the oswestry disability index (ODI) questionnaire, from baseline to the 2-year follow-up. Secondary outcomes were changes in the Zurich claudication questionnaire (ZCQ), a self-administered instrument used to evaluate symptom

Table 1 Inclusion and exclusion criteria for the NORDSTEN-SST trial

Inclusion criteria
Presence of clinical symptoms of spinal stenosis, such as neurogenic claudication or pain radiating bilaterally to the lower limbs
Non-response at least 3 months of receiving non-surgical treatment
Radiological findings corresponding to the clinical symptoms of LSS: Central-stenosis or lateral recess stenosis
Able to give informed consent and to answer the questionnaires
Over 18 years old
Able to understand both spoken and written Norwegian
Exclusion criteria
Degenerative lumbar spondylolisthesis with a slip ≥ 3 mm verified on standing plain X-rays in lateral view
Not willing to give written consent
Previous surgery at the level of stenosis
Fracture or former fusion in the thoraco-lumbar region
Cauda equina syndrome (bowel or bladder dysfunction) or fixed complete motor deficit
ASA classified 4 or 5
Over 80 years old
Presence of lumbosacral scoliosis of more than 20 degrees verified on AP view
Presence of distinct symptoms in one or both legs due to other diseases, e.g., polyneuropathy, vascular claudication, or osteoarthritis
LSS at four or more levels
Unable to comply fully with the protocol, including treatment, follow-up, or study procedures (psychosocially, mentally, or physically)
Participating in another clinical trial that may interfere with this trial

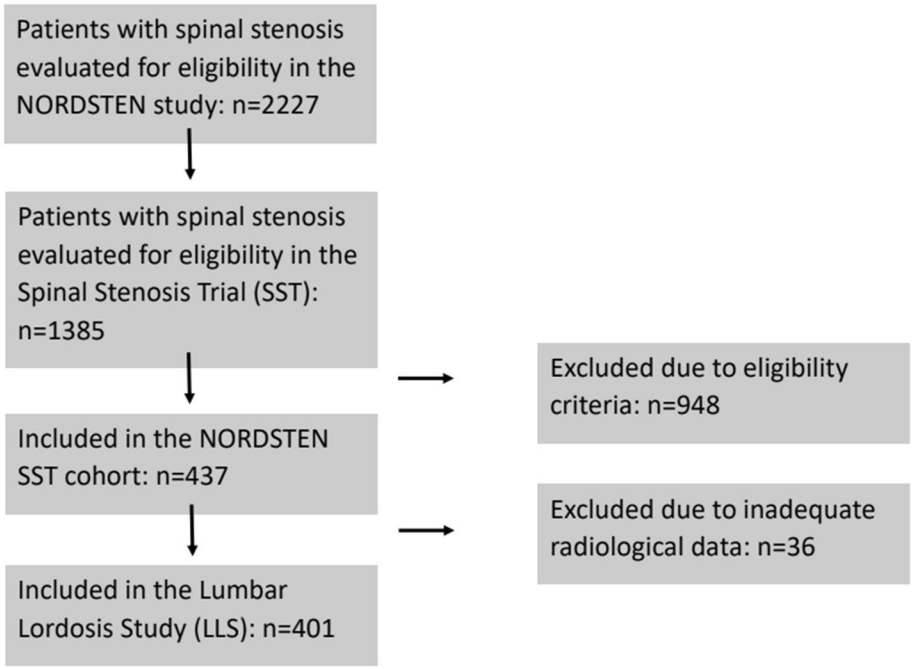

Fig. 1 Flowchart of the NORDSTEN study. SST and LLS cohort according to STROBE-statement

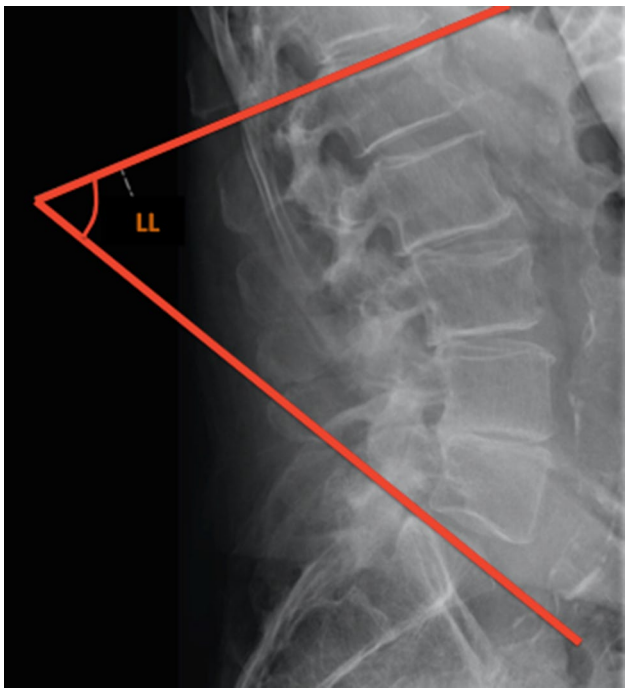

Fig. 2 Lumbar lordosis was measured on standing lateral X-rays of the lumbar spine at the intersection between the line ending from the upper plate of L1 and the other extending from the upper endplate of S1

severity, physical function, and surgical satisfaction in lumbar spinal stenosis. The ZCQ score includes values for physical function and symptom severity. Furthermore, changes in NRS back pain and leg pain were registered. At the 2-year follow-up, a 7-point global perceived effect (GPE) scale and questionnaire was used to collect data.

Statistical analysis

Descriptive statistics for continuous variables are presented as means with standard deviations, and categorical data are presented as numbers and percentages. The total cohort was divided into quintiles based on the preoperative LL and analyzed in relation to changes in PROMs 2 years after surgery. The mean changes in PROMs, ODI, ZCQ, GPE, and NRS for back and leg pain are presented with means with a 95% confidence interval (CI). At baseline, groups were compared using the ANOVA test for continuous variables and the Chi-square test for categorical variables. The quintiles were compared with a likelihood ratio test in relation to changes in PROMs 2 years after surgery. The changes in proms 2 years after surgery in relation to quintiles of lumbar lordosis were adjusted for respective baseline PROMs and for age, sex, smoking, BMI, Schizas score, and Pfirrmann score. Multiple regressions were also used to analyze the association between baseline parameters and clinical outcomes 2 years after surgery. The variables in the regression model were baseline PROMS, age, sex, BMI, Schizas score, and Pfirrmann score. A $p < 0.05$ was significant. We used SPSS (IBM SPSS Statistics for Mac, Version 26.0, Armonk, NY: IBM Corp. USA) for statistical analyses.

Results

Demographic characteristics

The patient characteristics for the quintiles are presented in Table 2. A total of 437 patients are included in the NORDSTEN-SST study; 401 had complete radiology examinations with standing X-rays before surgery and therefore were included in this study. The mean patient age was 67 years (8.2 SD). The study included 208 male and 193 female patients. Of the 401 patients included in this study, 314 were non-smokers, 81 (20%) were smokers, and six had missing information about smoking. The mean BMI before surgery was 27.7 (SD 4.2). There were no statistical differences between the clinical characteristics of the groups at baseline except for patients in the middle quintiles of lumbar lordosis (Q2 and Q3), who had less leg pain before surgery ($p = 0.04$).

Changes in PROMs 2 years after surgery

The patients included in this analysis showed significant improvements from baseline to the 2-year follow-up after surgery with a mean change for ODI of − 1.8 (CI − 17.1 − − 21); for ZCQ symptom score, the change was − 2.3 (CI − 2.2 − − 2.4); for ZCQ physical function score, the change was − 1.7 (− 1.6 − − 1.7); for NRS for back pain, the change was − 3.6 (− 3.3 − − 3.9); and for NRS leg pain, the change was − 2.9 (− 2.7 − − 3.2). These results agree with previously reported results. [8]

Association between lumbar lordosis and changes in PROMs 2 years after surgery

There were no statistically significant differences between the quintiles of LL in relation to changes in outcomes 2 years after surgery for ODI ($p = 0.51$, adj $p = 0.18$), ZQC symptom score ($p = 0.40$, adj $p = 0.24$), ZCQ function score ($p = 0.37$, adj $p = 0.40$), NRS back pain ($p = 0.93$, adj $p = 0.68$), NRS leg pain ($p = 0.52$, adj $p = 0.38$), and GPE ($p = 0.26$, adj $p = 0.10$) (Table 3).

Patients in the middle quintile (45.3–53 degrees) of lumbar lordosis had significantly higher changes in ZCQ symptom score ($p = 0.024$) and GPE ($p = 0.022$). No other quintiles were associated with changes in PROMs 2 years after surgery. All baseline PROMs, BMI, and smoking were associated with significant changes in the multiple regression analysis (Supplementary 1).

Discussion

In this prospective cohort study, no significant associations were found for the degree of the LL before surgery and changes in PROMs 2 years after surgery.

As the prevalence of lumbar spinal stenosis is increasing due to an aging population and lumbar decompressive surgery without instrumentation is the first choice of surgical treatment for these patients [11], identification of variables that can predict less favorable outcomes after decompression surgery is important. Because the incidence of LSS in adults correlates with the loss of LL [6], it is necessary to evaluate the association of preoperative LL with outcomes after non-instrumentation decompression surgery. Sagittal alignment measurements of radiographic parameters, such as high LL, have been demonstrated to be associated with less back pain in patients with spinal deformities and lumbar spinal stenosis [12, 13]. Furthermore, a possible restoration of a low LL after decompressive surgery may be important for the maintenance of the overall sagittal balance [14]. However, the relationship between LL and outcomes after decompressive surgery for lumbar spinal stenosis patients has been sparsely studied, and the few studies that have studied this relationship have produced contradictory findings [7, 15, 16]. Chang et al. [15] found a correlation between small lumbar lordosis and poor postoperative physical score and VAS score in a prospective cohort of 85 patients using a linear mixed effect model without adjusting for covariation factors. Similar findings were reported by Costa et al. [16]. They divided their 104 patients into two groups by the LL 50th percentile and found a weak but statistically significant correlation between a small LL before surgery and ODI 1 year after surgery. However, Mirzashahi et al. [7] reported that a lower LL was associated with a better postoperative improvement for VAS and ODI in spinal stenosis patients, but the association between small LL and PROMs found in the regression analyses was only reported for the subgroup of patients who underwent a fusion during decompressive surgery [7].

To evaluate the association between LL and outcomes in a systematic way, we divided our patient cohort into quintiles based on preoperative LL. We found no association between the patients within these quintiles and the PROMs evaluated 2 years after surgery, indicating that preoperative LL does not have any statistically significant effect on postoperative outcome for patients with spinal stenosis undergoing decompressive surgery.

Unlike most other studies, our study included a large number of patients, which allowed us to adjust for other variables in the analyses. Furthermore, in the adjusted analyses, no associations between the quintiles of lumbar lordosis and improvements 2 years after decompressive surgery

Table 2 The demographics, smoking status, preoperative PROMs, and radiographic findings for the LSS patients before decompressive surgery ($n=401$). The patients were divided into five quintiles based on lumbar lordosis before surgery

Lumbar lordosis	*Q*1 (14.5–37.3)	*Q*2 (37.7–45)	*Q*3 (45.3–53)	*Q*4 (53.5–60)	*Q*5 (60.3–82.3)	Total ($N=401$)
Age (mean/SD)	67.2 (7.76)	66.2 (8.05)	69.1 (6.97)	66.0 (8.96)	65.7 (9.1)	66.9 (8.2)
BMI (mean/SD)	28.0 (3.7)	28.4 (4.5)	27.3 (4)	28.2 (4.3)	26.9 (4.2)	27.7 (4.2)
ODI	40.5 (14.6)	37.7 (15)	37.3 (13.1)	39.2 (15.8)	37.7 (13.5)	38.5 (14.4)
Symptom (ZCQ)	3.3 (0.53)	3.3 (0.54)	3.4 (0.6)	3.4 (0.63)	3.4 (0.5)	3.4 (0.6)
Physical function (ZCQ)	2.6 (0.49)	2.5 (0.55)	2.5 (0.55)	2.5 (0.56)	2.4 (0.52)	2.52 (0.53)
Back pain (NRS)	6.5 (2.3)	6.2 (2.2)	5.9 (2.2)	6.5 (2.2)	6.3 (2.2)	6.3 (2.2)
Leg pain (NRS)	6.8 (2.1)	6.0 (2.3)	6.1 (2.0)	6.8 (1.9)	6.7 (1.7)	6.5 (2.0)
Male	41	44	47	40	36	208
Female	41	36	38	35	43	193
Smoking	18	16	17	17	13	81
Non-smoking	61	62	67	58	66	314
Schizas						
A	9	7	8	8	12	44
B	17	13	7	12	20	69
C	53	51	56	48	34	242
D	3	9	12	5	12	21
Pfirrman						
2	0	1	0	1	2	4
3	28	32	29	33	36	158
4	39	39	48	33	36	195
5	15	8	6	6	4	39

ODI Oswestry disability index, *ZCQ* Zurich claudication questionnaire, *NRS* Numeric pain rating scale

were detected. However, a small but significant association was found between patients in the third quintile (Q3) and changes in ZCQ symptom score as well as GPE in the multiple regression model. Even when these associations were significant, they were not clinically relevant.

The degree of lumbar lordosis before surgery was associated with leg pain at baseline in a somewhat unexpected way as the patients in the lowest quintile (Q1) and the two quintiles with the highest lumbar lordosis (Q4 and Q5) reported more leg pain before surgery compared to the two quintiles in the middle (Q2 and Q3). We do not have any clinical reasonable explanation for this observation, although it may have a biomechanical explanation or just be coincidental.

The evaluation of sagittal balance, including lumbar lordosis, with a standing X-ray before surgery has previously been shown to be significant for patients with spinal stenosis and degenerative deformities [12, 13]. This has raised both attention and discussion about the needs for preoperative evaluation of sagittal balance and lumbar lordosis also in patients without any clear deformity or clinical imbalance. Our study, however, suggests that there is no need to pay attention to the degree of the lordosis in non-deformity patients with spinal stenosis undergoing decompressive surgery. It needs to be remembered that this study has limited the evaluation of the effect of preoperative LL on outcomes 2 years after surgery. It remains to be investigated whether changes of lumbar lordosis after decompressive surgery, such as a restoration of a previously higher lordosis, influence patient-related outcomes.

Strengths and limitations

The main strength of this study is its large sample size and structured study protocol. To our knowledge, this study is the largest study of patients undergoing non-instrumented decompressive surgery for lumbar spinal stenosis that investigates the association between LL before surgery and postoperative outcomes. As this study has a cross-sectional design, the reason for a low LL is totally unknown: it may be due to patient phenotypes or acquired changes as the result of degeneration and spinal stenosis. The NORDSTEN-SST collected data using standing lumbar spine X-rays; however, full spine standing X-rays were not performed, so the overall sagittal balance could not be evaluated. Moreover, the patients in the cohort were operated on using three minimal invasive surgical techniques, which showed similar results in the full NORDSTEN-SST cohort [8].

Table 3 Patient-reported outcomes related to lumbar lordosis before decompressive surgery for lumbar spinal stenosis. The cohort was divided into quintiles and Changes of the different outcome parameters from baseline to 2 years after surgery are presented

	*Q*1	*Q*2	*Q*3	*Q*4	*Q*5	*P*
Lumbar lordosis	14.5–37.3	37.7–45.0	45.3–53	53.5–60	60.3–82.3	
Change ODI						
Unadjusted ($n=372$)	− 18.4	− 18.8	− 20.9	− 21.0	− 16.8	0.51
	(− 22.3 − − 14.5)	(− 22.6 − − 14.9	(− 24.7 − − 17.2)	(− 24.9 − − 17.0)	(− 20.7 − − 13.0)	
Adjusted ($n=355$)	− 17	− 19	− 22.0	− 20.7	− 16.5	0.18
	(− 21.3 − − 14.0)	(− 22.6 − − 15.8)	(− 25.4 − − 18.6)	(− 24.2 − − 17.2)	(− 20 − − 13.0)	
Change physical function (ZCQ)						
Unadjusted ($n=369$)	− 0.9	− 0.8	− 1.0	− 0.9	− 0.8	0.37
	(− 1.0 − − 0.7)	(− 1.0 − − 0.6)	(− 1.1 − − 0.8)	(− 1.0 − − 0.7)	(− 0.9 − − 0.6)	
Adjusted ($n=352$)	− 0.8	− 0.8	− 1.2	− 1.1	− 1.0	0.40
	(− 1.0 − − 0.7)	(− 1.0 − − 0.8)	(− 1.3 − − 1.0)	(− 1.0 − − 0.7)	(− 0.9 − − 0.6)	
Change symptoms (ZCQ)						
Unadjusted ($n=368$)	− 0.9	− 1.0	− 1.1	− 1.1	− 1.1	0.40
	(− 1.1 − − 0.7)	(− 1.2 − − 0.8)	(− 1.3 − − 1.0)	(− 1.3 − − 0.9)	(− 1.2 − − 0.9)	
Adjusted ($n=352$)	− 0.9	− 1.0	− 1.2	− 1.1	− 1.1	0.25
	(− 1.1 − − 0.7)	(− 1.2 − − 0.8)	(− 1.4 − − 1.0)	(− 1.3 − − 0.9)	(− 1.2 − − 0.8)	
Change NRS back pain						
Unadjusted ($n=359$)	− 2.4	− 2.6	− 2.6	− 2.7	− 2.9	0.93
	(− 3.1 − − 1.7)	(− 3.3 − − 1.9)	(− 3.2 − − 1.9)	(− 3.4 − − 2.0)	(− 3.5 − − 2.2)	
Adjusted ($n=343$)	− 2.3	− 2.7	− 3.0	− 2.6	− 2.8	0.68
	(− 2.9 − − 1.6)	(− 3.3 − − 2.1)	(3.6 − − 2.3)	(− 3.2 − − 2.0)	(− 3.3 − − 2.0)	
Change NRS leg						
Unadjusted ($n=356$)	− 3.4	− 3.1	− 3.6	− 4,0	− 3,4	0.52
	(− 4.1 − − 2.6)	(− 3.8 − − 2.4)	(− 4.3 − − 2.9)	(− 4.7 − − 3.3)	(− 4.1 − − 2.7)	
Adjusted ($n=342$)	− 3.1	− 3.5	− 3.9	− 3.8	− 3.2	0.38
	(− 3.8 − − 2.4)	(− 4.1 − − 2.8)	(− 4.5 − − 3.2)	(− 4.5 − − 3.2)	(− 3.9 − − 2.5)	
Change GPE						
Unadjusted ($n=377$)	2.6 (2.3–2.9)	2.4 (2.1–2.7)	2.2 (1.9–2.5)	2.5 (2.2–2.9)	2.6 (2.3–2.9)	0.26
Adjusted ($n=356$)	2.6 (2.3–3.0)	2.4 (2.1–2.7)	2.1 (1.8–2.4)	2.5 (2.2–2.8)	2.7 (2.4–3.0)	0.10

Conclusion

The degree of LL before surgery was not associated with changes in PROMs 2 years after surgery. Lumbar lordosis should not be a factor when considering decompressive surgery for LSS.

Ethics and trial registration

The Committee for Medical and Health Research Ethics of Central Norway approved the study (study identifier: 2011/2034). The study was registered at ClinicalTrials.gov on November 22, 2013, under the identifier NCT02007083. All patients provided written informed consent.

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