Original Clinical Article

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Anterior *versus* posterior fusion surgery in idiopathic scoliosis: a comparison of health-related quality of life and radiographic outcomes in Lenke 5C curves - results from the Swedish spine registry

Anastasios Charalampidis[1,2]
Hans Möller[1,3]
Paul Gerdhem[1,2]

Abstract

Purpose To compare health-related quality of life and radiographic outcomes in patients treated with either anterior or posterior fusion surgery for Lenke 5C type idiopathic scoliosis.

Methods We used data from the Swedish spine registry and identified 59 patients with idiopathic scoliosis treated with fusion for Lenke 5C type curves; 27 patients underwent anterior surgery and 32 underwent posterior surgery. All patients had pre- and postoperative radiographic data and postoperative clinical data at a minimum of two years after surgery. Patient-reported outcomes measures included the Scoliosis Research Society (SRS)-22r, EuroQoL 5 dimensions 3 levels (EQ-5D-3L), EQ-visual analogue scale (VAS) and VAS for back pain. Radiographic assessment included measurement of the angle of the major curve, disc angulation below the lowest instrumented vertebra, curve flexibility, rate of curve correction, differences in sagittal parameters, number of fused vertebrae and length of fusion.

Results The mean age at surgery was 16 years in both groups. The mean follow-up time was 3.8 years. There were no significant differences in the SRS-22r score and EQ-5D-3L index at follow-up (all $p \geq 0.2$). Postoperatively, both the anterior and posterior fusion group demonstrated a significant correction of the major curve ($p \leq 0.001$) with no significant difference of the correction rate between the groups ($p = 0.4$). The posterior fusion group had shorter operative time ($p < 0.001$) and higher perioperative blood loss ($p = 0.004$) while the anterior group had lower number of fused vertebrae ($p< 0.001$).

Conclusion The type of surgical approach for Lenke 5C curves is not associated with differences in health-related quality of life, despite the lower number of fused vertebrae after anterior surgery.

Level of Evidence: III

Cite this article: Charalampidis A, Möller H, Gerdhem P. Anterior *versus* posterior fusion surgery in idiopathic scoliosis: a comparison of health-related quality of life and radiographic outcomes in Lenke 5C curves - results from the Swedish spine registry. *J Child Orthop* 2021;15:464-471. DOI: 10.1302/1863-2548.15.210049

Keywords: idiopathic scoliosis; anterior fusion surgery; posterior fusion surgery; clinical outcome; quality of Life

Introduction

Thorarolumbar/lumbar curves (Lenke 5C) are curve types seen in patients with idiopathic scoliosis; surgical treatment of these curves may be performed by either anterior or posterior approaches.

Anterior surgery allows excellent control of the deformity with inclusion of fewer fusion levels and sparing of posterior paraspinal musculature.[1-4] Limitations of the anterior approach include higher pseudarthrosis rates, visible scars causing cosmetic problems, kyphosis tendency and possible injuries to adjacent organs.[5] In addition, reports of persisting pulmonary dysfunction after anterior surgery has been a concern,[6] but these findings have recently been challenged.[2]

Posterior spinal instrumentation started to evolve with the introduction of the Harrington rod in the 1960s[7] and was broadly popularized lately after the introduction of pedicle screw fixation systems; advocates of posterior surgery have reported better rates of correction, better sagittal alignment and similar complication rates compared with the anterior approach.[5,8,9] However, this method is associated with extensive soft-tissue dissection and longer fusion constructs compared to anterior surgery.[10]

[1] Department of Clinical Science, Intervention and Technology (CLINTEC), Karolinska Institutet
[2] Department of Reconstructive Orthopaedics, Karolinska University Hospital, Stockholm, Sweden
[3] Stockholm Center for Spine Surgery, Stockholm, Sweden

Correspondence should be sent to Anastasios Charalampidis, MD, Department of Clinical Science, Intervention and Technology (CLINTEC), Karolinska University Hospital, 141 86 Stockholm, Sweden.
E-mail: anastasios.charalampidis@sll.se

To date, the optimal approach for thoracolumbar/lumbar curves is still under debate with advocates on both sides. Moreover, studies with longer term follow-up comparing quality of life in patients with anterior and posterior surgery are limited.

The aim of this study was to compare clinical and radiographic outcomes in individuals with idiopathic scoliosis treated with anterior or posterior surgery for a major structural thoracolumbar or lumbar curve with non-structural thoracic curve(s) and the central sacral vertical line medial to the lumbar apex classified as Lenke type 5C.[11] The study design was retrospective on prospectively and consecutively collected data from the Swedish spine registry (Swespine).

Materials and methods

The Swedish spine registry (Swespine), includes data on spine surgical procedures in Sweden and has included data on spinal deformities since 2007.[12] Information regarding surgical procedures and diagnosis are reported by the surgeon to the Swespine registry, with a high degree of accuracy.[13] Patients treated for spinal deformity answer the Scoliosis Research Society-22 revised version (SRS-22r)[14] and EuroQoL 5 dimensions 3 levels (EQ-5D-3L)[15] at the two- and five-year follow-up without the assistance of healthcare personnel.

Participants were included in this study if they met the following criteria: 1) surgically treated for idiopathic scoliosis at ages ten to twenty years; 2) had postoperative patient-reported follow-up data at a minimum of two years; 3) had available radiographs pre- and postoperatively; 4) had a Lenke 5C type scoliosis and; 5) received either anterior or posterior surgery.

A total of 59 patients met the inclusion criteria (Fig. 1).

Patient demographics and surgeon-reported data

Patient demographic data including age at the time of surgery, sex and body mass index (BMI) were collected from the registry. Surgical data including operating time, type of surgery, blood loss, transfusion during surgery, operated vertebrae, complications and length of stay at the hospital (LOS) were reported at the time of discharge.

Patient-reported outcome measures

Health-related quality of life was assessed by the scoliosis specific SRS-22r and the generic quality of life instrument EQ-5D-3L, EQ-visual analogue scale (VAS) [15] and VAS for back pain[16].

The SRS-22r questionnaire contains five domains; pain, appearance, mental health, activity and satisfaction and is used to calculate the subscore (excluding the satisfaction

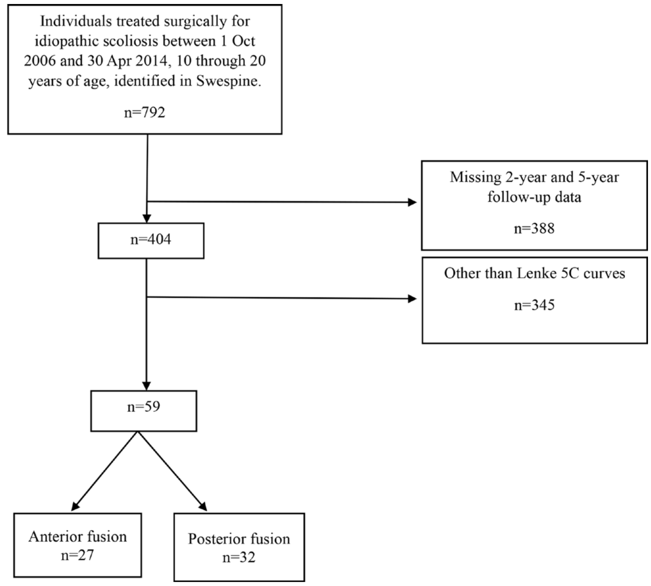

Fig. 1 Flowchart for the inclusion of the patients in the study.

domain) and the total score. Domain, subscore and total score range from 1 (worst) to 5 (best).[14]

The EQ-5D-3L reflects the societal view of health and is a non-disease-specific instrument designed to measure and value health-related quality of life. The UK-tariff was used. It ranges from -0.59 (worst) to 1.00 (best).[15] The EQ-VAS ranges from 0 (worst imaginable health state) to 100 (best imaginable health state).

VAS for back pain ranges from 0 (no pain) to 100 (worst possible pain).[16]

Radiographic outcomes

Each individual's preoperative and postoperative radiographs were analyzed by one of the authors, AC, not involved in patient care.

Preoperative radiographs were analyzed for primary curve coronary angle as measured by the Cobb technique, thoracic kyphosis Th2-Th12, lumbar lordosis L1-S1, direction of the convexity of the major curve, major curve flexibility on bending films according to the formula: (preoperative Cobb angle - bending Cobb angle)/(preoperative Cobb angle) × 100%[17] and classification of the curves according to the method proposed by Lenke et al.[11]

The parameters examined on postoperative radiographs were the angle of the major curve as measured by the Cobb technique and sagittal parameters such as thoracic kyphosis Th2-Th12 and lumbar lordosis L1-S1. The coronal angulation of the disc below the lowest instrumented vertebra (LIV) was measured as the angulation in degrees of the inferior endplate of the LIV relative to the superior endplate of the next caudal vertebra. Major curve correction was calculated according to the formula:

(Preoperative Cobb angle – Postoperative Cobb angle / (preoperative Cobb angle) × 100%.[17]

Number of screws, hooks and rods was recorded on the postoperative radiographs. The number of fused vertebrae was determined by counting the number of instrumented vertebrae. The implant density was calculated as the total number of screws divided by number of levels fused.[13] Distributions of the upper instrumented vertebra (UIV) and LIV were calculated.

Radiographic follow-up time was regarded as the time between the surgery and the last available radiograph.

Reoperation rate

Data on any reoperations was searched for in the Swespine registry until 12 September 2017.

Statistical analysis

Descriptive data are presented as mean (SD) or number (%). The *t*-test was used for continuous variables and the Pearson chi-squared test or Fisher's exact test was used for categorical variables. Two tailed paired sample *t*-test was used for within the group comparisons. Variables suggested to have an impact on outcome were entered as covariates in the analysis of covariance, sex, age at surgery and number of fused vertebrae.

In the main analysis, we used the longest possible follow-up data; five years in 35 patients and two years in 24 patients, giving a mean follow-up of 3.8 years. In secondary analyses only patients with two-year data were used (n = 52).

Statistical significance was set at p < 0.05. IBM SPSS statistical software version 26 was used for the analyses (IBM SPSS Statistics for windows; Armonk, New York, United States).

Results

Baseline characteristics are shown in Table 1. There were 27 patients in the anterior group and 32 in the posterior group. There were no significant differences in sex distribution, age at surgery and BMI between the two groups. Both groups had similar major curve magnitude and similar major curve flexibility. Sagittal parameters did not differ significantly between the groups. There was no significant difference in the distribution of the apex vertebra between the two groups (p = 0.2) (Fig. 2).

At the mean 3.8-year (range 2-5 years) follow-up time there were no statistically significant differences in the SRS-22r domain scores or in the total score between the anterior and the posterior fusion group (all p ≥ 0.2). Similarly, EQ-5D-3L index, EQ-VAS and VAS for back pain scores did not differ significantly between the anterior and the posterior fusion group (all p ≥ 0.6) (Table 2).

A sub-analysis of patients with two-year follow-up data did not reveal any statistically significant difference in SRS-22r scores, EQ-5D-3L, EQ-VAS and VAS for back pain scores between the anterior and posterior fusion group (all p ≥ 0.08) *(data not shown)*.

The mean average number of fused vertebrae was significantly higher in the posterior group (9 (SD 3) *versus* 5 (SD 1); p < 0.001). Of all 763 implants used, 761 (99.7%) were pedicle screws and two were hooks. The mean number of implants was significantly higher in the posterior group compared with the anterior group (16 (SD 5) *versus* 10 (SD 1); p < 0.001). There was no statistically significant difference in implant density between the anterior and posterior group (1.9 (SD 0.2) *versus* 1.7 (SD 0.2); p = 0.07, adjusted for number of fused vertebrae). In the anterior group, single rod constructs with one screw in each vertebra were used in one (4%) patient, single rod constructs with two screws in each vertebra were used in nineteen (70%) patients, while seven (26%) patients had dual rod constructs with two screws in each vertebra. Dual rod constructs were used in all patients in the posterior group.

Duration of surgery was significantly longer in the anterior group (272 mins (SD 83) *versus* 182 mins (SD 89); p < 0.001) while blood loss was higher in the posterior group (705 (SD 617) *versus* 324 (SD 276); p = 0.004). In total, 57 patients required blood transfusion during surgery. Fisher's exact test did not reveal any difference in transfusion rates between the anterior and posterior group (p = 0.8). The average LOS did not differ between the anterior and the posterior groups (8 (SD 2) *versus* 7 (SD 2); p = 0.053) (Table 3).

Postoperatively, both groups demonstrated a significant reduction in the magnitude of the major curve (p < 0.001) (Table 4). Postoperative angle of the major curve as measured by the Cobb technique, thoracic kyphosis, lumbar lordosis and major curve correction did not differ significantly between the two groups (all p ≥ 0.2). There was a significant difference in UIV distribution (p < 0.001); in the posterior group, 65% of the constructs ended above the level of Th10 while in the anterior group, the most cranial instrumented vertebra was Th10 (26%) and the most common UIV was Th11 (52%). Significant differences in lower instrumented vertebra distribution were also observed (p = 0.034); in the posterior group there was a higher percentage of LIV below the level of L3 compared with the anterior group (34% *versus* 11%). The most caudal instrumented vertebra in the posterior group was L5 (6%) while in the anterior was L4 (11%). There was also a significant difference in disc angulation below the LIV; the anterior group resulted in significantly higher disc angulation below the LIV compared to the posterior group (6 (SD 4) *versus* 3 (SD 3); p = 0.001) (Table 3).

Subgroup analysis between patients having UIV at the level of Th10 and those fused with longer constructs,

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Table 1 Demographic and radiographic data at baseline (n = 59)

	Anterior fusion group (n = 27)	Posterior fusion group (n = 32)	p-value
Females (%)	25 (*92*)	28 (*87*)	0.7┬
Mean age, yrs (SD)	16 (1.9)	16 (1.7)	0.5±
Mean BMI (SD)	21 (2.6)	20 (4)	0.6±
Radiographic data			
Mean preoperative major curve angle, ° (SD)	48 (7)	48 (10)	0.9±
Mean preoperative thoracic kyphosis Th2-Th12, ° (SD)	37 (11)	35 (12)	0.5±
Mean preoperative lumbar lordosis L1-S1, ° (SD)	52 (10)	54 (10)	0.4±
Major curve flexibility (%)	57 (*25*)	56 (*25*)	0.8±
Left sided convexity of the major curve (%)	23 (*85*)	27 (*84*)	0.9±
Sagittal modifier	-	-	0.2±
-	1	4	
N	24	21	
+	2	5	

Descriptive data presented as mean (sd), range or as a number (%)
BMI, body mass index
┬ chi-squared test
± independent samples t-test

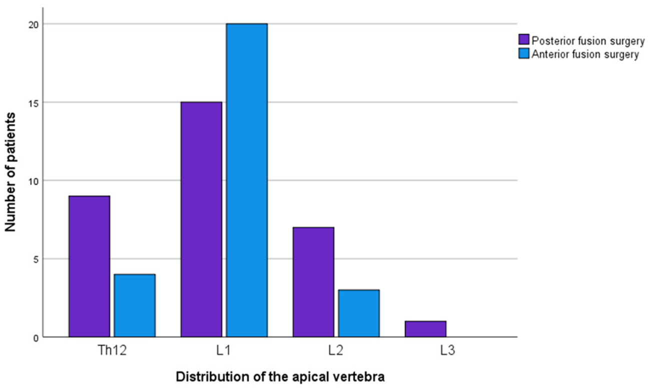

Fig. 2 Distribution of the apex vertebra between the two groups.

above Th10 vertebra, did not reveal significant differences in patient-reported outcome scores (all $p \geq 0.3$). Similarly, there were no significant differences in patient-reported outcome scores between patients having LIV at the level of L3 or below (all $p \geq 0.05$) (data not shown).

Reoperation rate

A total of eight (14%) reoperations were noted in this cohort; six in the posterior group and two reoperations in the anterior group ($p = 0.3$). Reasons for reoperation were the following: four due to curve progress, three due to a malpositioned screw and one due to pseudarthrosis. The mean time for reoperation was 16 months (SD 10) after index surgery.

Discussion

In this nationwide study, we explored clinical and radiographic outcomes in patients treated with either anterior or posterior fusion surgery for idiopathic scoliosis. The key finding of the current study was that both anterior and posterior fusion surgery are effective for correction of Lenke 5C scoliotic curves, with similar clinical and radiographic outcomes at the mean 3.8-year follow-up.

The primary aim in surgery for idiopathic scoliosis is to avoid further progression of the scoliotic curve that might lead to future complications and low quality of life. Thus, correction of the scoliotic curves in order to achieve a well-balanced spine is considered paramount. Nevertheless, there is still some grade of debate as to whether anterior or posterior fusion surgery is the optimal approach to accomplish that; with only few reports in the literature comparing these two approaches. Moreover, long-term outcome studies are limited.[18] Recently, Miyanji et al[3] reported no difference in SRS-22r scores at two-year follow-up in a cohort of 161 patients treated with either anterior or posterior fusion surgery. In keeping with Miyanji et al[3] are the results reported recently by O'Donnell et al;[4] in a retrospective study, 149 patients with Lenke 5C were operated with either anterior or posterior fusion surgery; at two-year follow-up, no differences were noted in clinical outcome scores. Similarly, Dong et al,[19] in a retrospective analysis of 65 patients with Lenke 5C curves found no differences in SRS-22r scores or Short Form (SF)-36 scores at a mean four-year follow-up. Our results are fairly consistent with previous reports that showed no differences in the SRS scores between the anterior and posterior fusion group; the highest SRS-22r score was observed in the function domain in both groups, indicating satisfactory performance after surgery, not affected by the difference in surgical approach.

In the present study, longer fusion constructs were observed in the posterior fusion group; on average posterior fusion involved four additional segments compared with anterior fusion. This is consistent with previous reports showing up to four segment's difference in fusion length when it comes to posterior surgery.[20] In our cohort, these additional levels were largely explained by a larger variation in UIV selection in the posterior fusion

Table 2 Patient-reported outcome scores at the mean 3.8-year follow-up (n = 59)

	Anterior fusion group (n = 27)	Posterior fusion group (n = 32)	Unadjusted p-value	Adjusted p-value
SRS-22r function	4.3 (0.7)	4.2 (0.7)	0.5±	0.2‡
SRS-22r pain	3.9 (1)	3.9 (1)	0.8±	0.7‡
SRS-22r self-image	4.0 (0.7)	3.9 (1)	0.5±	0.3‡
SRS-22r mental health	3.7 (0.8)	3.6 (1)	0.6±	0.3‡
SRS-22r satisfaction	4.2 (0.8)	4 (1)	0.6±	0.3‡
SRS-22r total score	4.0 (0.7)	3.9 (0.9)	0.8±	0.3‡
EQ-5D-3L	0.78 (0.24)	0.76 (0.33)	0.8±	0.8‡
EQ-VAS	74 (20)	78 (22)	0.4±	0.8‡
VAS for back pain	27 (27)	26 (26)	0.9±	0.6‡

Descriptive data presented as means (SD)
The p-values are unadjusted or adjusted for sex, age at surgery and number of fused vertebrae
SRS, Scoliosis Research Society questionnaire; EQ-5D-3L, EuroQol 5 dimensional quality of life questionnaire, 3 level; EQ-VAS, EuroQol visual analogue scale measuring quality of life
± Analysis of variance
‡ Analysis of covariance

Table 3 Inpatient and radiographic postoperative data (n = 59)

	Anterior fusion group (n = 27)	Posterior fusion group (n = 32)	Unadjusted p-value	Adjusted p-value
Inpatient data				
Mean fused vertebrae (SD)	5 (1)	9 (3)	**< 0.001±**	
Mean duration of surgery, mins (SD)	272 (83)	182 (89)	**< 0.001±**	
Mean blood loss, ml (SD)	324 (276)	705 (617)	**0.004±**	
Mean length of stay, days (SD)	8 (2)	7 (2)	0.053±	
Radiographic data				
Mean postoperative major curve angle, ° (SD)	17 (10)	17 (9)	0.9±	0.7‡
Mean postoperative thoracic kyphosis Th2-Th12, ° (SD)	37 (11)	39 (13)	0.6±	0.7‡
Postoperative lumbar lordosis L1-S1, ° (SD)	52 (13)	53 (10)	0.8±	0.9‡
Major curve correction (%)	68 (*18*)	65 (*17*)	0.7±	0.4‡
Mean radiographic follow-up, mths (SD)	22 (28)	19 (18)	0.6±	0.08‡
UIV distribution (%)			**< 0.001±**	
Th9 or above	0 (*0*)	21(*65*)		
Th10	*7* (*26*)	5 (*16*)		
Th11	14 (*52*)	5 (*16*)		
Th12	6 (*22*)	0 (*0*)		
L1	0 (*0*)	1 (*3*)		
LIV distribution (%)			**0.034±**	
L1	0 (*0*)	0 (*0*)		
L2	4 (*15*)	0 (*0*)		
L3	20 (*74*)	21 (*66*)		
L4	3 (*11*)	9 (*28*)		
L5	0 (*0*)	2 (*6*)		
Mean disc angle below LIV, ° (SD)	6 (4)	3 (3)	**0.001±**	

Descriptive data presented as mean (SD), range or as a number (%)
The p-values are unadjusted or adjusted for sex, age at surgery and number of fused vertebrae
UIV, upper instrumented vertebra; LIV, lower instrumented vertebra
Bold values indicate statistical significance (p< 0.05)
± Analysis of variance
‡ Analysis of covariance

Table 4 Postoperative radiographic changes in the two groups (n = 59)

	Anterior fusion group (n = 27)			Posterior fusion group (n = 32)		
	Preoperative	Postoperative	p-value	Preoperative	Postoperative	p-value
Major curve angle, ° (SD)	48 (7)	17 (10)	**< 0.001†**	48 (10)	17 (9)	**< 0.001†**
Thoracic kyphosis Th2-Th12, ° (SD)	37 (11)	38 (11)	0.7†	35 (12)	38 (13)	0.07†
Lumbar lordosis L1-S1, ° (SD)	52 (10)	53 (11)	0.8†	54 (10)	53 (10)	0.3†

Descriptive data presented as mean (SD)
Bold values indicate statistical significance (p< 0.05)
† Paired samples t-test

group; interestingly, in 65% of the patients in the posterior group UIV selection was noted at or above the level of Th9, while none of the patients in the anterior group had UIV above the level of Th10. While still controversial, extended fusion to the thoracic curve in Lenke 5C curve types was reported in previous studies;[21] in cases of stiffer thoracic curves, in order to decrease the risk for coronal decompensation and curve progression.[22] Similarly, there was a higher percentage of LIV selection at the level of L4 or below in the posterior fusion group than the anterior fusion group (34% *versus* 11%). Two patients in the posterior fusion group had LIV at the level of L5; although rare, fusion to L5 in Lenke 5C curves was also reported in previous studies.[23] Theoretically, a shorter fusion may give the advantage of lower loading of the lumbar segments and, therefore, less degeneration of the lumbar spine over time. However, the clinical significance of a shorter fusion in still unclear.[24] Danielsson and Nachemson[25] found no difference in clinical outcome -measured by the SF-36 23 years after index surgery for idiopathic scoliosis between patients that had fusion ending below the level of L3 *versus* those with fusion ending more proximally in the lumbar spine. The results of this study were recently challenged by Diarbakerli et al;[26] in a subgroup analysis of 381 surgically treated patients for idiopathic scoliosis, the authors demonstrated that adding fusion levels distally in the lumbar spine may have a negative impact on quality of life, mainly driven by differences in the function domain of the SRS-22r. Although not a subject of investigation in the current study, we found no significant relationship between caudal level of fusion and clinical outcome. However, our sample size was not large and, therefore, these differences may not have been detected by our analysis.

While anterior fusion surgery has the advantage of a shorter fusion, it comes at the expense of a higher disc angulation below the LIV, as reported in the current and other studies.[3,4] Controversy still exists; several investigators have raised concerns on the impact of disc degeneration secondary to disc angulation below the fusion mass[27] while others have found that preserving more levels below the LIV is beneficial in order to decrease the incidence of lumbar back pain.[1] At short-term, these radiological differences do not seem to affect patient reported outcome. Long-term follow-up studies are needed to address this knowledge gap.

Although posterior fusion surgery was found to be associated with longer fusion constructs, duration of surgery was significantly shorter compared with anterior fusion surgery. In contrast, perioperative blood loss was significantly higher in the posterior group; not unexpected since posterior fusion is generally associated with more extensive soft-tissue exposure and longer fusion segments.[10] However, these differences did not have an impact on clinical outcome as seen in the current and previous studies.[3,4]

In the present study there were no differences in radiographic outcomes between the anterior and posterior fusion groups, with the exception of a higher disc angulation below the LIV in the anterior group. Postoperatively, both groups demonstrated a significant improvement of the major scoliotic curve with similar correction rates. While earlier studies indicated a greater correction of the major curve by anterior fusion surgery,[28] recent developments in fixation techniques with the introduction of pedicle screw systems allowed for greater amount of correction with posterior only approaches.[9] Consequently, more recent reports found no significant differences between anterior and posterior techniques in the surgical treatment of patients with idiopathic scoliosis.[3,4,10] While previous investigators showed that posterior fusion may result in better sagittal plane correction,[8,9] in our study, both techniques resulted in similar sagittal radiographic outcomes and no significant changes of the sagittal parameters were noted after surgery compared with baseline. Possibly, restoring the sagittal profile was not the primary goal of surgery in this cohort since baseline data showed sagittal parameter values within the normal range.

Although there was no significant difference in the reoperation rate between anterior and posterior fusion surgery, three patients, all from the posterior group, were reoperated due to a malpositioned pedicle screw causing persistent postoperative radicular pain. Malpositioning of screws is a known complication in posterior fusion surgery and has been reported in up to 9% of cases.[29]

This study has some limitations. First, it is a registry-based study and the analysis of prospectively collected data was conducted retrospectively. Secondly, baseline quality of life data was not available in the registry for the majority of the patients in this cohort and, therefore, not included in the analysis. Moreover, there was no information about the number and experience of the involved surgeons, which has previously been reported to have a possible impact on outcome.[30] However, all spine deformity surgeons in Sweden have several years of experience with both anterior and posterior surgery. A formal cost-effectiveness analysis was not performed. The implant cost is probably lower in the anterior group, but on the other hand the duration of surgery was longer. In some countries there may be a need for and cost of an access surgeon in anterior surgery, but in Sweden anterior access is performed by the spine deformity surgeon. Although comparable with previous studies, the follow-up time in this cohort is relatively short. Longer follow-up time would be desirable in order to evaluate long-term outcomes of fusion surgery in idiopathic scoliosis. Measurements of the correction of rotational deformity were not performed on postoperative radiographs due to implants obscuring the assessment of rotation. However, Vavruch et al,[20] in a retrospective study of 53 patients treated with either anterior or posterior surgery for Lenke type 1 curves, found no difference in vertebral axial rotation between the groups at two-year follow-up. Finally, all radiographic assessment was conducted by one researcher.

The study is strengthened, however, by its nationwide sample giving the data high external validity, reflecting different surgical traditions and strategies in the treatment of these scoliotic curves.

Conclusion

In this nationwide study, there were no significant differences in quality of life assessed with SRS-22r and EQ-5D-3L between anterior and posterior fusion surgery in patients with idiopathic scoliosis. The current results indicate that both anterior and posterior surgery could be offered for patients with idiopathic scoliosis and that equal clinical patient-reported outcome could be expected with the use of either method.

Received 02 March 2021, accepted after revision 07 September 2021

COMPLIANCE WITH ETHICAL STANDARDS

ACKNOWLEDGEMENTS

Carina Blom for assisting with data retrieval from Swespine. David Hacksell for a preliminary analysis of Swespine data before decision on how to proceed to the final data extraction for this report.

FUNDING STATEMENT

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

ETHICAL STATEMENT

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The Regional Ethical Review Board in Stockholm approved the study (Dnr: 2012/172-31/4).

Informed consent: As in the majority of the Swedish quality registries, patient participation in the registry Swespine is made using the opt-out method. This means that surgical information may be registered without consent, but the collected information is deleted if the patient contacts the registry. Answering the patient-reported outcome questionnaire is voluntary.

ICMJE CONFLICT OF INTEREST STATEMENT

This study was financially supported by funds from CIMED, Karolinska Institutet, Karolinska Institutet funds, Region Stockholm (ALF project). PG was supported by Region Stockholm in a clinical research appointment.

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

AC: Study design, Data collection, Data analysis, Preparation of the manuscript, Revision of manuscript, Approved the final version of the manuscript.

HM: Study design, Data collection, Data analysis, Preparation of the manuscript, Revision of manuscript, Approved the final version of the manuscript.

PG: Study design, Data collection, Data analysis, Preparation of the manuscript, Revision of manuscript, Approved the final version of the manuscript.

REFERENCES

1. **Kaneda K, Shono Y, Satoh S, Abumi K.** New anterior instrumentation for the management of thoracolumbar and lumbar scoliosis. Application of the Kaneda two-rod system. *Spine* 1996;21:1250-1261.

2. **Sudo H, Ito M, Kaneda K, Shono Y, Abumi K.** Long-term outcomes of anterior dual-rod instrumentation for thoracolumbar and lumbar curves in adolescent idiopathic scoliosis: a twelve to twenty-three-year follow-up study. *J Bone Joint Surg [Am]* 2013;95-A:e49.

3. **Miyanji F, Nasto LA, Bastrom T, et al.** A detailed comparative analysis of anterior versus posterior approach to Lenke 5C curves. *Spine* 2018;43:E285-E291.

4. **O'Donnell C, Michael N, Pan X, et al.** Anterior spinal fusion and posterior spinal fusion both effectively treat Lenke Type 5 curves in adolescent idiopathic scoliosis: a multicenter study. *Spine Deform* 2018;6:231-240.

5. **Coe JD, Arlet V, Donaldson W, et al.** Complications in spinal fusion for adolescent idiopathic scoliosis in the new millennium. A report of the Scoliosis Research Society Morbidity and Mortality Committee. *Spine* 2006;31:345-349.

6. **Gitelman Y, Lenke LG, Bridwell KH, Auerbach JD, Sides BA.** Pulmonary function in adolescent idiopathic scoliosis relative to the surgical procedure: a 10-year follow-up analysis. *Spine* 2011;36:1665-1672.

7. **Harrington PR.** Treatment of scoliosis. Correction and internal fixation by spine instrumentation. *J Bone Joint Surg [Am]* 1962;44-A:591-610.

8. **Geck MJ, Rinella A, Hawthorne D, et al.** Comparison of surgical treatment in Lenke 5C adolescent idiopathic scoliosis: anterior dual rod versus posterior pedicle fixation surgery: a comparison of two practices. *Spine* 2009;34:1942-1951.

9. **Shufflebarger HL, Geck MJ, Clark CE.** The posterior approach for lumbar and thoracolumbar adolescent idiopathic scoliosis: posterior shortening and pedicle screws. *Spine* 2004;29:269-276.

10. **Wang Y, Fei Q, Qiu G, et al.** Anterior spinal fusion versus posterior spinal fusion for moderate lumbar/thoracolumbar adolescent idiopathic scoliosis: a prospective study. *Spine* 2008;33:2166-2172.

11. **Lenke LG, Betz RR, Harms J, et al.** Adolescent idiopathic scoliosis: a new classification to determine extent of spinal arthrodesis. *J Bone Joint Surg [Am]* 2001;83-A:1169-1181.

12. **Ersberg A, Gerdhem P.** Pre- and postoperative quality of life in patients treated for scoliosis. *Acta Orthop* 2013;84:537-543.

13. **Charalampidis A, Möller A, Gerdhem P.** Implant density unrelated to outcome in 328 individuals treated for idiopathic scoliosis in the Swedish Spine register. *J Bone Joint Surg [Br]* 2018;100-B:1080-1086.

14. **Danielsson AJ, Romberg K.** Reliability and validity of the Swedish version of the Scoliosis Research Society-22 (SRS-22r) patient questionnaire for idiopathic scoliosis. *Spine* 2013;38:1875-1884.

15. **Brooks R.** EuroQol: the current state of play. *Health Policy* 1996;37:53-72.

16. **McCormack HM, Horne DJ, Sheather S.** Clinical applications of visual analogue scales: a critical review. *Psychol Med* 1988;18:1007-1019.

17. Larson AN, Polly DW Jr, Diamond B, et al. Minimize Implants Maximize Outcomes Study Group. Does higher anchor density result in increased curve correction and improved clinical outcomes in adolescent idiopathic scoliosis? *Spine* 2014;39:571-578.

18. Luo M, Wang W, Shen M, Xia L. Anterior versus posterior approach in Lenke 5C adolescent idiopathic scoliosis: a meta-analysis of fusion segments and radiological outcomes. *J Orthop Surg Res* 2016;11:77.

19. Dong Y, Weng X, Zhao H, et al. Lenke 5C Curves in Adolescent Idiopathic Scoliosis: Anterior vs Posterior Selective Fusion. *Neurosurgery* 2016;78:324-331.

20. Vavruch L, Brink RC, Malmqvist M, et al. Surgical outcomes of anterior versus posterior fusion in Lenke Type 1 adolescent idiopathic scoliosis. *Spine* 2019;44:E823-E832.

21. Hwang CJ, Lee CS, Kim H, Lee DH, Cho JH. Spontaneous correction of coronal imbalance after selective thoracolumbar-lumbar fusion in patients with Lenke-5C adolescent idiopathic scoliosis. *Spine J* 2018;18:1822-1828.

22. Sanders AE, Baumann R, Brown H, et al. Selective anterior fusion of thoracolumbar/lumbar curves in adolescents: when can the associated thoracic curve be left unfused? *Spine* 2003;28:706-713.

23. Yang X, Liu L, Song Y, et al. Pre- and postoperative spinopelvic sagittal balance in adolescent patients with lenke type 5 idiopathic scoliosis. *Spine* 2015;40:102-108.

24. Green DW, Lawhorne TW III, Widmann RF, et al. Long-term magnetic resonance imaging follow-up demonstrates minimal transitional level lumbar disc degeneration after posterior spine fusion for adolescent idiopathic scoliosis. *Spine* 2011;36:1948-1954.

25. Danielsson AJ, Nachemson AL. Back pain and function 23 years after fusion for adolescent idiopathic scoliosis: a case-control study-part II. *Spine* 2003;28:E373-E383.

26. Diarbakerli E, Grauers A, Danielsson A, Gerdhem P. Health-related quality of life in adulthood in untreated and treated individuals with adolescent or juvenile idiopathic scoliosis. *J Bone Joint Surg [Am]* 2018;100-A:811-817.

27. Kahraman SMD, Karadereler SMD, Kaya OMD, et al. Assessment of the disc and facet degeneration in the unfused lumbar spine after stopping fusion at l3 in AIS: An MRI study. how much disc wedging and residual curve can be accepted? *Spine J* 2016;16:S347.

28. Luk KD, Leong JC, Reyes L, Hsu LC. The comparative results of treatment in idiopathic thoracolumbar and lumbar scoliosis using the Harrington, Dwyer, and Zielke instrumentations. *Spine* 1989;14:275-280.

29. Ledonio CG, Polly DW Jr, Vitale MG, Wang Q, Richards BS. Pediatric pedicle screws: comparative effectiveness and safety: a systematic literature review from the Scoliosis Research Society and the Pediatric Orthopaedic Society of North America task force. *J Bone Joint Surg [Am]* 2011;93-A:1227-1234.

30. Cahill PJ, Pahys JM, Asghar J, et al. The effect of surgeon experience on outcomes of surgery for adolescent idiopathic scoliosis. *J Bone Joint Surg [Am]* 2014;96-A:1333-1339.