Outcomes of Lenke V adolescent idiopathic scoliosis treated by anterior correction and fusion

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Abstract

Background

Adolescent idiopathic scoliosis (AIS) surgical correction is required for curves progressing to exceed 40–45°, with the option of an anterior and posterior approach. Anterior correction may allow fewer lumbar levels to be fused, but there are intuitive concerns regarding diaphragmatic and pulmonary consequences, as well as overall safety. The main hypothesis of the study was that the radiographically determined pulmonary function of AIS patients who underwent anterior correction improved between pre- and postoperative assessments.

Methods

A retrospective study was conducted on 46 consecutive patients who underwent anterior correction of AIS. Among the usual data collected (Cobb angle, sagittal balance angles, demographic data, clinical scores), pre- and postoperative measurement of T1-diaphragm/T1T12 and AVDR (apical vertebra deviation ratio) ratios were used to evaluate pulmonary function.

Results

The mean correction of the Cobb angle was 53° ± 12 to 15° ± 12. The AVDR improved significantly ($p < 0.001$) from 0.18 to 0.07 postoperatively. The T1-D/T1T12 ratio ($p = 0.57$) was unchanged. Scoliosis Research Society-22 (SRS-22) scoring improved for all sub-components at follow-up.

Conclusion

Anterior correction for lumbar scoliosis provides an effective curve correction and improves the AVDR ratio, which correlates to pulmonary function (forced and total lung capacities). The unchanged T1-D/T1T12 ratio confirms no radiographic deterioration of the lung fields with diaphragmatic takedown and repair.

Level of evidence: 4

Keywords: adolescent idiopathic scoliosis, quality of life, surgery, pulmonary function, outcomes

Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional deformity of the spine, affecting 1–3% of the population, with a genetic origin.[1-3] Most cases are managed conservatively with surveillance or bracing. Curves exceeding 45° in the thoracic spine and 40° in the lumbar spine require correction and fusion surgery to prevent further curve progression and restrictive pulmonary insufficiency (curves above 70°).[4-7] Surgery may be performed either by posterior or anterior approaches.[8] Posterior approaches are particularly useful for thoracic curves (Lenke I/II), notably to correct the thoracic hypokyphosis frequently observed in AIS.[5,9-11] Anterior approaches via the thoracolumbar approach allow additional disc releases with effective correction of thoracolumbar and lumbar curves (Lenke V and VI), with fewer lumbar levels fused than with posterior approaches.[12,13] The sparing of the distal level may reduce long-term low back pain associated with lower instrumented vertebrae (LIV) distal to L3, as seen with posterior fusions.[14] However, the anterior approach requires diaphragm takedown and repair with intuitive concerns around subsequent dysfunction and respiratory consequences.[15]

Literature provides conflicting insight regarding the consequences of the approach in anterior scoliosis correction, the interpretation of the results being difficult knowing that the correction of the scoliosis itself may improve pulmonary function. However, the possible diminution of pulmonary function appears to be found mostly at early postoperative analysis, and to disappear at two years of follow-up.[13,15,16] Moreover, most series are limited in terms of cohort size and follow-up duration and do not provide a global assessment of postoperative status with health-related quality of life (HRQOL) scores.

The aim of this study was to analyse the impact of anterior scoliosis surgery in Lenke V patients on quality of life and radiographically determined pulmonary function.

Methods

A retrospective single-surgeon monocentric study was conducted on a longitudinal cohort of surgical patients who underwent AIS fusion surgery by an anterior approach in a tertiary hospital between June 2003 and June 2023. This study received ethical approval (number R039/2016). The exclusion criterion were non-idiopathic scoliosis and missing follow-up data regarding radiographic assessment or HRQOL scores.

The patients' charts were reviewed along with radiographic measurements (pre- and postoperative) by two spinal surgeons, on the preoperative and latest postoperative radiographs.

Statistical analysis

The statistical analysis was realised on XLSTAT, with t-tests; p-values lower than 0.05 were considered significant.

The data collected were:

- Demographic (preoperative): age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) score
- Clinical (preoperative and at last follow-up): HRQOL patient-reported outcome measure using Scoliosis Research Society-22 (SRS-22) scores
- Radiographic – spinal (preoperative and at last follow-up): type of Lenke curve, Cobb angles of the curves, thoracic kyphosis (TK), lumbar lordosis (LL), T1 tilt, sagittal vertical axis (SVA), pelvic incidence (PI), LIV disc obliquity (in degrees, only for postoperative assessment)
- Operative: upper and lower levels of instrumented fusion (UIV and LIV), surgical blood loss (% estimated blood volume [EBV]) and cc), duration of surgery, occurrence and nature of postoperative complications
- Radiographic – pulmonary function: T1T12 height (mm), T1-diaphragm (T1-D) height (mm), T1-D/T1T12 ratio, apical vertebra deviation ratio (AVDR), as defined by Deng et al.,[17] and illustrated in *Figure 1*.

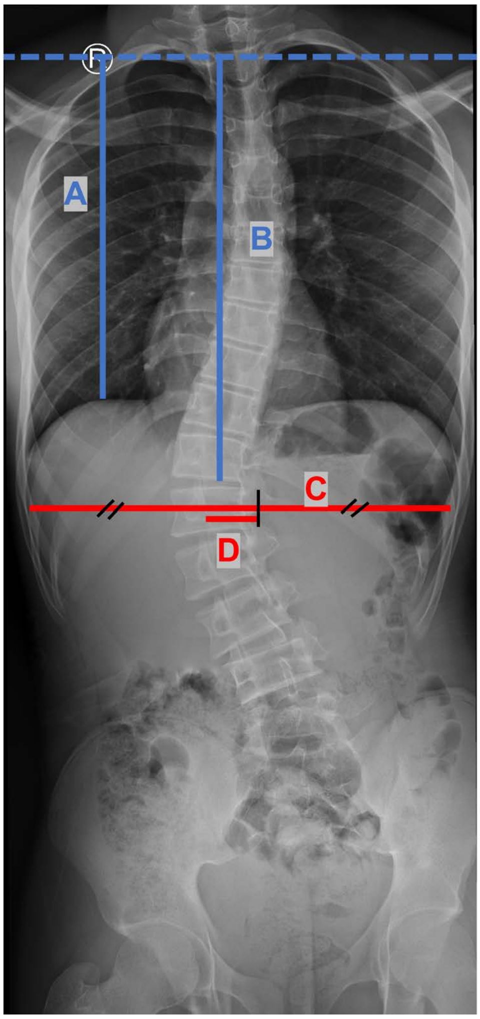

Figure 1. Anteroposterior full spine radiography. Line A represents the T1 diaphragm distance, measured in millimetres (mm). Line B represents the T1–T12 distance, in mm. The division A/B corresponds to the T1-D/T1T12 ratio. Line C is drawn at the apex vertebra and joins the two chest walls. The bisector of line C is then marked. Line D is drawn between the centre of the apex vertebral body and the bisector of line C. The division C/D corresponds to the AVDR ratio.

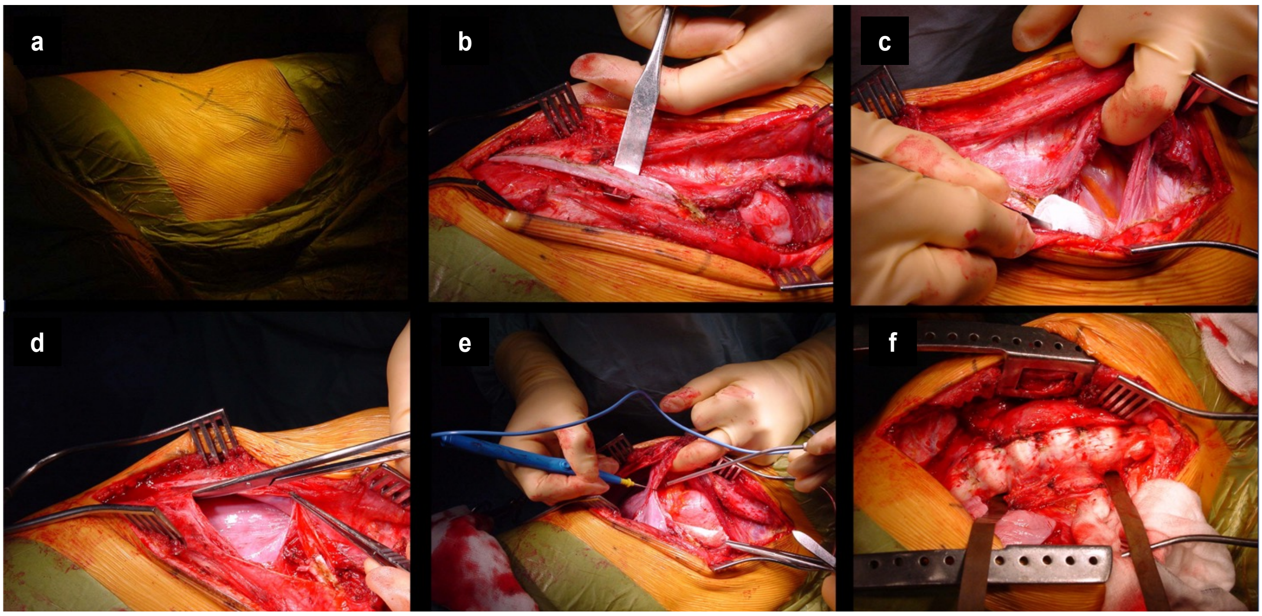

Figure 2. Intraoperative pictures of the anterior approach. Numeration of pictures from a to f refer to the 'Surgical technique' paragraph in the Methods section of the paper.

The AVDR, as defined by Deng et al., was clinically correlated on a cohort of 108 AIS patients to pulmonary function testing with 'significant negative correlation between the AVDR and predicted values of forced vital capacity (FVC%), FEV1%, predicted values of vital capacity, and predicted values of total lung capacity ($r = -0.46$ to -0.52, $p < 0.01$). The AVDR could predict the value of each of these variables. One of the linear equations is as follows: FVC% = 110.70 − 99.73 × AVDR (R2 = 0.272).'

Surgical technique

All patients were operated on by one senior spine surgeon in the lateral decubitus position, convex side of the curve up. A curvilinear incision was made along the ninth rib inferiorly to the lateral edge of the rectus, midway between the umbilicus and pubis (*Figure 2a*). The extent of this extensile approach depended on the proximal and distal access required.

The anterior third to half of the ninth rib was removed subperiosteally, and the chest opened through the rib bed. The retroperitoneal space was entered at the costal margin by splitting the cartilaginous rib remnant with diathermy (*Figures 2b* and *2c*). This plane was developed with blunt dissection, with a cottonoid/ Peanut swab on a stick, freeing the peritoneum from the abdominal wall. Once safe, the external and internal obliques, as well as the transversus muscles were cut. The blunt dissection then continued posterior to the sac, down onto the psoas and spine. The peritoneum was reflected off the undersurface of the ipsilateral diaphragm. This was then circumferentially detached with cautery, at 15–20 mm from its chest wall, coming down onto the spine where the crus and psoas meet around the T12/L1 disc (*Figures 2d and e*). The psoas was retracted posteriorly to expose the spine, attempting to minimise disruption to the sympathetic chain as much as possible (*Figure 2f*). Levels were confirmed, both anatomically with the psoas reaching the T12/L1 disc and anteroposterior (AP) fluoroscopy with a marker in place.

A copper malleable retractor was placed anterior to the disc to protect the great vessels. An annulotomy and complete discectomy were performed, cleaving the cartilage endplates off with a Cobb to visualise the bony endplates and posterior annulus/posterior longitudinal ligament (PLL).

Screws were placed in each vertebral body, parallel to the endplate and canal. A suitably contoured 6 mm rod was placed from UIV to LIV, and the apex de-rotated to the rod. Further segmental compression was applied to ensure the screws ended up parallel to each other.

The diaphragm was repaired with a continuous 1 Vicryl suture, with 5 mm increments and 10 mm on the remnant attached to the chest wall to accommodate the spontaneous retraction.

All patients had a rib block and intercostal chest drain, which was removed between days 2 and 4, according to drainage volume (< 70 ml/12 hours) and serosanguineous nature rather than bloodied.

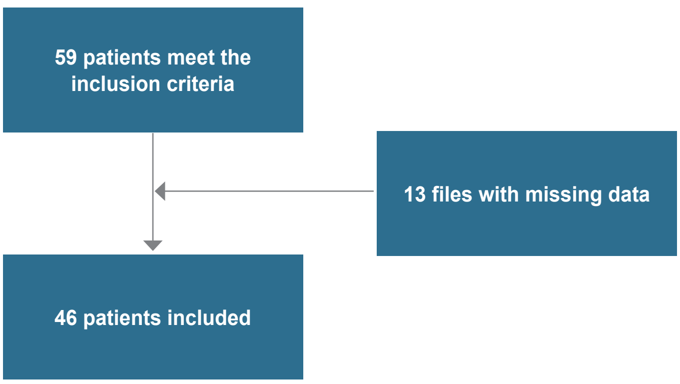

Figure 3. Flowchart of the study

Results

Patients

Forty-six patients were included in the study, after 13 were excluded for missing data. A flowchart is available as *Figure 3*. The cohort consisted of 36 females (78%) and ten males (22%). The mean age at surgery was 15.5 ± 2.2 years [9–20]. Forty patients (87%) were ASA I and the remaining six (13%) were graded ASA II. The mean follow-up duration was 21.8 months ± 18 [6–80].

Surgical data

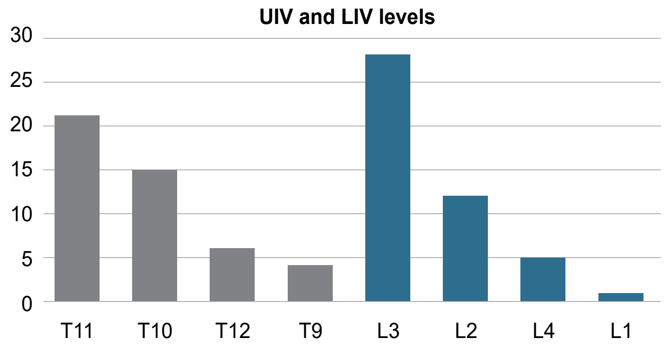

Figure 4. Histogram representing the distribution of UIV (upper instrumented vertebra) levels (in grey) and LIV (lower instrumented vertebra) levels (in blue)

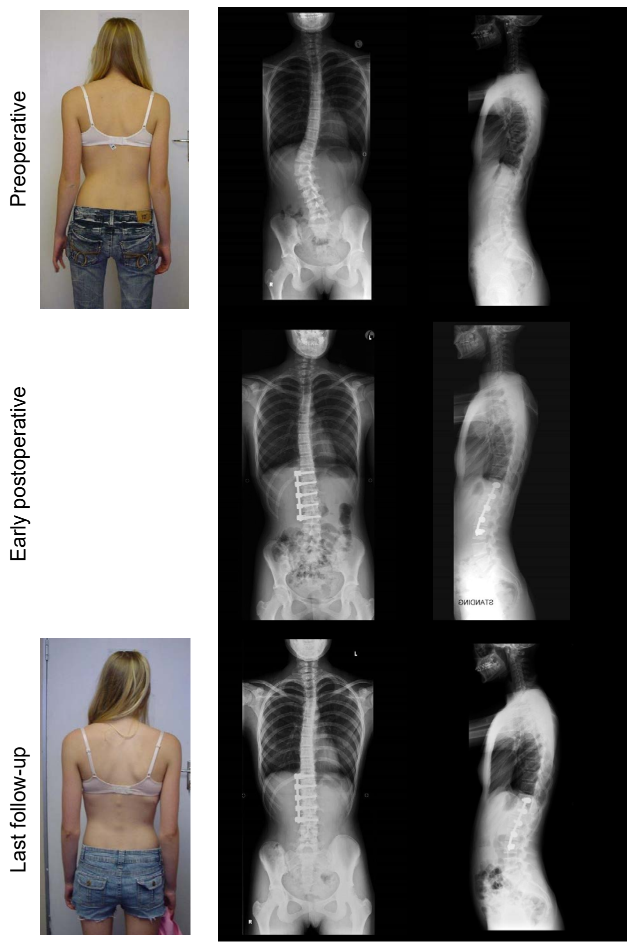

Figure 5. Clinical picture, anteroposterior (AP) and lateral radiographs of the spine, preoperatively, at early follow-up and last follow-up

Table I: Pre- and postoperative values of the radiographic parameters of the cohort, expressed with mean value ± standard deviation (SD) and [minimum; maximum]

		Preoperative	Postoperative	p-value
Cobb main curve (°)		53 ± 12; [32–83]	15 ± 12; [0–39]	< 0.001**
Cobb proximal curve (°)		26 ± 10; [8–50]	15 ± 10; [0–43]	< 0.001**
Cobb distal curve (°)		20 ± 9; [0–34]	9 ± 7; [0–39]	< 0.01*
T1 tilt (°)		4 ± 4; [1–22]	3 ± 2; [0–9]	0.17
TK (°)		41 ± 13; [20–62]	42 ± 12; [19–66]	0.24
LL (°)		50 ± 15; [20–80]	46 ± 13; [26–66]	0.44
PI (°)		52 ± 13; [35–73]	49 ± 12; [25–70]	0.26
PI-LL mismatch (°)		0 ± 17; [−35–25]	2 ± 12; [−28–27]	0.44
SVA (mm)		1 ± 27; [−58–75]	5 ± 25; [−38–75]	0.46
T1-T12 height (mm)		242 ± 28; [186–327]	247 ± 24; [178–308]	0.58
T1-D height (mm)		183 ± 31; [109–257]	189 ± 27; [128–255]	0.61
Ratio T1-D/T1T12		0.75. ± 0.09; [0.51–0.91]	0.76 ± 0.08; [0.53–0.89]	0.57
AVDR	mean	0.18 ± 0.05; [0.07–0.30]	0.07 ± 0.04; [0–0.24]	< 0.001**
	n > 0.2	15 (32%)	2 (4%)	
Disc obliquity at LIV (°)			5.8 ± 3.9; [0–16]	

* significant; ** very significant; TK: thoracic kyphosis; LL: lumbar lordosis; PI: pelvic incidence; SVA: sagittal vertebral axis; T1-D: T1-diaphragm; AVDR: apical vertebra deviation ratio; LIV: lower instrumented vertebra

Table II: Pre- and postoperative values (mean value, min, max, SD) of the SRS-22 total scores and its sub-component

		Function	Pain	Self-image	Mental health	Satisfaction	Total
Preop	Mean	3.63	2.80	2.60	2.30		3.57
	Min	2.20	3.60	2.40	2.40		2.70
	Max	4.40	3.60	2.40	2.40		4.50
	SD	0.62	0.87	0.58	0.58		0.52
Postop	Mean	2.00	2.80	2.20	5.00	3.60	3.65
	Min	2.60	2.00	2.80	2.20	5.00	2.70
	Max	4.60	2.00	2.80	2.20	5.00	4.40
	SD	0.67	0.55	0.78	0.61	1.39	0.62

min: minimum; max: maximum; SD: standard deviation; SRS: Scoliosis Research Society

The mean duration of surgery was 148 minutes ± 25 [100;196]. The mean blood loss was 423 cc ± 228 [150;1 200], corresponding to 10.8 ± 6 [4;31] %EBV. The mean number of levels fused was 5.7 ± 0.7 [4;7]. The distribution of UIV and LIV is shown in *Figure 4*. There were no neurological complications. All but one chest tube drains were removed before day 4 postoperative (one patient suffered from pleural effusion, requiring surveillance and additional drainage duration, with favourable outcome).

Radiographical results

The thoracolumbar mean Cobb angle improved from 53° ± 12; [32–83] preoperatively to 15° ± 12; [0–39], p < 0.001 postoperatively, with the proximal and distal contra-curves improving from 26° ± 10 [8–50] to 15° ± 10; [0–43], p < 0.001, and 20° ± 9; [0–34] to 9° ± 7; [0–39], p < 0.01, respectively (*Table I*).

The AVDR improved significantly (p < 0.001) from 0.18 ± 0.05; [0.07–0.30] preoperatively to 0.07 ± 0.04; [0–0.24] postoperatively. Thirty-two per cent of the patients had an AVDR greater than the 0.2 threshold in preoperative versus only 4% postoperatively. A clinical example of correction is shown in *Figure 5*.

The radiographic data are summarised in *Table I*.

Clinical results

The postoperative assessment of SRS-22 revealed an improvement in the total score, as well as in all components (*Table II* and *Figure 6*). The improvement reached minimally clinically significant

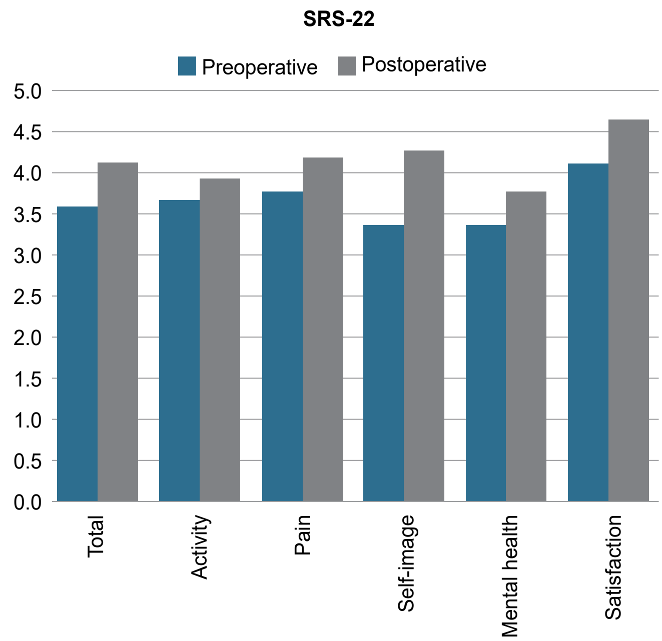

Figure 6. Histogram representing the value for the cohort of the pre- and postoperative values of the SRS-22 scores and its sub-components

difference (MCID), as defined in AIS patients by Carreon et al. for activity (0.08) and pain (0.2).[18]

No significant correlation was found between postoperative AVDR and postoperative SRS total score (p = 0.18) or its sub-domains (activity: p = 0.13, pain p = 0.09, appearance: p = 0.47, mental health: p = 0.33, and satisfaction: p = 0.59).

Preoperative VAS (back pain) was 2.3 ± 1.8, [0;6] and at follow-up 1.9 ± 1.3, [0;5], with no significant difference (p = 0.31).

Discussion

The results confirm a significant improvement in radiographic pulmonary metric AVDR and patient-reported outcome measure SRS-22 total score, including all sub-scores. Moreover, the ratio of patients presenting with an AVDR > 0.2, indicating pulmonary dysfunction, decreased from 32% of the cohort to 4% postoperatively, confirming the efficiency of anterior fusion to correct, not only the spinal curves, but also the chest cage deformity in the axial plane. Those results on AVDR come along with an excellent Cobb angle correction (53° ± 12 versus 15° ± 12 in postoperative), supporting the findings of Little et al., who found a statistically significant correlation between the postoperative Cobb angle and chest wall angle (CWA).[19] This 72% Cobb angle correction is superior to most posterior fusion series. It may be explained by the more flexible thoracolumbar and lumbar region as they are not attached to ribs. However, it may well be due to the surgical technique of complete annulotomy and discectomy, allowing more effective reduction of the vertebral bodies into the desired position for fusion.[20-22] Although the meta-analysis of Franic et al. failed to prove better coronal reduction with anterior approach, several studies have demonstrated the better correction of apical vertebra rotation with anterior approaches.[8] This may reshape of the chest cavity to a straighter position, allowing the pleural cavities to expand.[23,24] The clinical results are comparable to similar series in the literature, treated by anterior or posterior fusion.[25,26]

The T1-D/T1T12 ratio remained equal at postoperative follow-up, negating the concerns around diaphragmatic ascension due to dehiscence, dysfunction or atelectasis. It therefore highlights the special attention that must be paid to the surgical technique, as the diligent repair of the diaphragm after the approach might be crucial in limiting its pulmonary consequences.

Regarding sagittal balance, no significant changes between pre- and postoperative parameters were measured, with normal parameters at both times of assessment. Importantly, there was no loss of thoracic kyphosis (41° ± 13; [20–62] versus 42° ± 12; [19–66]).

Study limitations are notably inherited from its retrospective design and due to the sample size. The use of AVDR instead of functional pulmonary testing may also be criticised. However, the relationship between AVDR and pulmonary function (forced vital capacity and total lung capacity) has been studied by et Deng al. on a cohort of 108 AIS patients, and AVDR has been demonstrated to be a moderate-to-strong predictor of pulmonary function outcome, eligible to replace pulmonary testing.[17] Moreover, thoracic radiographs are a less invasive test for patients (and done in routine follow-up) and are less costly to the healthcare system than pulmonary function testing, which is also compliance dependent.

The postoperative disc obliquity at LIV at follow-up may also be noted (5.8 ± 3.9; [0–16]) and long-term follow-up of these patients will be needed to assess the evolution of the distal contra-curve and lumbar degeneration. However, in the dilemma between long corrective fusions and selective instrumentations, the sparing of levels (5.7 fused in average in this study) with anterior fusion (2.5 spared levels compared to posterior fusion according to Betz et al.) might allow these young patients several years of lumbar mobility and reduced back pain, possibly at the risk of a longer fusion when older.[14,27,28]

Conclusion

In conclusion, anterior fusion for Lenke V AIS provides an effective correction of the curve in the coronal plan with no negative impact on the sagittal profile. The radiographically determined pulmonary function, illustrated here by the AVDR, improved significantly and the T1-D/T1T12 ratio remained stable, suggesting the absence of ongoing diaphragmatic dysfunction, when proper attention is paid to surgical repair of the diaphragm.

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Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

Prior to commencement, this study received institutional ethical approval, R039/2016. The study received IRB approval HREC REF 409/2023 from the Health Research Ethics Committee (IRB number: IRB00001938). All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Consent was obtained from all patients participating in the study.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies. No generative AI or AI-assisted technologies were used in the writing process.

Author contributions

LMH: conception; design; analysis, acquisition and interpretation of data; drafted and critically revised article; approved version to be published; agreed to be accountable for all aspects of the work

DA: conception; design; acquisition, analysis and interpretation of data; drafted and critically revised article; approved version to be published; agreed to be accountable for all aspects of the work

AvdM: conception; design; acquisition, analysis and interpretation of data; drafted and critically revised article; approved version to be published; agreed to be accountable for all aspects of the work

RD: conception; design; analysis and interpretation of data; drafted and critically revised article; approved version to be published; agreed to be accountable for all aspects of the work

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