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ORIGINAL ARTICLE

Outcome of surgery for degenerative lumbar scoliosis: an observational study using the Swedish Spine register

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Abstract
Purpose The outcome of surgery for degenerative lumbar scoliosis was studied in the Swedish Spine register.
Methods 209 patients (mean age 66 years) were identified; 45 had undergone decompression and/or fusion of one segment (minor group) and 164 had undergone fusion of two or more segments, with or without decompression (major group).
Results VAS back pain, VAS leg pain, ODI and EQ-5D index improved after surgery in both groups ($p < 0.05$), with medium to large effect sizes of surgery. Global assessment for back pain and satisfaction was significantly better in the major group than in the minor group ($p < 0.05$) at the 2-year follow-up. Additional spine surgery was observed in 57 out of the 209 patients during a mean period of 5.4 years.
Conclusion Surgery for degenerative lumbar scoliosis improves quality of life with medium to large effect sizes, but carries a high risk of additional surgery.

Keywords Degenerative lumbar scoliosis · Spinal deformity · Lumbar spine · Spinal surgery

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Introduction

Degenerative lumbar scoliosis is defined as a lumbar deformity with a Cobb angle of $\geq 10°$ in the coronal plane developing after skeletal maturity [1]. The estimated prevalence ranges from 6 to 68% and increases with age and only a minority are symptomatic [2–4].

Symptoms for degenerative lumbar scoliosis are primarily chronic back pain and leg pain, and may severely reduce the health-related quality of life [5, 6]. Even though evidence for effectiveness of non-operative treatment is scarce, such attempts should be performed before surgical procedures [7].

Surgical treatments include decompression, with or without more or less extensive fusion with treatments decisions based on symptoms and pathology [6]. The risks that different surgical strategies carry are not evident. The possible risk of deformity progression after minor surgery might influence decision making towards major surgery, while comorbidities might influence the decision towards minor surgery.

Little is known about patient-reported quality of life outcomes after surgery [4, 6, 8–10]. In addition, more follow-up data regarding the risk of repeated surgery after several years is needed [8, 11, 12].

The aim was to evaluate (1) outcome, (2) effect size of surgery, and (3) risk of repeated surgery for degenerative lumbar scoliosis in the Swedish Spine register (Swespine). We hypothesized that surgery for degenerative lumbar scoliosis would increase quality of life.

Methods

In Sweden, 90% of all the spine clinics use Swespine [13], and degenerative lumbar scoliosis has been possible to register since 2001. Patients complete the outcome questionnaires, including data on anthropometry, smoking status and comorbidities, before surgery and via mail at 1, 2, 5 and 10 years after surgery [13]. The treating surgeon records diagnosis, type of surgery, complications during the inpatient stay, and any new spine surgeries. Complications during the first 3 postoperative months are reported by the patient at the 1-year follow-up.

Patients

In this retrospectively designed study on prospectively collected data, we included patients treated for the first time for degenerative lumbar scoliosis with decompression and/or fusion. A flow chart of the study is presented in Fig. 1. The inclusion criteria were fulfilled by 209 patients. Of these, 155 patients answered to the 1 year and 139 patients to the 2-year follow-up questionnaire.

Validation of diagnosis

Classification of the radiological curve pattern or any other radiological information is not included in the Swespine register. We therefore validated the diagnosis by obtaining radiographs from a random sample of 41 patients and another 3 patients with radiographs from our own clinic. The correct diagnosis, degenerative lumbar scoliosis with a Cobb angle of ≥10°, was confirmed for all 44 patients. The mean (SD) preoperative Cobb angle was 21 (7) degrees and the mean (SD) postoperative Cobb angle was 16 (7) degrees. Due to the lack of standardized radiographs in the different clinics we did not attempt to classify the curve patterns.

Outcome

Primary outcome measures

We considered global assessment of back pain and global assessment of leg pain reported at the follow-ups as the primary outcomes [14]. The global assessment questions, “How is your back/leg pain today compared to before surgery?” were dichotomized into “pain free”/”much better” vs. “somewhat better”/”unchanged”/”worse”.

Secondary outcome measures

Secondary outcomes included the satisfaction question, “Are you satisfied with the outcome of the surgery?” which was dichotomized into “satisfied” vs. “undecided”/”dissatisfied”, the visual analog scale (VAS) for back pain and VAS for leg pain ranging from 0 (no pain) to 100 (worst possible pain), Oswestry disability index ranging

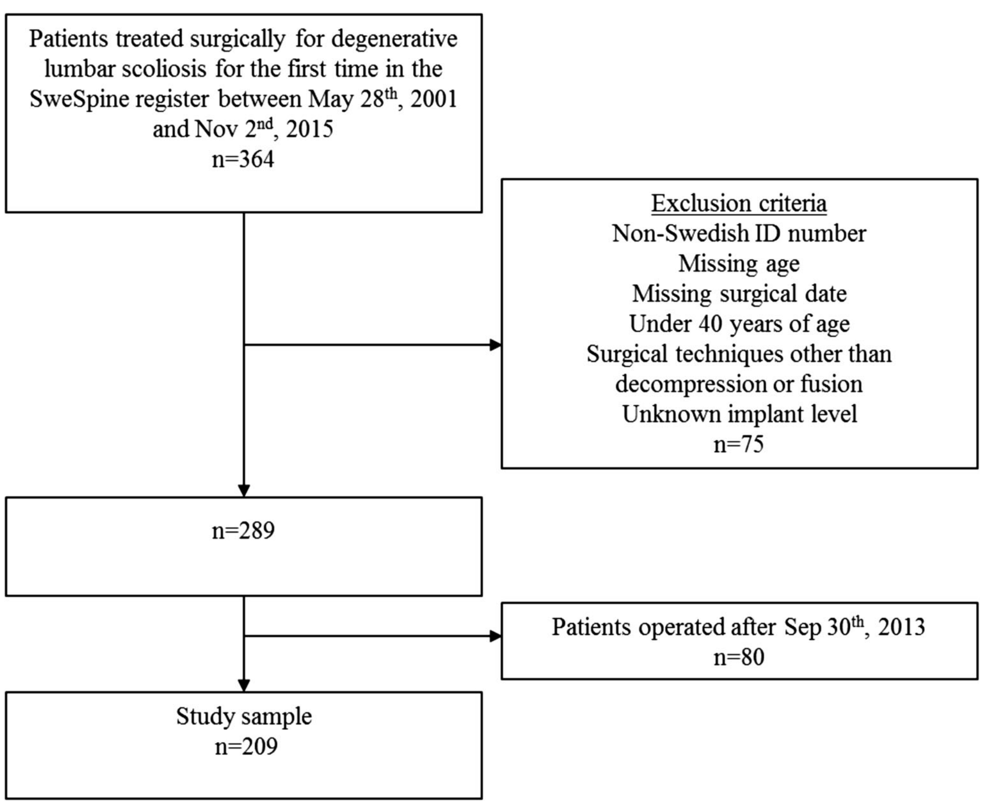

Fig. 1 Flowchart of the participants in the study

from 0 (no disability) to 100 (severe disability) [15], and EuroQol-5 dimensions (EQ-5D). The answers on the five EQ-5D questions (domains) were translated to an index obtained from the UK EQ-5D tariff and ranges from −0.59 (worst) and 1.0 (best) [16].

Surgery

Patients were divided into two groups based on the extensity of surgery. Isolated decompression with or without fusion of one spinal segment, i.e., two vertebras, were considered as the minor group. Fusions of two or more spinal segments, i.e., three vertebras or more with or without decompression were considered as the major group. In secondary analyses, subgroups within the minor and major groups were compared.

Additional surgery and mortality data

Additional surgeries of the lumbar spine were searched in the Swespine database for the 209 patients until Nov 2, 2015. Any deaths were sought for all 209 patients in the Swedish population register until Nov 2, 2015.

Statistics

Descriptive data are presented as mean (SD), median or proportion (%). Due to unequal group sizes and variances, the Welch–Satterthwaite t test was used to compare unpaired continuous data. Pearson's Chi-squared test or Fischer's exact test was used for categorical data. Paired data was analyzed with Wilcoxon signed-rank test. These analyzes were performed with SPSS, version 22 (IBM, Armonk, NY, USA), which was also used to create the box plots.

The a priori power calculation was based on the assumption that the effect size of surgery was 0.5. Using the program G*power [17], with power set to 80% and alfa 0.05, the required sample size was 35.

The effect size of surgery was calculated using $r = z/\sqrt{(n \text{ observations used to calculate } z)}$ and estimated according to Cohen [18]. z was obtained using the Wilcoxon signed-rank test.

The cumulative incidence function and competing risks proportional hazards regression were analyzed according to Fine and Gray [19] to describe the risk of additional spine surgery taking the competing risk, mortality into account by applying the PHREG procedure in the Statistical analysis system (SAS) version 9.4 (SAS institute, Cary, NC, USA).

$p < 0.05$ was considered as level of significance.

Ethical approval

This study was conducted in accordance with the Helsinki Declaration. Ethical approval was obtained from the Stockholm Regional Ethical Board (Number 2012/172-31/4 and 2016/1557-32).

Results

The preoperative characteristics did not differ between the major and minor group, with the exception of body weight (Table 1). Within the minor group, patients undergoing decompression had similar preoperative characteristics as those undergoing short fusion with or without decompression (all $p > 0.05$).

After a decrease between 1 and 2 years, global assessment for back pain was significantly better in the major group than in the minor group (Table 2). The same pattern was seen for satisfaction (Table 2).

EQ-5D index was lower in the major surgery group than in the minor surgery group at baseline (Fig. 2). The only EQ-5D domain that differed significantly between the groups was the "pain/discomfort" domain. All patients answering had at least moderate pain/discomfort; 102 out of 131 (78%) had severe pain/discomfort in the major surgery group compared to 18 out of 37 (49%) in the minor surgery group ($p = 0.001$). The initial improvement from preoperative to the 1-year follow-up in VAS back and leg pain, ODI and EQ-5D index did not change significantly between 1 and 2 years (Fig. 2). The effect size of surgery was medium to large for VAS back pain, VAS leg pain, ODI and EQ-5D index (Table 3).

In the minor group, 3 out of 45 patients, and in the major group, 21 out of 164 patients, had at least one complication within the first 3 months after the index surgery ($p = 0.25$).

Subgroup analyses

When comparing patients within the minor group, patients undergoing decompression only had similar outcomes compared to those undergoing short fusion or decompression and fusion (all $p > 0.05$). When comparing patients within the major group, those fused at four or more segments ($n = 97$) had more previous surgeries ($p = 0.048$) and had more intermittent consumption and less regular consumption of analgesics than those fused at two or three segments ($n = 67$) ($p = 0.001$), but the two groups had similar outcomes (all $p > 0.05$).

Risk of additional surgery

The mean observational period for additional lumbar spine surgery was for more than 95% of the patients longer than the 2-year follow-up, with a mean of 5.4 years, consisting

Table 1 Preoperative characteristics of patients with 2-year follow-up data

Descriptive data	Minor surgery[a] ($n = 45$)	Major surgery[b] ($n = 164$)	p value
Females	32 (71%)	114 (70%)	1.00
Age at surgery	67 (9)	66 (8)	0.50
Height (cm)	170 (9)	166 (20)	0.17
Weight (kg)	81 (15)	75 (15)	0.042
Smoking status			0.42
Non-smoker	31 (82%)	114 (88%)	
Smoker	7 (18%)	16 (12%)	
Previous surgery			0.45
No	26 (68%)	81 (61%)	
Yes	12 (32%)	51 (39%)	
Analgesic consumption			0.92
No consumption	4 (11%)	8 (6%)	
Intermittent consumption	26 (68%)	96 (72%)	
Regular consumption	8 (21%)	29 (22%)	
Walking capacity (m)			0.83
<500	27 (75%)	95 (72%)	
>500	9 (25%)	37 (28%)	
Duration of back pain (year)			0.33
<1	5 (14%)	10 (8%)	
>1	32 (87%)	121 (92%)	
Duration of leg pain (year)			0.48
<1	9 (25%)	22 (19%)	
>1	27 (75%)	96 (81%)	
Comorbidity			0.82
No comorbidity	17 (65%)	71 (68%)	
Comorbidity	9 (35%)	33 (32%)	

Data are presented as mean (SD) or as n (%). Numbers do not always correspond to group numbers due to missing data

p values are given for the Pearson's Chi-squared test, Fisher's exact test and Welch–Satterthwaite t test for the differences between the two groups

[a] 22 patients underwent isolated decompression, 8 underwent isolated short fusion and 15 underwent decompression and short fusion

[b] 35 underwent isolated long fusion and 129 underwent decompression and long fusion

of 1130 person-years, Among the 209 individuals, at least one additional spine surgery was observed in 57 individuals. In 56 individuals, these surgeries were within or in immediate proximity to the area of the index surgery; fusion extending cranially or/and caudally ($n = 20$), pseudarthrosis ($n = 9$), implant extraction or repositioning ($n = 16$), infection ($n = 4$), and others ($n = 7$). In one patient, the additional surgery consisted of a decompression on a level above the index surgery. Mortality during the follow-up was seen in 22 individuals. The probability of additional spine surgery was continuously increasing during the follow-up (Fig. 3). The hazard ratio (HR) for at least one additional spine surgical procedure for the major spine surgery group was 2.12 (0.98–4.57) compared to the minor surgery group (1.00; reference). When comparing those fused at four or more segments to those fused at two or three segments, the HR was 1.08 (0.62–1.90).

Non-response analysis

When comparing preoperative VAS back pain, VAS leg pain, ODI and EQ-5D index between the group without ($n = 70$) and the group with outcome data at 2 years ($n = 139$), there were no statistically significant differences (all $p > 0.05$).

Discussion

In this nationwide study of degenerative lumbar scoliosis, surgery improved quality of life over 2 years, but 27% of the patients were subjected to additional lumbar spine surgery over a mean 5.4 year period.

Global assessment of back pain and leg pain was chosen as primary outcome since they aggregate important

Table 2 Global assessment and satisfaction outcome at 1- and 2-year follow-ups

	Minor surgery	Major surgery	p value
Global assessment back pain			
1 year			
Pain free/much better	16 (46%)	65 (59%)	0.24
Somewhat better/unchanged/worse	19 (54%)	46 (41%)	
2 years			
Pain free/much better	7 (22%)	54 (51%)	0.004
Somewhat better/unchanged/worse	25 (78%)	51 (49%)	
Global assessment leg pain			
1 year			
Pain free/much better	16 (46%)	68 (65%)	0.047
Somewhat better/unchanged/worse	19 (54%)	36 (35%)	
2 years			
Pain free/much better	9 (30%)	45 (51%)	0.06
Somewhat better/unchanged/worse	21 (70%)	44 (49%)	
Patient satisfaction			
1 year			
Satisfied	18 (51%)	67 (59%)	0.44
Undecided/dissatisfied	17 (49%)	46 (41%)	
2 years			
Satisfied	12 (36%)	60 (58%)	0.045
Undecided/dissatisfied	21 (63%)	44 (42%)	

Data are presented as n (%). Numbers do not always correspond to group numbers due to missing data

p values are given for the Fisher's exact test for the differences between the two groups

dimensions for the patient [14], and represents the main symptoms and indications for treatment in patients with degenerative lumbar scoliosis [6]. Both the primary and secondary outcome measures indicated an improvement after surgery. Change in VAS back pain, VAS leg pain and ODI exceeded the minimal clinically important difference for both minor and major surgeries and for EQ-5D for major surgery [20–22], and were without significant change between 1 and 2 years. However, the trend of deterioration in global assessment for both back and leg pain between 1 and 2 years is of some concern.

The effect sizes of surgery on VAS back and leg pain, ODI and EQ-5D, global assessment and satisfaction seemed to point at a more beneficial effect of surgery for the major surgery group. Preoperative characteristics could not explain this, as the only substantial preoperative difference was in the EQ-5D domain "pain/disability" which was worse in the major surgery group. One has to bear in mind that the group differences have to be interpreted with great caution. The choice of surgical treatment could be dependent on differences in patient characteristics and surgeon preferences not captured in this study. For example, it is likely that decompression is more often performed in individuals with neurogenic claudication, while fusion is more often performed in individuals with predominant back pain, even though this was not evident from the present data.

Previous reports on surgical results after degenerative lumbar scoliosis are somewhat contradictory. One study found that isolated decompression and short fusion surgery improved ODI while long fusion did not [10], and another found no difference in global outcome between groups [8]. Differences in baseline group characteristics such as age and symptoms may explain the differences between these studies and the present study.

The patient-reported outcome data in this study does not necessarily reflect the long term outcome in terms of risk for additional spine surgery, due to a much longer follow-up. Over a mean 5.4-year period, 27% of the patients were subjected to additional lumbar spine surgery. This is similar to Brodke et al. [23] who reported a repeated surgery rate of 26% after a mean follow-up of 5.2 years in 96 patients treated for lumbar spinal stenosis and degenerative deformity. More extensive surgery may carry a higher risk of reoperation. One study reported a reoperation rate of 7% for isolated decompression, 15% for short fusion and 28% for long fusion in patients with degenerative lumbar scoliosis 2 years after the index surgery [8]. Charosky et al. [11] reported a 44% risk of reoperation after a mean follow-up of 5.8 years in patients that had undergone primary

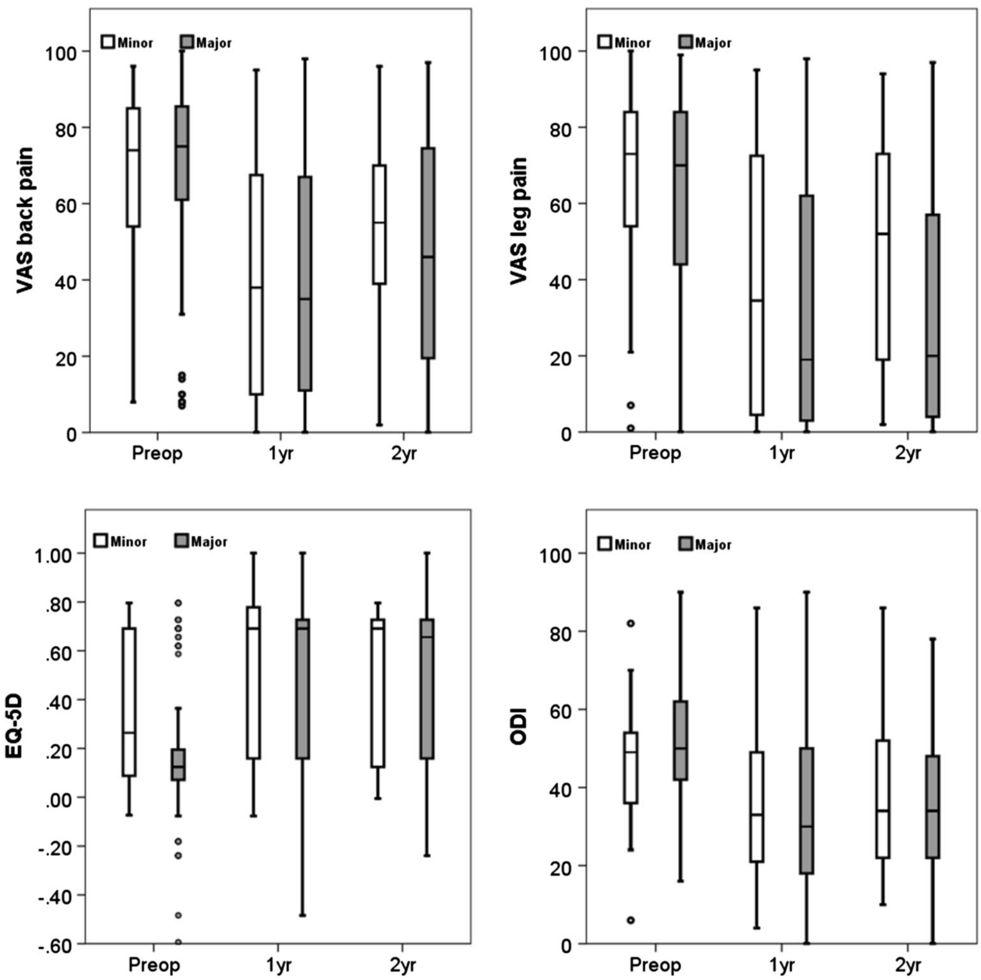

Fig. 2 Box plot showing VAS back pain, VAS leg pain, ODI and EQ-5D index preoperatively and at the 1- and 2-year follow-ups in the minor surgery group (*white boxes*) and major surgery group (*gray boxes*). The change between baseline and 1 year was significant for all outcomes ($p = 0.012$ or less). No statistically significant changes in outcome were seen between the 1- and 2-year follow-ups (p values ranging between 0.12 and 0.76). The *boxes* represent the inner quartile range (IQR) with median denoted by *horizontal line*. The inner fences represent minimum and maximum values or 1.5 times IQR, with outliers more than 1.5 times the IQR shown

Table 3 Effect size of surgery for the patient-reported outcome measures from preoperative to the 1-year follow-up and to the 2-year follow-up

	Preoperative—1 year		Preoperative—2 years	
	r (effect size)	Cohen's criteria	r (effect size)	Cohen's criteria
Major surgery				
VAS back pain	0.4	Medium to large	0.4	Medium to large
VAS leg pain	0.4	Medium to large	0.4	Medium to large
ODI	0.5	Large	0.5	Large
EQ-5D index	0.5	Large	0.5	Large
Minor surgery				
VAS back pain	0.5	Large	0.3	Medium
VAS leg pain	0.4	Medium to large	0.3	Medium
ODI	0.3	Medium	0.3	Medium
EQ-5D index	0.3	Medium	0.3	Medium

Effect size according to Cohen's criteria (Cohen 1988): small $r = 0.1$, medium $r = 0.3$, large $r = 0.5$

VAS visual analog scale, *ODI* Oswestry disability index, *EQ-5D* EuroQol-5 dimensions

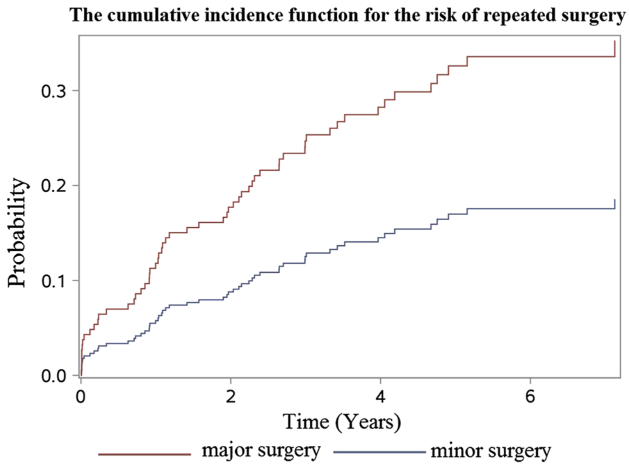

Fig. 3 The cumulative incidence function for the probability of repeated lumbar surgery in the minor ($n = 45$) and in the major surgery group ($n = 164$) is shown

adult scoliosis surgery with a mean of seven instrumented levels. Our figures point in the same direction but were without significant differences between the major and minor surgery groups.

There are some shortcomings with this study. The study is retrospective in its design, which limits our possibilities to draw conclusions on preferred types of surgery. Patient characteristics that possibly impacted on the choice of surgery type could not be identified other than that the major surgery group seemed to have more general pain as assessed with EQ-5D.

The proportion of patients operated with isolated decompression and short fusion was small compared to other studies evaluating quality of life outcomes [8, 10]. We cannot exclude that patients with degenerative lumbar scoliosis and concomitant spinal stenosis that were surgically treated might have been entered into the Swespine registry with the diagnosis "spinal stenosis" instead of "degenerative lumbar scoliosis". However, the validity of the diagnosis and extent of surgery is very high in Swespine [24].

A registration of various radiological variables would have been beneficial. However, the registration of radiological data is not part of the present Swespine protocol. A random sample of radiographs confirmed the diagnosis in all cases. We could therefore be fairly certain about the credibility of the diagnosis in the database. Due to the lack of standardization of radiographs we did not attempt to make any additional classification of curve patterns.

Another possible limitation is missing data, including the patients lost to follow-up. Questionnaire non-responders in other studies of lumbar degenerative disorders have not been found to differ substantially from questionnaire responders [25, 26]. We did not find any differences in the baseline variables for the patients that responded to the 2-year follow-up and those who did not, supporting the assumption that missing data was lost at random and our study cohort therefore representative.

The number of patients treated for degenerative lumbar scoliosis in this study is small, but with a growing elderly population it is likely that an increased number of patients will be considered for surgical treatment. Besides the development of strategies for patient selection and surgical strategies, there is a need for improved non-surgical care.

Despite the difficulty in the clinic to choose the optimal surgical treatment for degenerative lumbar scoliosis, patients seemed to increase their quality of life up to 2 years postoperatively. The risk of repeated surgery over a mean 5 year period was high.

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Author contributions TC: study design, data analysis, and manuscript writing. PG: study design, data collection, data analysis, manuscript writing, and financing.

Compliance with ethical standards

Conflict of interest The authors have no competing interests.

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References

1. Aebi M (2005) The adult scoliosis. Eur Spine J 14(10):925–948. doi:10.1007/s00586-005-1053-9
2. Xu L, Sun X, Huang S, Zhu Z, Qiao J, Zhu F, Mao S, Ding Y, Qiu Y (2013) Degenerative lumbar scoliosis in Chinese Han population: prevalence and relationship to age, gender, bone mineral density, and body mass index. Eur Spine J 22(6):1326–1331. doi:10.1007/s00586-013-2678-8
3. Schwab F, Dubey A, Gamez L, Elfegoun AB, Hwang K, Pagala M, Farcy JP (2005) Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. Spine 30(9):1082
4. Ploumis A, Transfledt EE, Denis F (2007) Degenerative lumbar scoliosis associated with spinal stenosis. Spine J 7(4):428–436. doi:10.1016/j.spinee.2006.07.015
5. Pellisé F, Vila-Casademunt A, Ferrer M, Domingo-Sàbat M, Bagó J, Pérez-Grueso F, Alanay A, Mannion A, Acaroglu E (2015) Impact on health related quality of life of adult spinal deformity (ASD) compared with other chronic conditions. Eur Spine J 24(1):3–11. doi:10.1007/s00586-014-3542-1

6. Cho KJ, Kim YT, Shin SH, Suk SI (2014) Surgical treatment of adult degenerative scoliosis. Asian Spine J 8(3):371–381. doi:10.4184/asj.2014.8.3.371
7. Monticone M, Ambrosini E, Cazzaniga D, Rocca B, Motta L, Cerri C, Brayda-Bruno M, Lovi A (2016) Adults with idiopathic scoliosis improve disability after motor and cognitive rehabilitation: results of a randomised controlled trial. Eur Spine J. doi:10.1007/s00586-016-4528-y
8. Kleinstueck FS, Fekete TF, Jeszenszky D, Haschtmann D, Mannion AF (2014) Adult degenerative scoliosis: comparison of patient-rated outcome after three different surgical treatments. Eur Spine J. doi:10.1007/s00586-014-3484-7
9. Palmisani M, Dema E, Cervellati S (2013) Surgical treatment of adult degenerative scoliosis. Eur Spine J 22(Suppl 6):S829–S833. doi:10.1007/s00586-013-3012-1
10. Transfeldt EE, Topp R, Mehbod AA, Winter RB (2010) Surgical outcomes of decompression, decompression with limited fusion, and decompression with full curve fusion for degenerative scoliosis with radiculopathy. Spine (Phila Pa 1976) 35(20):1872–1875. doi:10.1097/BRS.0b013e3181ce63a2
11. Charosky S, Guigui P, Blamoutier A, Roussouly P, Chopin D (2012) Complications and risk factors of primary adult scoliosis surgery: a multicenter study of 306 patients. Spine 37(8):693. doi:10.1097/BRS.0b013e31822ff5c1
12. Lad PS, Babu GR, Ugiliweneza GB, Patil GC, Boakye GM (2014) Surgery for spinal stenosis: long-term reoperation rates, health care cost, and impact of instrumentation. Spine 39(12):978–987. doi:10.1097/BRS.0000000000000314
13. Stromqvist B, Fritzell P, Hagg O, Jonsson B, Sanden B, Swedish Society of Spinal Surgery (2013) Swespine: the Swedish spine register : the 2012 report. Eur Spine J 22(4):953–974. doi:10.1007/s00586-013-2758-9
14. Hägg O, Fritzell P, Odén A, Nordwall A (2002) Simplifying outcome measurement: evaluation of instruments for measuring outcome after fusion surgery for chronic low back pain. Spine 27(11):1213
15. Fairbank JC, Pynsent PB (2000) The Oswestry Disability Index. Spine (Phila Pa 1976) 25(22):2940–2952 **(discussion 2952)**
16. Burstrom K, Johannesson M, Diderichsen F (2001) Swedish population health-related quality of life results using the EQ-5D. Qual Life Res 10(7):621–635
17. Faul F, Erdfelder E, Lang AG, Buchner A (2007) G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 39(2):175–191
18. Cohen J (1988) Statistical power analysis for the behavioral sciences. L. Erlbaum Associates, Hillsdale
19. Fine J, Gray R (1999) A proportional hazards model for the subdistribution of a competing risk. J Am Stat Assoc 94(446):496–509. doi:10.1080/01621459.1999.10474144
20. Solberg T, Johnsen LG, Nygaard OP, Grotle M (2013) Can we define success criteria for lumbar disc surgery? Estimates for a substantial amount of improvement in core outcome measures. Acta Orthop 84(2):196–201. doi:10.3109/17453674.2013.786634
21. Todd KH, Funk KG, Funk JP, Bonacci R (1996) Clinical significance of reported changes in pain severity. Ann Emerg Med 27(4):485–489
22. Hagg O, Fritzell P, Nordwall A (2003) The clinical importance of changes in outcome scores after treatment for chronic low back pain. Eur Spine J 12(1):12–20
23. Brodke SD, Annis DP, Lawrence MB, Woodbury DA, Daubs DM (2013) Reoperation and revision rates of 3 surgical treatment methods for lumbar stenosis associated with degenerative scoliosis and spondylolisthesis. Spine 38(26):2287–2294. doi:10.1097/BRS.0000000000000068
24. Endler P, Ekman P, Möller H, Gerdhem P (2017) A prospective study on the outcome of non-instrumented posterolateral fusion, instrumented posterolateral fusion and interbody fusion in isthmic spondylolisthesis. J Bone Joint Surg Am 99(99):743–752
25. Solberg TK, Sørlie A, Sjaavik K, Nygaard ØP, Ingebrigtsen T (2011) Would loss to follow-up bias the outcome evaluation of patients operated for degenerative disorders of the lumbar spine? Acta Orthop 82(1):56–63. doi:10.3109/17453674.2010.548024
26. Højmark K, Støttrup C, Carreon L, Andersen MO (2016) Patient-reported outcome measures unbiased by loss of follow-up. Single-center study based on DaneSpine, the Danish spine surgery registry. Eur Spine J 25(1):282–286. doi:10.1007/s00586-015-4127-3