

Lowest instrumented vertebra selection by the proportion of vertebral body area within the Harrington stable zone in Lenke type 1A adolescent idiopathic scoliosis: a self-paired comparison with the last substantially touched vertebra

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Research Article

Keywords: Adolescent idiopathic scoliosis, Lowest instrumented vertebra, Harrington stable zone, Half-area rule, Spinal fusion, Distal adding-on

Posted Date: September 30th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11009218/v1>

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Additional Declarations: No competing interests reported.

Abstract

Purpose

The last substantially touched vertebra (LSTV) rule for selecting the lowest instrumented vertebra (LIV) in Lenke 1A adolescent idiopathic scoliosis (AIS) considers only the relation between the centre sacral vertical line and the pedicles. We evaluated a criterion taking the LIV as the most cephalad vertebra below the apex with at least 50% of its projected body area within the Harrington stable zone (half-area rule).

Methods

Seventy-nine consecutive patients with Lenke 1A AIS (mean age 14.25 ± 1.94 years) underwent posterior pedicle screw fusion (2015–2023) with the LIV chosen by the half-area rule (minimum follow-up 24 months). The LSTV was identified retrospectively on the same standing radiographs (self-paired design). Radiographic parameters were measured preoperatively, at 1 month and at 2 years; the rules were compared with paired tests, and distal adding-on and associated factors were assessed.

Results

The main thoracic curve improved from $54.24^\circ \pm 13.55^\circ$ to $16.53^\circ \pm 7.56^\circ$ at 2 years (correction 69.60%) and coronal balance from 13.49 ± 9.24 to 8.44 ± 6.28 mm ($P < 0.001$). The half-area rule selected the same level as the LSTV in 39.2% of patients and one level more cephalad in 60.8% (mean 0.61 ± 0.49 levels, $P < 0.001$) and never distal. Adding-on occurred in 11 patients (13.9%) with no revisions.

Conclusion

The half-area rule achieved satisfactory correction and coronal balance with a low adding-on rate while sparing one fusion level in 60.8% of patients, offering a quantitative adjunct read directly from standing radiographs.

1. Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity affecting the physical and psychological wellbeing of growing patients [1]. Its prevalence is about 1.65–3.1%, with female predominance increasing with curve magnitude [2]. For curves exceeding 40° , posterior pedicle screw instrumentation and fusion remains the mainstay of treatment, the guiding principle being the greatest correction over the shortest possible fusion [3, 4]. Within that principle the choice of the lowest instrumented vertebra (LIV) is decisive: fusing too far distally sacrifices lumbar motion and hastens

adjacent-segment degeneration [5, 6], whereas stopping too proximally leaves the construct vulnerable to distal adding-on (AO) [7–9].

Successive LIV rules have been built around the neutral vertebra, the stable vertebra (SV) [10], the end vertebra and the last touched vertebra (LTV) [11]. Cho et al introduced the substantially touched vertebra (STV), requiring the centre sacral vertical line (CSVL) to cross at least the medial pedicle border, and derived the last substantially touched vertebra (LSTV) rule [12]; Qin et al recommended the STV, or nSTV + 1, as the LIV [13]. These rules reduced adding-on and are supported by meta-analysis in Lenke type 1A curves [14].

The LSTV rule nevertheless rests entirely on a line-to-pedicle relationship and says nothing about how much of the vertebral body itself is load-bearing within the stable region. The stable zone described by Harrington—the band bounded by two vertical lines through the lumbosacral facet joints [15]—provides such a geometric boundary, yet the proportion of the vertebral body required to lie within it has never been specified. We therefore defined a threshold of 50% of the projected vertebral body area within the zone on standing posteroanterior radiographs, taking the most cephalad vertebra below the apex that satisfies it as the LIV (the half-area rule). It is a two-dimensional projected-area measurement; vertebral rotation was not assessed [16].

We hypothesised that the half-area rule would select an LIV more cephalad than the LSTV while maintaining satisfactory correction without a disproportionate increase in adding-on, and sought the factors associated with adding-on.

2. Materials and methods

2.1. Study design and patients

This retrospective, self-paired cohort study was conducted at a single centre and reported in accordance with the STROBE statement. In every patient the LIV was selected at surgery by the half-area rule; the level the LSTV rule would have chosen was determined afterwards on the same preoperative radiographs, so each patient served as his or her own control. The prespecified hypothesis was that the half-area rule would select a more cephalad LIV with correction and adding-on within the range reported for the LSTV. Ethics approval and the waiver of informed consent are reported on the title page.

Between January 2015 and December 2023, consecutive patients with Lenke type 1A AIS underwent posterior correction and fusion by a single surgical team. Inclusion criteria were (i) Lenke type 1A AIS [1]; (ii) a main thoracic Cobb angle of at least 40° with flexibility demonstrated on bending films; (iii) selective posterior thoracic fusion with segmental pedicle screws, the LIV chosen by the half-area rule; and (iv) complete records with at least 24 months of follow-up. Non-idiopathic scoliosis, previous spinal surgery, age below 10 or above 18 years and incomplete follow-up were exclusion criteria. Seventy-nine patients (56 girls, 23 boys; mean age 14.25 ± 1.94 years, range 10–18 years) were included; demographic and preoperative details are given in Table 1.

Table 1
Demographic data and preoperative radiographic parameters (n = 79)

Variable	Value	Comment
Sex (female/male)	56 / 23	70.9% / 29.1%
Age (years)	14.25 ± 1.94	Range 10–18
Risser sign (grade)	3.23 ± 1.20	Median 3 (3–4)
Curve direction (right/left)	50 / 29	63.3% / 36.7%
Main thoracic Cobb angle (°)	54.24 ± 13.55	Range 40–85
Lumbar Cobb angle (°)	27.08 ± 7.18	Range 10–47
Proximal thoracic Cobb angle (°)	26.06 ± 6.44	Range 13–39
Apical vertebral translation (cm)	5.17 ± 1.94	—
Coronal balance (mm)	13.49 ± 9.24	—
Continuous data are presented as mean ± standard deviation.		

2.2. Definition of the half-area rule

All measurements were made on standing posteroanterior full-spine radiographs. Two vertical lines through the left and right lumbosacral facet joints delimited the Harrington stable zone [15]. A vertebra satisfied the half-area criterion when at least 50% of its projected body area lay within the zone, and the most cephalad such vertebra below the apex of the main thoracic curve was designated the LIV; the mechanical analogy underlying the threshold is illustrated in Fig. 1. Two observers applied the rule independently, with excellent agreement ($\kappa = 0.89$), consistent with published reliability data [17]. On the same radiographs the LSTV—the most cephalad vertebra below the apex at which the CSVL crosses at least the medial pedicle border—was identified after Cho et al [12] and Qin et al [13]; it was assessed retrospectively and did not influence the surgical plan.

2.3. Surgical technique and follow-up

All operations were performed by the same team under general anaesthesia with spinal cord monitoring. Through a posterior midline approach, pedicle screws were placed bilaterally at each planned level; correction was achieved by translation and derotation over rods contoured to the physiological sagittal profile [3], followed by posterolateral bone grafting. Patients wore a brace for three months and were reviewed radiographically at 1, 3, 6, 12 and 24 months.

2.4. Outcome measures

The primary outcome was the vertebral level selected as the LIV by each rule. Because the upper instrumented vertebra is identical under either rule, the difference between the two selections equals the

number of fusion levels spared, and one vertebral level—the smallest difference anatomically possible—was prespecified as the minimal clinically important difference (MCID).

Secondary outcomes were radiographic parameters measured preoperatively, at 1 month and at 2 years: the Cobb angles of the main thoracic, lumbar and proximal thoracic curves and the correction rate of the main curve; coronal balance (horizontal distance between the C7 plumb line and the CSVL), radiographic shoulder height (RSH), clavicle angle and T1 tilt [18]; thoracic kyphosis (TK, T5–T12), proximal thoracic kyphosis (PTK, T2–T5), thoracolumbar kyphosis (TLK, T10–L2), lumbar lordosis (LL, L1–S1) and the sagittal vertical axis (SVA); and LIV translation, LIV + 1 translation, the angulation of the first disc below the LIV and apical rotation graded after Nash and Moe [19]. Distal adding-on was defined after Wang et al [7] as an increase of more than 5° in the angulation of the first disc below the LIV, or of more than 5 mm in the distance of LIV + 1 from the CSVL, relative to the immediate postoperative film. All measurements and the assessment of adding-on were made independently by two physicians uninvolved in the operations.

2.5. Statistical analysis

Statistical analyses used SPSS 26.0 (IBM Corp., Armonk, NY, USA). Continuous data are presented as mean $\pm$ standard deviation; normality was assessed with the Shapiro–Wilk test. The three time points were compared by repeated-measures analysis of variance with Greenhouse–Geisser correction where Mauchly's test indicated non-sphericity and Bonferroni-adjusted pairwise contrasts. Preoperative and 2-year values, and the levels selected by the two rules, were compared with the paired t test or Wilcoxon signed-rank test according to the distribution of the differences; agreement between the rules was expressed as a linear weighted kappa. Patients with and without adding-on were compared with the independent-samples t test or Mann–Whitney U test and the chi-square or Fisher exact test. Multivariable logistic regression was planned for variables reaching $P < 0.05$ but was not fitted, 11 events being too few. Tests were two-sided with $\alpha = 0.05$.

3. Results

3.1. Patient characteristics

All 79 patients completed at least 24 months of follow-up. No neurological injury, deep infection or implant failure occurred, and no patient underwent revision surgery.

3.2. Comparison of the two LIV selection rules

The half-area rule and the LSTV rule selected the same vertebra in 31 of the 79 patients (39.2%). In the remaining 48 (60.8%) the half-area rule selected a level one vertebra more cephalad, and never a level distal to the LSTV. The mean cephalad shift was 0.61 ± 0.49 levels (paired $t = 10.99$, $P < 0.001$; Wilcoxon $P < 0.001$), reaching the prespecified MCID of one level in 60.8%; the linear weighted kappa between the rules was 0.563 (moderate agreement). The half-area rule thus spared on average 0.61 fusion levels per patient (Table 2, Fig. 2).

Table 2
Comparison of the two LIV selection rules (self-paired, n = 79)

Comparison	n (%)	Statistic
Identical level selected by both rules	31 (39.2)	—
Half-area rule one level cephalad to LSTV	48 (60.8)	—
Half-area rule ≥ 2 levels cephalad to LSTV	0 (0)	—
Half-area rule distal to LSTV	0 (0)	—
Mean cephalad shift (levels)	0.61 ± 0.49	$t = 10.99, P < 0.001$
Levels between half-area LIV and stable vertebra	1.82 ± 1.01	—
LIV, lowest instrumented vertebra; LSTV, last substantially touched vertebra. “Cephalad” denotes an LIV closer to the head than the level selected by the comparator rule		

3.3. Coronal and sagittal parameters

The main thoracic curve fell from $54.24^\circ \pm 13.55^\circ$ before surgery to $14.51^\circ \pm 7.08^\circ$ at 1 month and $16.53^\circ \pm 7.56^\circ$ at 2 years, a final correction rate of $69.60\% \pm 10.75\%$ (loss $2.03^\circ \pm 4.61^\circ$) (Greenhouse–Geisser-corrected $F = 879.72, P < 0.001$). The lumbar curve corrected spontaneously from $27.08^\circ \pm 7.18^\circ$ to $9.05^\circ \pm 4.28^\circ$ and the proximal thoracic curve from $26.06^\circ \pm 6.44^\circ$ to $17.91^\circ \pm 4.49^\circ$ (both $P < 0.001$; Table 3 and Fig. 3). Coronal balance improved from 13.49 ± 9.24 mm to 8.44 ± 6.28 mm at 2 years ($P < 0.001$), the change occurring mainly between 1 month and 2 years.

Table 3
Repeated-measures analysis of variance for the main coronal parameters across the three time points (n = 79)

Parameter	Preoperative	1 month	2 years	F	P
Main thoracic Cobb angle ($^\circ$)	54.24 ± 13.55	14.51 ± 7.08	16.53 ± 7.56	879.72	< 0.001
Lumbar Cobb angle ($^\circ$)	27.08 ± 7.18	8.24 ± 4.49	9.05 ± 4.28	472.48	< 0.001
Proximal thoracic Cobb angle ($^\circ$)	26.06 ± 6.44	17.68 ± 4.38	17.91 ± 4.49	350.36	< 0.001
Coronal balance (mm)	13.49 ± 9.24	11.51 ± 9.37	8.44 ± 6.28	8.51	< 0.001
P values for Mauchly’s test of sphericity were $< 0.001, < 0.001, < 0.001$ and 0.022, respectively; degrees of freedom were corrected by the Greenhouse–Geisser method in every case ($\epsilon = 0.627, 0.673, 0.602$ and 0.913). The F values shown are the corrected statistics					

RSH changed from -1.80 ± 13.31 mm to 1.57 ± 10.64 mm ($P = 0.019$), whereas the clavicle angle ($P = 0.245$) and T1 tilt ($P = 0.056$) did not. In the sagittal plane, TK and PTK increased, TLK and LL decreased

slightly and the SVA moved towards neutral (all $P < 0.05$). LIV and LIV + 1 translation both decreased ($P < 0.001$) and the Nash–Moe grade improved from 2.15 ± 0.80 to 1.05 ± 0.55 ($P < 0.001$) (Table 4, Fig. 4).

Table 4
Paired comparison of preoperative and 2-year values (n = 79)

Parameter	Preoperative	2 years	Test	P
Thoracic kyphosis, T5–T12 (°)	20.70 ± 8.88	23.11 ± 9.76	Wilcoxon	< 0.001
Proximal thoracic kyphosis, T2–T5 (°)	9.80 ± 5.66	12.14 ± 6.72	Paired t	< 0.001
Thoracolumbar kyphosis, T10–L2 (°)	4.15 ± 6.64	2.78 ± 6.76	Paired t	0.028
Lumbar lordosis, L1–S1 (°)	46.42 ± 9.55	44.87 ± 10.26	Paired t	0.021
Sagittal vertical axis (cm)	-1.17 ± 2.01	-0.33 ± 1.91	Paired t	< 0.001
Radiographic shoulder height (mm)	-1.80 ± 13.31	1.57 ± 10.64	Paired t	0.019
Clavicle angle (°)	-0.30 ± 2.76	0.09 ± 2.48	Paired t	0.245
T1 tilt (°)	-0.37 ± 3.52	0.58 ± 2.49	Paired t	0.056
LIV translation (cm)	1.65 ± 0.69	0.75 ± 0.42	Paired t	< 0.001
LIV + 1 translation (cm)	1.45 ± 0.87	0.91 ± 0.76	Paired t	< 0.001
Angulation of the disc below the LIV (°)	3.25 ± 2.30	2.95 ± 2.07	Wilcoxon	0.051
Apical rotation, Nash–Moe (grade)	2.15 ± 0.80	1.05 ± 0.55	Wilcoxon	< 0.001
Normality of the paired differences was assessed with the Shapiro–Wilk test; the paired t test was used for normally distributed differences and the Wilcoxon signed-rank test otherwise. LIV, lowest instrumented vertebra				

3.4. Distal adding-on and associated factors

Adding-on was present in 11 patients (13.9%) at the 2-year review; none had neurological symptoms and none was revised. On univariate analysis, patients with adding-on had a more flexible main thoracic curve before surgery than those without ($60.02\% \pm 20.82\%$ versus $45.35\% \pm 20.56\%$, $P = 0.031$) and less preoperative thoracic kyphosis ($16.36^\circ \pm 7.63^\circ$ versus $21.40^\circ \pm 8.91^\circ$, $P = 0.046$). The groups did not differ in the other variables examined (Table 5); no multivariable model was fitted. Representative patients with and without adding-on are shown in Figs. 5 and 6.

Table 5
Univariate comparison of patients with and without distal adding-on

Variable	AO (n = 11)	No AO (n = 68)	Test	P
Age (years)	14.45 ± 2.25	14.22 ± 1.91	U	0.637
Risser sign (grade)	3.36 ± 1.50	3.21 ± 1.15	U	0.293
Sex (female/male)	7 / 4	49 / 19	Fisher	0.722
Curve direction (right/left)	6 / 5	44 / 24	Fisher	0.520
Main thoracic Cobb angle (°)	55.91 ± 16.51	53.97 ± 13.14	U	0.501
Main thoracic curve flexibility (%)	60.02 ± 20.82	45.35 ± 20.56	t	0.031
Lumbar Cobb angle (°)	26.45 ± 8.24	27.18 ± 7.06	t	0.759
Proximal thoracic Cobb angle (°)	23.55 ± 7.69	26.47 ± 6.19	t	0.164
Coronal balance (mm)	14.08 ± 8.83	13.40 ± 9.37	U	0.702
Thoracic kyphosis (°)	16.36 ± 7.63	21.40 ± 8.91	U	0.046
Apical vertebral translation (cm)	5.36 ± 2.12	5.14 ± 1.92	U	0.497
LIV translation (cm)	1.90 ± 0.82	1.61 ± 0.66	t	0.204
LIV + 1 translation (cm)	1.70 ± 0.99	1.41 ± 0.84	t	0.298
Angulation of the disc below the LIV (°)	2.59 ± 2.18	3.35 ± 2.32	U	0.321
Levels between LIV and stable vertebra	2.00 ± 1.10	1.79 ± 1.00	U	0.423
Main thoracic Cobb angle at 1 month (°)	14.82 ± 7.70	14.46 ± 7.03	U	0.776
Unless stated otherwise, values are preoperative. AO, distal adding-on; LIV, lowest instrumented vertebra; t, independent-samples t test; U, Mann–Whitney U test; Fisher, Fisher exact test. Categorical data are given as counts				

4. Discussion

This study quantified a two-dimensional LIV selection strategy combining the Harrington stable zone with a 50% projected-area threshold in Lenke type 1A AIS, with three main findings. First, the correction achieved—69.60% of the main thoracic curve, with a final coronal balance of 8.44 mm—is comparable with recent cohorts [14, 20]. Second, adding-on occurred in 13.9% of patients, at the lower end of the range reported for Lenke 1A curves [8, 9]. Third, the LIV chosen by the rule was on average 0.61 levels cephalad to the LSTV, one level higher in 60.8% of patients and never lower, so most patients were fused one level shorter without loss of correction.

Adding-on was associated not with LIV position relative to the stable vertebra, as in most series, but with greater preoperative flexibility and less thoracic kyphosis. Two mechanisms are consistent with these data. A flexible curve straightens more on bending, so vertebrae enter the stable zone sooner and the rule selects a higher LIV; flexibility also leaves the discs below the fusion more mobile, and their tilting and translation are what the definition of adding-on measures. Sakai et al reported the same association with preoperative main-curve flexibility [21]. Flexibility is in turn linked to skeletal immaturity, which this sample could not separate. Thoracic kyphosis lies in a plane the rule does not measure, and the present data do not explain its association with adding-on. The traditional LIV variables could scarcely emerge here, since one rule governed every patient and the distance from the LIV to the stable vertebra varied little (1.82 ± 1.01 levels).

Reported rates in Lenke 1A curves span 3.6% for fusion to the STV to 49% after deliberately short fusions [7, 13], with 19.7% [12], 29% [8], 16.7% for fusion to the LSTV [20] and pooled rates of 15.6–29.4% [9]. Our 13.9% lies at the lower end of that range, although the rule moved the LIV 0.61 levels cephalad relative to the simulated LSTV.

The final correction rate of 69.60% is essentially the same as the 68.2% of Bai et al [20], the 69.4–73.8% of Qin et al [13] and the 68% of Lehman et al [4]. The half-area rule is thus on a par with the LSTV rule for correction, but no superiority can be claimed: the LSTV arm was simulated on the same radiographs rather than independently operated.

The level in question usually lies at the thoracolumbar junction or upper lumbar spine, where preserving one motion segment increases lumbar flexion–extension by roughly 15–22% [5]; fusion to L3 or below doubled the ten-year incidence of back pain versus ending at L1 or above [22]; adjacent-segment degeneration affects almost half of patients and correlates with the number of levels fused [6]; and outcomes decades later remain poorer than in age-matched controls [23]. Here 60.8% of patients were fused one level shorter, though the long-term consequence was not assessed.

The mechanics are elementary statics: once at least half of the projected body area lies within the stable zone, the geometric centre of the body falls within the base of support and the toppling moment produced by eccentric coronal load is greatly reduced, limiting shear at the LIV and the disc below it. Consistently, LIV and LIV + 1 translation decreased by two years and the disc below the LIV showed no angular deterioration at cohort level. Finite element work shows markedly higher compressive stress on the concavity of a scoliotic segment [24], and cumulative eccentric loading is a recognised driver of curve progression [25].

What is measured, however, is a projected area on a static film, not a three-dimensional analysis. Against that stands its practicality: the criterion is read from a routine standing posteroanterior radiograph by drawing three lines, needs no reconstruction, software or extra radiation, and is judged consistently across surgeons.

This single-centre retrospective cohort of 79 patients simulated the LSTV comparator on the same radiographs, which eliminates baseline imbalance but precludes comparing clinical endpoints between independently treated groups. With only 11 adding-on events the multivariable analysis was underpowered, so the associations with flexibility and kyphosis are exploratory. The rule takes no account of vertebral rotation or of the sagittal plane, and at least five distinct three-dimensional configurations exist within Lenke type 1 curves [16]. Finally, the 50% threshold was adopted a priori from the mechanical reasoning above rather than fitted to these data, and thresholds above and below it were not examined; the proportion of the body within the stable zone is a continuous quantity, and a cohort large enough to locate the optimal cut-off by receiver-operating-characteristic analysis across a 40–60% range would establish whether 50% is the right one.

5. Conclusions

In Lenke type 1A AIS, selecting the LIV as the most cephalad vertebra below the apex with at least 50% of its projected body area within the Harrington stable zone achieved a main thoracic correction rate of 69.60%, a final coronal balance of 8.44 mm and an adding-on rate of 13.9% at 24 months. The level selected was on average 0.61 vertebrae cephalad to the simulated LSTV, and 60.8% of patients were fused one level shorter. Greater preoperative curve flexibility and lesser thoracic kyphosis were associated with adding-on on univariate analysis.

Abbreviations

AIS
adolescent idiopathic scoliosis
AO
distal adding-on
CSV
centre sacral vertical line
LIV
lowest instrumented vertebra
LL
lumbar lordosis
LSTV
last substantially touched vertebra
LTV
last touched vertebra
MCID
minimal clinically important difference
nSTV
non-substantially touched vertebra
PTK

proximal thoracic kyphosis
RSH
radiographic shoulder height
STV
substantially touched vertebra
SV
stable vertebra
SVA
sagittal vertical axis
TK
thoracic kyphosis
TLK
thoracolumbar kyphosis

Declarations

Author Contribution

JEZ participated in study design, analyzed data and wrote the manuscript; XXH participated in study design, guided the research, supported the funds and revised the draft manuscript; ZS participated in study design, guided the research and reviewed the thesis; LK participated in study design, guided the research and reviewed the thesis; ZQ participated in study design, prepared figures, sorted the image data and other data; ZQS participated in study design, prepared figures, sorted the image data and other data; WXH participated in study design, prepared figures, sorted the image data and other data; All authors reviewed the manuscript.

Data Availability

Data availability :The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

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Figures

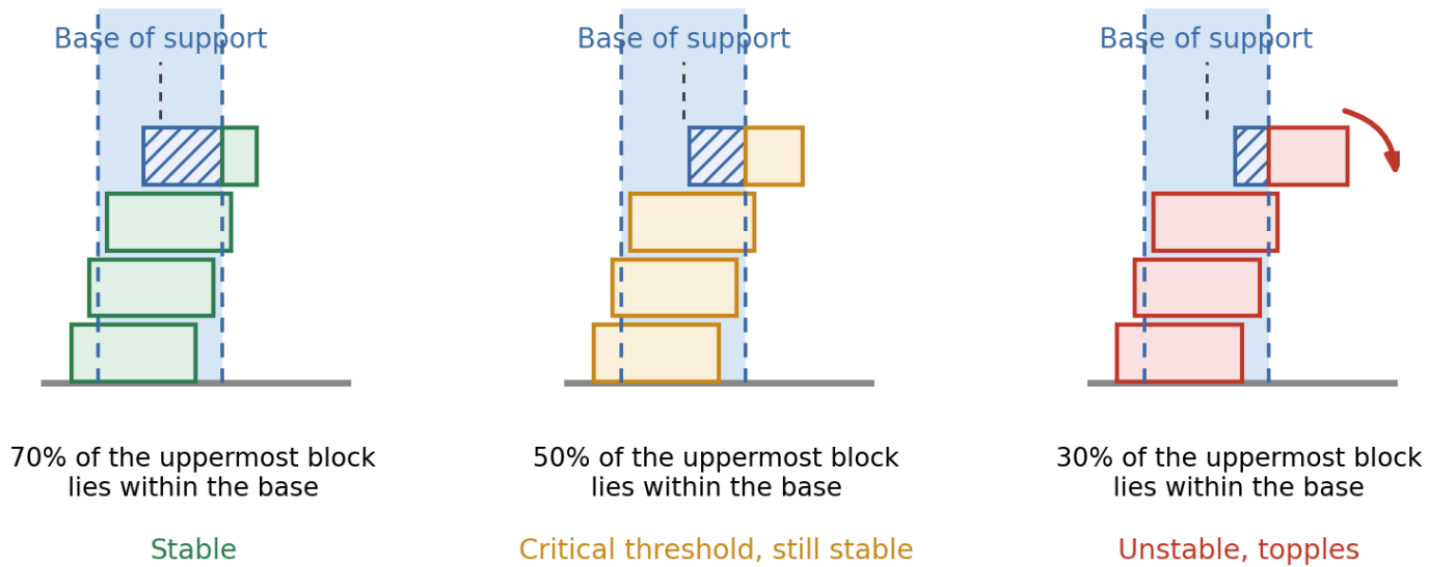


Figure 1

Mechanical analogy for the half-area rule. The shaded band represents the base of support (the Harrington stable zone). When at least 50% of the uppermost block remains within the base, the stack stays balanced (left and centre panels); once the overlap falls below 50%, the stack becomes unstable and topples (right panel)

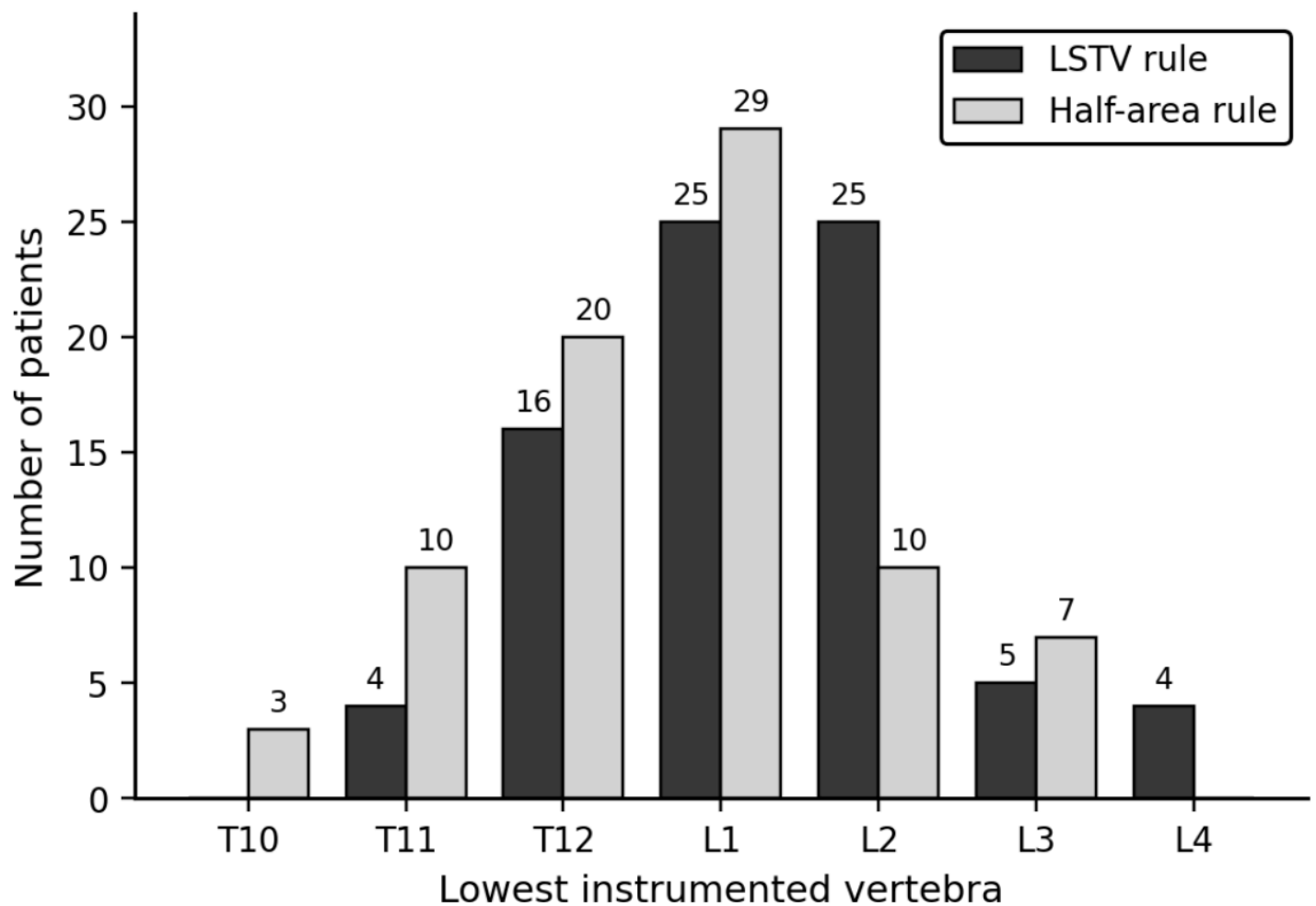


Figure 2

Distribution of the lowest instrumented vertebra selected by the two rules in the same 79 patients. LSTV, last substantially touched vertebra

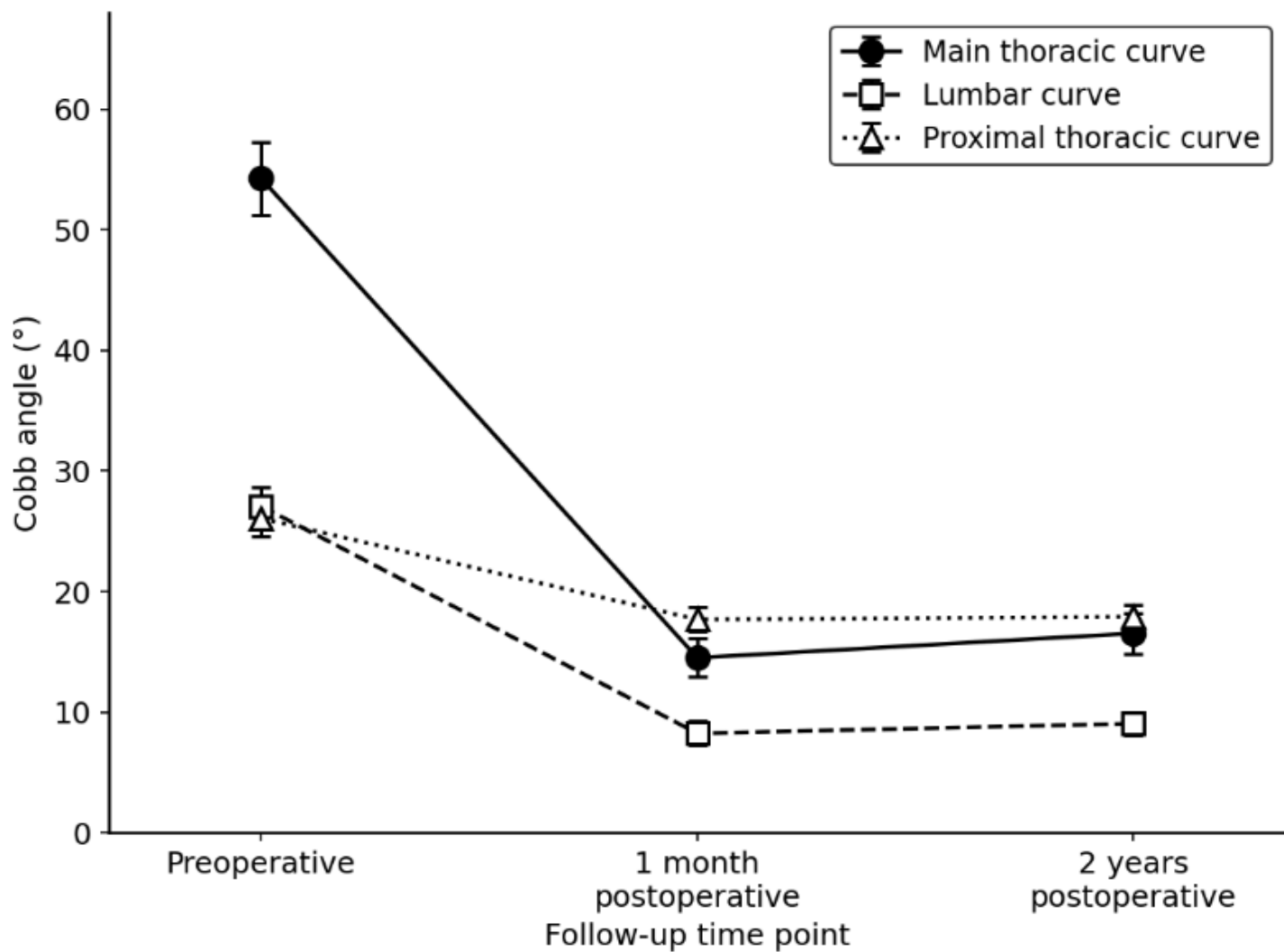


Figure 3

Cobb angles of the three curves at the three follow-up time points (mean $\pm$ 95% confidence interval)

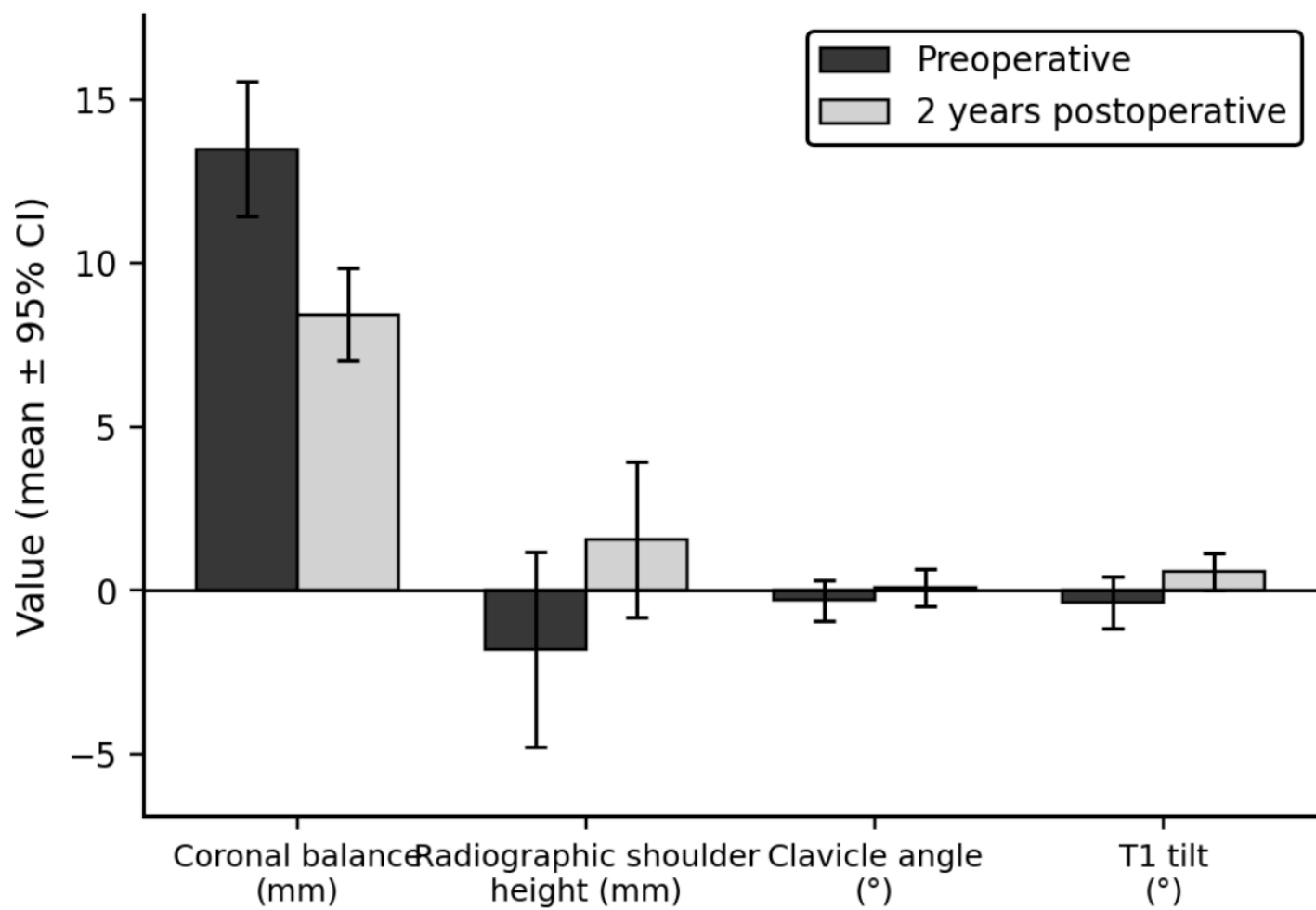


Figure 4

Coronal balance and shoulder balance parameters before surgery and at 2 years (mean $\pm$ 95% confidence interval)

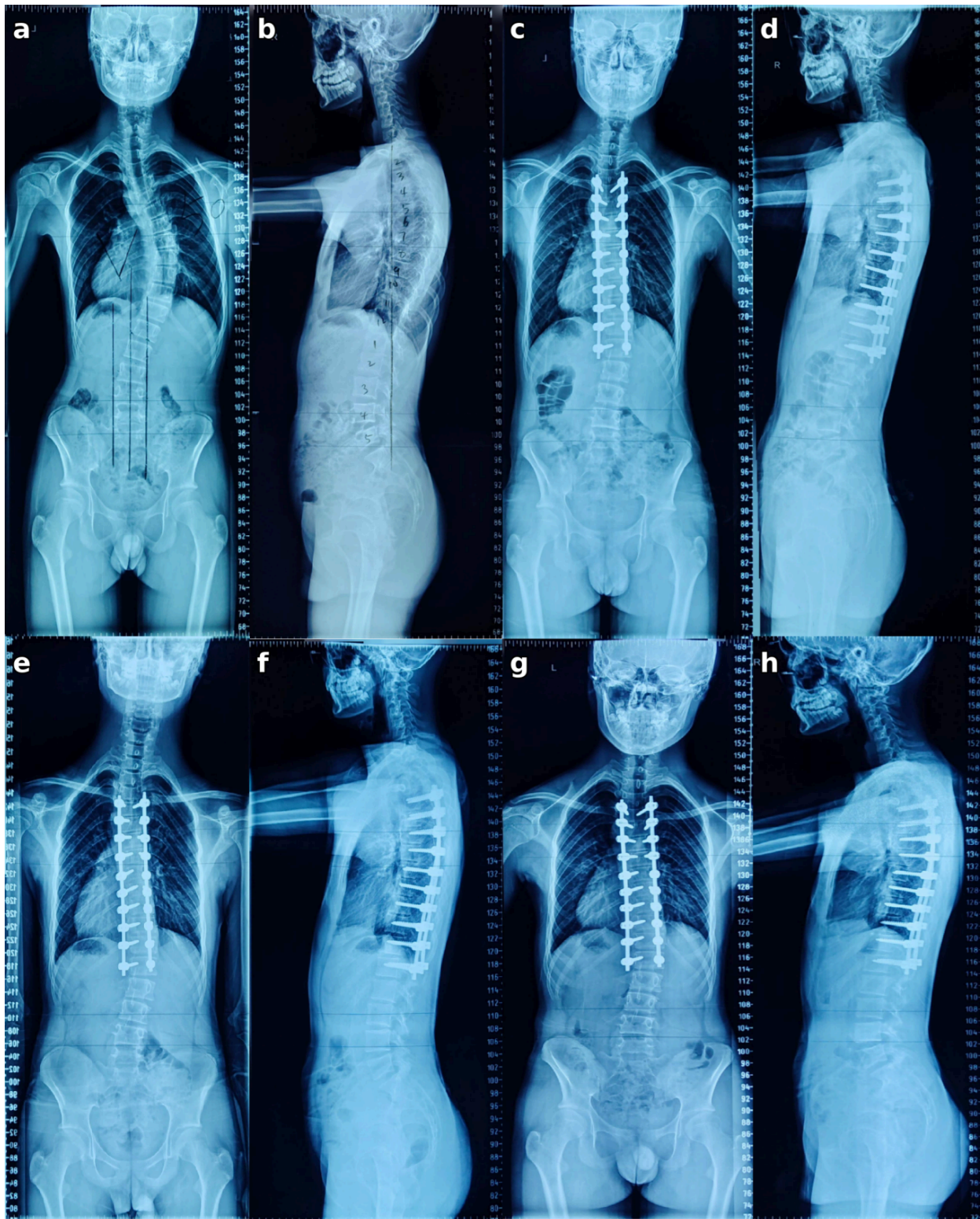


Figure 5

Representative patient in whom distal adding-on developed. **a, b** Preoperative standing posteroanterior and lateral radiographs. **c, d** One month after posterior pedicle screw instrumentation and fusion, with the lowest instrumented vertebra selected by the half-area rule. **e, f** One year after surgery. **g, h** Two years after surgery. Adding-on was recorded at the 2-year review according to the criteria of Wang et al: an increase of more than 5° in the angulation of the first disc below the lowest instrumented vertebra, or

of more than 5 mm in the distance of the vertebra immediately below it from the centre sacral vertical line, relative to the immediate postoperative film. The patient had no neurological symptoms and was not revised

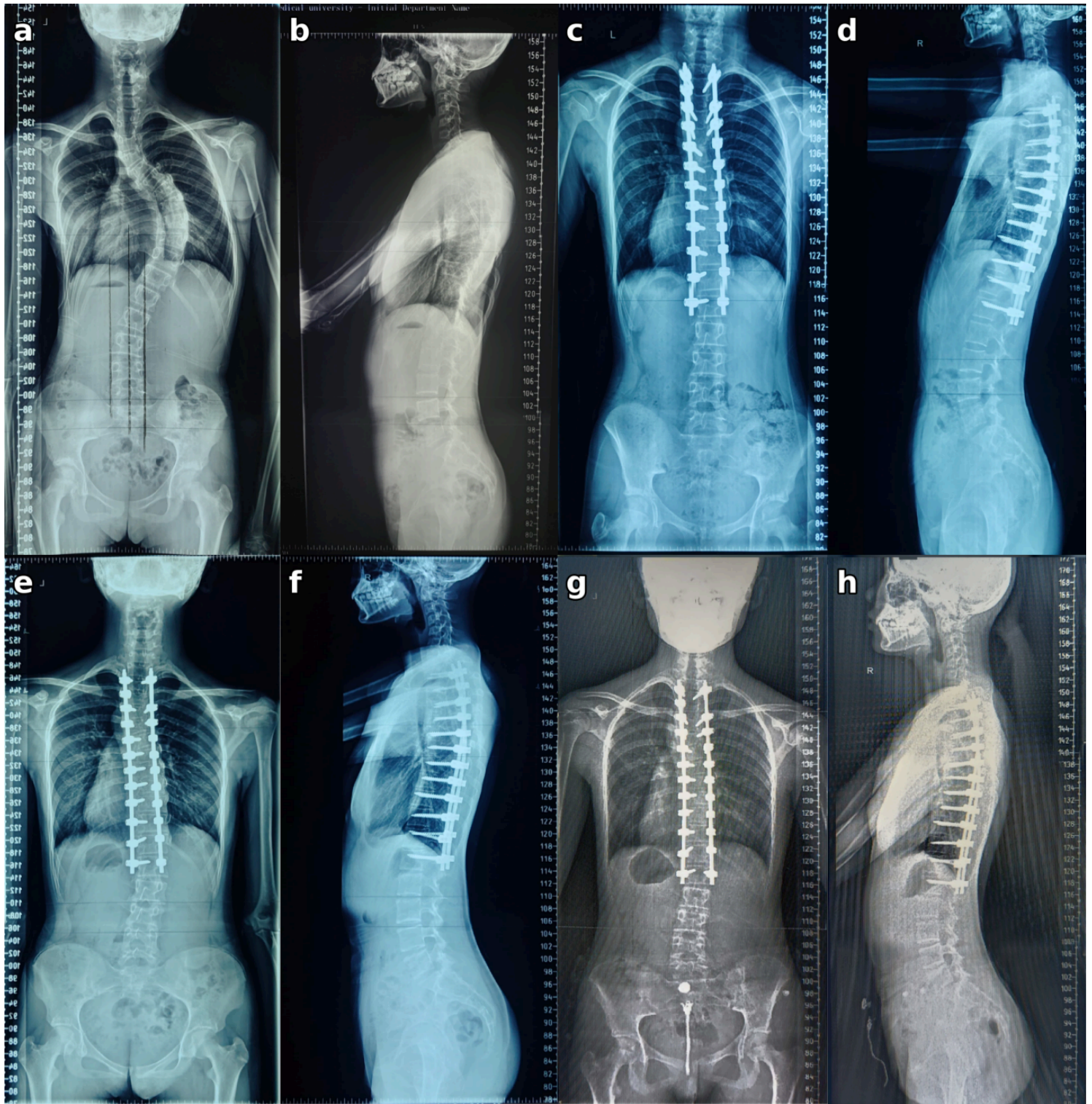


Figure 6

Representative patient in whom distal adding-on did not develop. **a, b** Preoperative standing posteroanterior and lateral radiographs. **c, d** One month after surgery. **e, f** One year after surgery. **g, h**

Two years after surgery. The lowest instrumented vertebra was selected by the half-area rule, and neither adding-on criterion was met at any follow-up visit