



PREDICTING THE RISK OF INSUFFICIENT CORRECTION OF THE LUMBAR COUNTERCURVE IN SURGICAL TREATMENT OF PATIENTS WITH SEVERE IDIOPATHIC SCOLIOSIS WITH A PRIMARY THORACIC CURVE

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Objective. To identify the factors affecting the degree of lumbar countercurve correction, in order to predict the risks of its insufficient correction during surgical treatment of severe idiopathic scoliosis with a primary thoracic curve.

Material and Methods. The outcomes of treatment of 168 patients with idiopathic scoliosis with a median thoracic curve of 90.5° and lumbar countercurve of 62.0° operated on in 1999–2021, were analyzed. The median postoperative follow-up period was 4.6 years. Logistic regression models were used to identify predictors of insufficient lumbar countercurve correction.

Results. Taking into account the lumbar countercurve correction magnitude, patients were divided into two groups: less than 50% of the initial magnitude ($n = 62$; 36.9%) and more than 50% of the initial magnitude ($n = 101$; 60.1%). Significant differences were found in the groups in gender (men, 26.0% vs 11.9%), age (16.0 vs 14.0 years; $p < 0.001$), and countercurve mobility (36.7 vs 47.6%; $p < 0.001$). Building single-factor logistic regression models allowed identifying predictors of insufficient correction: countercurve more than 37.5°, age more than 15.8 years, male gender, and countercurve mobility less than 31.4%. A formula based on a multivariate model was developed to predict the risk of insufficient correction of the lumbar countercurve with a sensitivity of 73.8%.

Conclusion. The combination of factors including lumbar countercurve greater than 37.7°, its mobility less than 31.4%, male gender, scapular tilt less than 12.0°, and a plumb-to-umbilicus distance less than 5 mm allows for predicting the risk of lumbar countercurve correction of less than 50% with a diagnostic accuracy of 81.0%.

Key Words: severe idiopathic scoliosis; lumbar countercurve; predictors, prediction.

Please cite this paper as: Vasyura AS, Buzunov AV, Sergunin AY, Lukinov VL, Novikov VV. Predicting the risk of insufficient correction of the lumbar countercurve in surgical treatment of patients with severe idiopathic scoliosis with a primary thoracic curve. *Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika)*. 2026;23(2):16–25. In Russian. DOI: <http://dx.doi.org/10.14531/ss2026.2.16-25>

Idiopathic scoliosis with a primary thoracic curve is the most common form of spinal deformity; one of the tasks of surgical treatment of which is halting further curvature progression via minimal fusion length while preserving global balance [1].

For Lenke type 1 idiopathic scoliosis, selective thoracic fusion with instrumental fixation of thoracic curve is recommended to achieve spontaneous correction of the lumbar spine curvature [2]. Later, this approach was applied to Lenke types 2–4 deformities [1, 3]. However, severe and rigid thoracic scoliosis, characterized by clinical manifestations and internal mechanisms distinct from those of typical idiopathic scoliosis, necessitates a specialized approach for predict-

ing the risks of the adding-on phenomenon and choosing the appropriate lower instrumented vertebra [4].

In the presence of a lumbar scoliotic curve (lumbar countercurve), while aiming to include as few vertebrae as possible in the fusion zone, it is essential to ensure that the caudal instrumented vertebra is stable, neutral, and horizontal relative to the sacrum [5].

Since modern research focuses primarily on evaluating the efficacy of selective spinal fusion and the degree of spontaneous correction of lumbar and thoracolumbar curves, it is of clinical relevance to investigate the factors influencing the correction of lumbar countercurves in the surgical treatment of severe idiopathic scoliosis with a primary thoracic curve.

The objective of the study is to identify the factors influencing the degree of lumbar countercurve correction in order to predict the risk of undercorrection during the surgical treatment of severe idiopathic scoliosis.

Material and Methods

A retrospective, single-center, non-randomized, controlled cohort study was conducted to evaluate the outcomes of surgical treatment of 168 patients with severe (greater than 80°) forms of idiopathic scoliosis.

Inclusion criteria: idiopathic scoliosis with a primary thoracic curve >80° and a structural lumbar countercurve (Lenke type 3 or 4); no baseline neurological

deficits; and no history of prior surgical intervention for spinal deformity.

Exclusion criteria: idiopathic scoliosis with a primary thoracic curve greater than 80° and absence of a structural lumbar countercurve (Lenke types 1 and 2); baseline neurological symptoms; prior surgery for deformity of the spine.

The median (Me) primary thoracic curve was 90.5° (interquartile range [IQR], 84.0°–100.0°), while the median lumbar countercurve was 62.0° (IQR, 53.0°–72.5°) (Lenke types 3–4). Patients underwent surgery between 1999 and 2021 using posterior segmental instrumentation with hook, hybrid, and pedicle screw fixation. The study population included 137 females (81.5%) and 31 males (18.5%). Median age of patients at the time of surgery was 15 years (IQR, 13.0–17.0). The median postoperative follow-up period was 4.6 years (IQR, 3.0–6.2).

Evaluation included full-spine (C7–S1) anteroposterior and lateral radiographs in the standing position, along with dynamic views, as well as pre- and postoperative orthopedic examination data.

The final sample, accounting for data completeness, included 154 out of 168 patients who were divided into two groups based on the correction of the lumbar countercurve: less than 50% and more than 50% of the baseline value, comprising 62 patients (38%) and 101 patients (62%), respectively.

A statistical analysis of 398 clinical and radiological parameters was performed according to M.V. Mikhaylovskiy [6]. The Shapiro–Wilk test was used to assess the normality of continuous data distribution. Continuous variables were described as Me and interquartile range (IQR), mean (M) and standard deviation (SD), and dispersion (minimum to maximum). Continuous variables were compared between groups using the Mann–Whitney *U* test, with the average difference estimated via the pseudomedian (pMe) of pairwise differences and the standardized mean difference (SMD) with 95% confidence intervals (95% CI). To identify pairwise numerical associations between continuous variables, Spearman's correlation coef-

ficient (*r*) and the corresponding *p*-value were calculated. Qualitative variables are presented as observed frequencies and percentages. To compare qualitative variables, the two-tailed Fisher's exact test was used, and the odds ratio (OR) with a 95% confidence interval (CI) was calculated.

A multivariate mathematical model designed to identify predictors of under-correction in lumbar countercurve was developed using multiple regression analysis. The level of statistical significance (*p*) was set at *p* < 0.05. All statistical tests were two-tailed. ROC analysis was used to determine the cut-off values for continuous variables, with the optimal thresholds selected based on the maximum Youden's index within the multivariate model. Statistical analyses were performed using RStudio IDE (version 2025.09.1+401 «Cucumberleaf Sunflower», USA) and R software (version 4.4.2 (2024-10-31 ucrt), Austria).

The study was approved by the Biomedical Ethics Committee (Extract No. 025/25 from the minutes of meeting No. 007/25 dated 28.10.2025) and complies with international and domestic regulatory documents, including the ethical standards of the Declaration of Helsinki of the World Medical Association ('Ethical Principles for Medical Research Involving Human Subjects') and Order No. 200н of the Ministry of Health of the Russian Federation 'On Approval of the Rules of Good Clinical Practice' dated 01.04.2016. All participants provided informed consent to participate in the study.

Results

In the total cohort of 168 patients, Me lumbar countercurve was 62.0° (IQR: 53.0–72.5°), with a median mobility of 43.3% (IQR: 30.6–58.1%) and a median L5 vertebral tilt of 8.0° (IQR: 3.0–13.3°). The apex of the lumbar countercurve was identified in 154 patients; it was located at the L1–L2 level in 20%, at L2–L4 in 70%, and at L4–L5 in 10% of cases. The lowest stable vertebra was the L5 in 97 (64.2%) out of 151 patients. The distance from the plumb

line to the umbilicus was measured in 83 (49%) patients, with a median of 10.0 mm (IQR: 5.0–15.0). The Me shoulder blade tilt in 142 (85%) patients was 8.0° (IQR: 5.3–12.0°). Following surgical treatment, the Me correction of the lumbar countercurve was 56.4% (IQR: 41.2–67.9%), and the median L5 vertebra tilt in 107 patients was 6.0° (IQR: 3.0–10.0°). The distribution of the lowest instrumented vertebra (LIV) levels was determined in 148 patients: L2 in 3 (2.0%), L3 in 21 (14.2%), L4 in 71 (48.0%), and L5 in 28 (18.9%). The Me tilt of the LIV after surgery was 8.0° (IQR: 4.0–12.0°). The median thoracic scoliotic curve was 90.5° (IQR: 84.0–100.0°), and the Me correction rate was 57.2% (IQR: 46.5–66.7%).

Discrepancies in size between the overall cohort and the comparison group are due to the incompleteness of the collected data. There was no significant difference in the baseline lumbar scoliotic curve between the two groups: Me 62.0° (IQR: 52.8–72.0°) in Group 1 versus Me 64.0° (IQR: 54.0–75.8°) in Group 2 (*p* = 0.275). Table 1 shows the statistically significant parameters.

Significant differences in gender distribution were identified, with a higher proportion of men in Group 1 compared to Group 2 (26.0% vs. 11.9%; OR = 2.6; 95% CI: 1.1–6.0; *p* = 0.032).

Patients in Group 1 were significantly older (by an average of 2 years; *p* < 0.001) and, consequently, presented with a more advanced bone maturity (Risser sign) by an average of one grade (95% CI: 0–1 grade; *p* < 0.001). In Group 1, lumbar countercurve mobility was on average 12.1% lower (95% CI: 5.4–18.5%; *p* < 0.001). Patients in Group 1 exhibited more pronounced thoracic kyphosis and lumbar lordosis. The degree of countercurve correction also differed significantly, being on average 29.4% lower Group 1 (95% CI: 25.2–33.7%; *p* < 0.001); additionally, Group 1 demonstrated a significantly lower correction of the thoracic scoliotic curve, with an average difference of 13.3% (95% CI: 8.7–17.4%; *p* < 0.001). Significant clinical differences were identified in Group 1, which exhibited a greater scapular tilt by an average of 2° (95% CI: 1–3°; *p* < 0.001).

Univariate and multivariate logistic regression models were build to identify and analyze the factors associated with insufficient correction of the lumbar countercurve (less than 50%; Table 2).

In univariate logistic regression models, significant direct associations with undercorrection of lumbar countercurve were identified for the following variables:

1) a lumbar countercurve greater than 37.5° is associated with a 7.5-fold increase in the odds of undercorrection;

2) an age over 15.8 years at the time of surgery was associated with a 3.3-fold increase in the odds of undercorrection;

3) males exhibited a 3.28-fold higher likelihood of undercorrection;

4) a lumbar countercurve mobility of less than 31.4% is associated with a 5.7-fold increase in the odds of undercorrection.

A lumbar countercurve mobility of less than 31.4% correlated with a lumbar curve greater than 37.5° (Spearman's correlation coefficient $r = 0.40$; $p < 0.001$) and was therefore excluded from the multivariate model.

The risk of undercorrection of the lumbar compensatory curve can be evaluated using the derived multivariate logistic regression model: $p = 1 - 1/(1 +$

$\exp(B + A1X1 + A2X2 + A3X3 + A4X4 + A5X5)$), where p is the probability of the correction being less than 50% (risk of undercorrection), and $\exp$ is the exponential function (Table 3).

Using ROC analysis, the multifactorial risk model for insufficient correction of the lumbar countercurve demonstrated an optimal balance of sensitivity (73.8%) and specificity (85.7%) at a probability threshold p of 51.1%. Using the obtained threshold value, a lumbar compensatory curve correction of less than 50% was predicted in patients with a model-calculated probability (p) greater than 51.1% (Fig. 1).

Table 1

Statistically significant differences between the study groups

Indicator	Correction of lumbar countercurve less than 50 % (n = 62)	Correction of lumbar countercurve 50 % (n = 101)	Comparison	
	Me (Q1–Q3) M ± SD Min–max		Difference estimation pMe [95% CI] SMD [95% CI]	p-level
Gender, n (%)	F – 46 (74.0) M – 16 (26.0)	F – 89 (88.1) M – 12 (11.9)	OR male: 2.6 95% CI: 1.1–6.0	0.032*
Age at surgery, years	16.0 (14.8–21.0) 17.8 ± 5.0 11.0–33.0	14.0 (13.0–16.0) 14.8 ± 3.8 10.0–39.0	–2.0 [–3.0; –1.0] 0.7 [0.4; 1.0]	<0.001*
Risser, grade	4.0 (3.0–4.0) 3.5 ± 1.3 0.0–5.0	3.0 (2.0–4.0) 2.7 ± 1.4 0.0–5.0	–1.0 [–1.0; –0.0] 0.6 [0.2; 0.9]	<0.001*
Mobility of the lumbar countercurve, %	36.7 (21.2–50.7) 36.8 ± 19.4 1.7–91.7	47.6 (36.8–64.4) 47.9 ± 17.3 1.3–84.0	12.1 [5.4; 18.5] –0.6 [–1.0; –0.3]	<0.001*
Thoracic kyphosis, deg.	49.0 (30.5–68.0) 54.2 ± 30.2 11.0–158.0	40.0 (28.0–51.8) 40.5 ± 20.4 –4.0–117.0	–10.0 [–18.0; –3.0] 0.6 [0.2; 0.9]	<0.001*
Lumbar lordosis, deg.	68.0 (59.8–76.3) 68.6 ± 16.5 30.0–116.0	63.0 (54.0–69.0) 61.9 ± 11.7 34.0–98.0	–7.0 [–11.0; –2.0] 0.5 [0.2; 0.8]	0.003*
Countercurve correction, %	39.0 (27.8–44.1) 34.7 ± 12.7 0.0–50.0	65.4 (57.4–73.3) 66.4 ± 10.6 50.5–93.8	29.4 [25.2; 33.7] –2.8 [–3.2; –2.3]	<0.001*
Correction of the primary curve in standing position, %	46.0 (39.0–58.5) 48.2 ± 14.8 10.5–80.0	60.2 (55.0–69.1) 61.0 ± 11.2 34.4–88.0	13.3 [8.7; 17.4] –1.0 [–1.3; –0.7]	<0.001*
Shoulder blade tilt, deg.	8.0 (6.0–10.0) 8.9 ± 3.4 4.0–18.0	7.0 (5.0–8.0) 6.9 ± 2.9 3.0–16.0	–2.0 [–3.0; –1.0] 0.6 [0.3; 1.0]	<0.001*

* Statistically significant differences.

The predictive ability of the resulting multivariate model was validated using baseline data from 105 patients with a known final outcome and complete datasets for all model variables (Table 4).

By validating the developed model on historical data with known outcomes, it successfully predicted the risk of lumbar countercurve undercorrection in 31 out of 42 patients, and a correction of over 50% in 54 out of 63 patients (Table 5).

Clinical cases

Patient G., presenting with severe right-sided thoracic grade 4 idiopathic scoliosis. Predictors of undercorrection of the lumbar countercurve: 1) lumbar countercurve magnitude of 83° ; 2) age – 17 years; 3) shoulder blade tilt – 15° ; 4) male; 5) the plumb line anterior to the umbilicus is less than 5.0 mm. The calculated probability of insufficient correction of the lumbar countercurve (less than 50%) is 87.3%, which exceeds the critical threshold of 51.1% (insufficient correction is probable, Fig. 2).

Female patient Sh. with severe (grade 4) right-sided thoracic idiopathic scoliosis. Predictors of risk for undercorrection of lumbar countercurve: 1) lumbar curve magnitude of 68° ; 2) age of 13 years; 3) shoulder blade tilt – 4° ; 4) female sex; 5) anterior plumb line deviation from the umbilicus of less than 5.0 mm the predicted probability of inadequate correction of the lumbar countercurve was 18.3%, which is below the threshold of 51.1%, indicat-

ing the absence of a risk of undercorrection (Fig. 3).

Discussion

In studies describing the results of surgical treatment for severe thoracic scoliosis, emphasis is often placed on the correction of the primary scoliotic curve [7]. A correction degree of more than 50% can be considered optimal [8]; furthermore, even in long-term follow-up periods (exceeding 10 years), the correction rate achieved with pedicle screw fixation remains above 55% [9]. Assessment of the lumbar countercurve correction and its baseline mobility is less frequently reported: Zang et al. [10] described the outcomes of surgical treatment in 15 patients with idiopathic scoliosis. The primary thoracic curve of $106.7^\circ \pm 15.0^\circ$ with a mobility of $16.9^\circ \pm 10.0^\circ$ was corrected to $43.1^\circ \pm 25.2^\circ$, while the lumbar countercurve of $41.2^\circ \pm 18.4^\circ$ with a mobility of $33.0^\circ \pm 25.0^\circ$ was reduced to $12.2^\circ \pm 8.9^\circ$.

Li et al. [4] reported the treatment results of 93 patients with severe thoracic scoliosis. In 72 of these patients without the adding-on phenomenon, the thoracic scoliotic curve was 104.3° (range, $85\text{--}135^\circ$) and the lumbar countercurve was 50.3° (range, $21\text{--}80^\circ$). The mobility of the lumbar countercurve was 42.5° , and its postoperative magnitude was 20.1° (range, $5\text{--}47^\circ$).

In patients with severe deformities ranging from 81° to 146° , V.U. Sattaev et al. [11] utilized halo-tibial traction

and observed a reduction in the lumbar countercurve from $43.6^\circ \pm 9.4^\circ$ to $36.9^\circ \pm 2.9^\circ$ during pre-operative side-bending toward the apex of the curve, and further down to $10.8^\circ \pm 1.4^\circ$ following two-stage surgical correction.

N.I. Zagorodniy et al. [12] reported an $80.0\% \pm 15.6\%$ correction of the lumbar countercurve achieved during surgical management of severe idiopathic scoliosis with an initial lumbar countercurve of $58.3^\circ \pm 13.4^\circ$.

We considered that a similar correction rate of 50% is applicable to lumbar countercurves. This is supported by literature data demonstrating spontaneous correction of at least 50% following selective spinal fusion [13] and 60% correction with instrumentation, which may serve as a threshold value for optimal correction.

Schulz et al. [15] state that the criteria for successful surgical treatment using selective spinal fusion include a lumbar scoliotic curve of less than 26° , frontal imbalance of no more than 2 cm, lumbar countercurve correction of more than 37%, and trunk shift of less than 1.5 cm.

In our study, following the classic approach to instrumentation of structural lumbar countercurve [5], the lumbar curves were included in the fusion zone. This approach corresponded to a median lumbar scoliotic curve of 62.0° , a magnitude at which spontaneous correction is unlikely to be expected.

With the widespread adoption of selective spinal fusion, most researchers consider it crucial to predict the risks

Table 2

Univariate and multivariate logistic regression models for the risk of undercorrection of lumbar countercurve (less than 50%)

Covariates	Univariate models		Multifactorial models	
	OR [95% CI]	p	OR [95% CI]	p
Lumbar countercurve magnitude exceeding 37.5°	7.54 [3.63; 16.35]	<0.001*	8.51 [3.25; 24.52]	<0.001*
Age at surgery >15.8 years.	4.18 [2.12; 8.49]	<0.001*	3.25 [1.23; 9.05]	0.019*
Male gender	3.28 [1.39; 8.07]	0.008*	3.36 [0.97; 12.61]	0.060
Scapular asymmetry of less than 12.0°	1.91 [0.87; 4.45]	0.118	2.81 [0.97; 9.01]	0.067
The anterior plumb line is located less than 5.0 mm from the umbilicus	0.52 [0.24; 1.09]	0.094	0.43 [0.12; 1.28]	0.140
Lumbar countercurve mobility of less than 31.4%	5.68 [2.59; 13.10]	<0.001*	—	—

* Statistically significant differences.

Table 3

Coefficients and variables of the multivariate logistic regression model for the risk of undercorrection of lumbar countercurve (less than 50%)

Coefficients and variables	Description	Allowable values of variables in the formula
B	Constant free coefficient	-3.6357987
A1	Constant coefficient for lumbar countercurve	2.1413022
X1	Lumbar countercurve correction variable	0 – lumbar lordosis angle less than or equal to 37.5°; 1 – lumbar lordosis of more than 37.5°
A2	Age at surgery constant coefficient	1.1790018
X2	Age at surgery variable	0 – age at the time of surgery ≤ 15.8 years; 1 – Age at surgery > 15.8 years.
A3	Constant coefficient for shoulder blade tilt	1.0345380
X3	Variable for shoulder blade tilt	0 – shoulder blade tilt ≤ 12.0°; 1 – shoulder blade tilt > 12.0°
A4	Fixed effect for patient gender	1.2121713
X4	Variable for patient gender	0 – male; 1 – female
A5	Fixed distance from the plumb line anterior to the umbilicus	0.8701294
X5	Variable for the distance from the plumb line anterior to the umbilicus	0 = anterior plumb line distance equal to or greater than 5.0 mm from the umbilicus; 1 – the anterior plumb line is less than 5.0 mm from the umbilicus.

of inadequate spontaneous correction of the lumbar countercurve, its progression, and the occurrence of the adding-on phenomenon.

Based on an evaluation of treatment outcomes in 130 patients using multivariate regression analysis, Chen et al. [3] established that LIV tilt of more than 10° and a main thoracic curve correction of more than 53% are significant predictors of lumbar countercurve progression in selective spinal fusion, with the prognostic model demonstrating a sensitivity and specificity of 89% and 67%, respectively. A strong correlation was found between the tilt of LIV and the postoperative lumbar countercurve when the lower instrumented level was at L1 or above. When comparing the two patient groups with varying degrees of lumbar scoliotic curve correction, we found no significant differences in the baseline L5 tilt, the apical level of the lumbar countercurve, or the tilt of LIV. This lack of variance is likely due to the predominant caudal fixation level at L4 ($n = 71$; 48%).

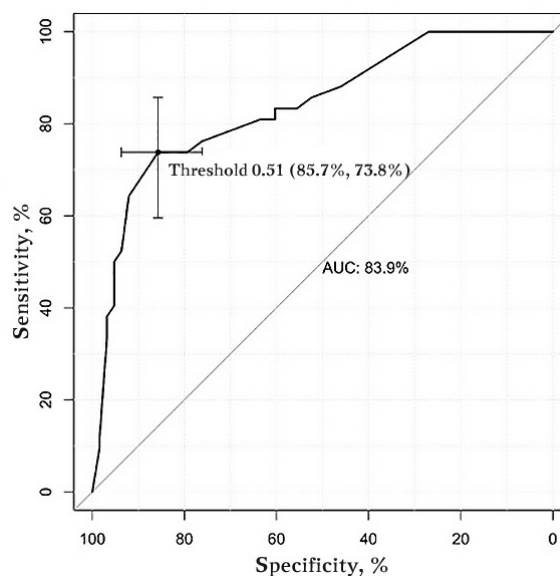


Fig. 1

The ROC curve (with a threshold value of 51.1%) of a multivariate risk model for a less than 50% correction degree of the lumbar countercurve

Table 4

Contingency of the multifactorial model for lumbar countercurve correction is less than 50%

Prognosis	Correction less than 50%	Correction more than 50%	Total
Correction of the lumbar countercurve will be less than 50%	31 (true positives prognosis)	9 (false positive prediction)	40
Correction of the lumbar countercurve will exceed 50%	11 (false negative predictions)	11 (true negative predictions)	65
Total	42	63	105

Table 5

Predictive characteristics of a multifactorial model for correcting lumbar countercurve of less than 50%

Characteristics	Value [95% CI]
Frequency of the method occurrence	38.1 % [28.8; 48.1]
Actual frequency of occurrence	40.0 % [30.6; 50.0]
Sensitivity	73.8 % [58.0; 86.1]
Specificity	85.7 % [74.6; 93.3]
The positive predictive value	77.5 % [61.5; 89.2]
Negative predictive value	83.1 % [71.7; 91.2]
Positive likelihood ratio	5.2 [2.7; 9.7]
Negative likelihood ratio	0.3 [0.2; 0.5]
Youden's index	0.6 [0.3; 0.8]
Diagnostic accuracy	81.0 % [72.1; 88.0]

Uehara et. al. [16] attempted to predict the magnitude of spontaneous correction of the lumbar (thoracolumbar) scoliotic curve based on preoperative traction radiographs. The greatest correlation with the magnitude of spontaneous lumbar curve correction following selective spinal fusion was found for the preoperative traction spine-view Cobb angle.

Rajan et al. [17] evaluated the residual lumbar scoliosis curve following selective spinal fusion in patients with Lenke type 1 and 2 idiopathic scoliosis, utilizing supine, prone, and lateral bending radiographs. The mean lumbar curve was 33.2° in the standing position, 24.8° in the supine position, 8.2° during lateral bending, and 12.1° postoperatively. The authors incorporated Lenke A, B, and C modifiers into the predictive models. The three regression models constructed by the authors demonstrated similar predictive accuracy within 5.6°.

We identified significant differences in the baseline mobility of lumbar scoliotic curves between the comparison groups; functional bending radiographs demonstrated a 37.6% correction in the <50% correction group compared to 47.6% in the >50% correction group.

In a multicenter study by Solla et al. [18], which developed a clinical predictive model for lumbar curve changes following selective thoracic fusion, the correction of the primary scoliotic curve was identified as a prognostic factor. We also identified significant differences in thoracic curve correction between the comparison groups, which reached 46.0% and 60.2%, respectively. This aligns with the findings of Koller et al., who demonstrated that thoracic scoliotic curve cor-

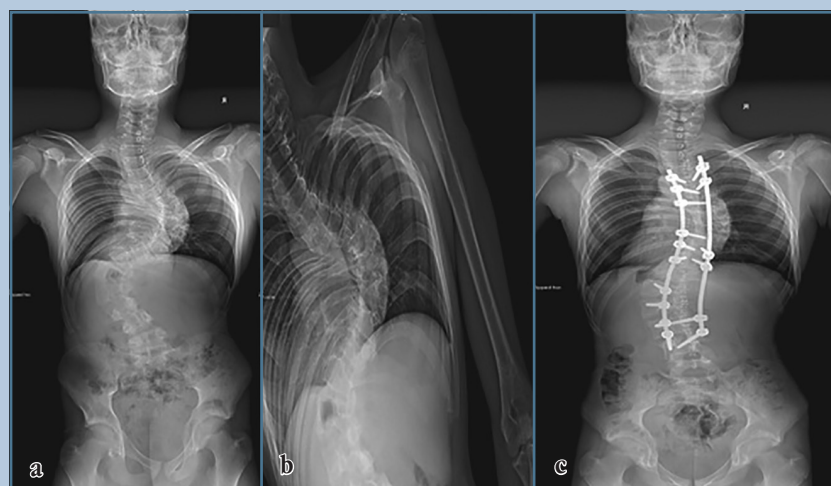


Fig. 2

X-rays of patient G.: **a** – right-sided thoracic scoliosis curve (99°) with lumbar countercurve (83°); **b** – rigid lumbar curve with tilt towards the apex (82°) without mobility; **c** – postoperative right-sided thoracic curve of 61° (38.4% correction) and lumbar countercurve of 53° (35.3% correction)

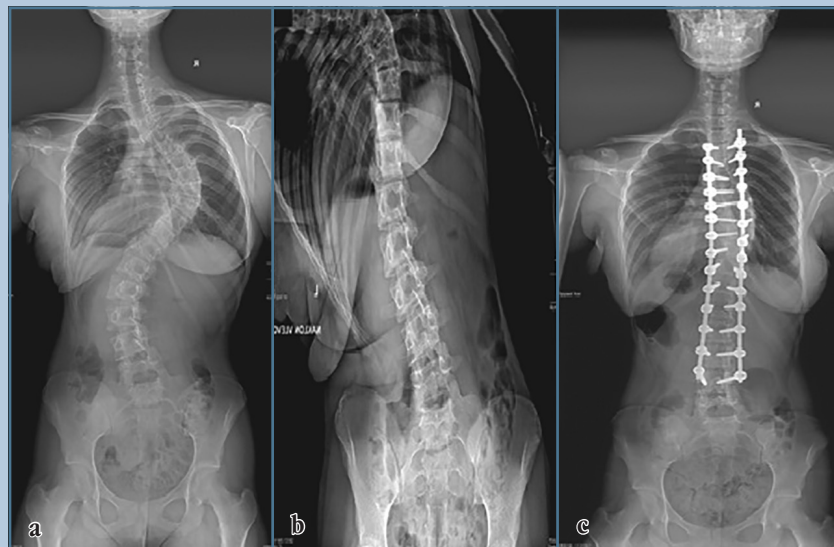


Fig. 3

X-rays of female patient Sh.: **a** – right-sided thoracic scoliotic curve of 86°, lumbar countercurve of 68°; **b** – lumbar scoliotic curve with a tilt toward the apex of 24° (65% mobility); **c** – postoperative right-sided thoracic scoliotic curve of 37° (57.0% correction), lumbar countercurve of 8° (88.0% correction)

rection, along with baseline clinical and radiological parameters, serves as a significant prognostic factor.

Since the lumbar countercurve was instrumented in all patients, we established comparison groups based on a 50% threshold for its optimal correction. Significant differences were identified across nine clinical and radiological parameters. Specifically, the group with less than 50% correction had a higher predominance of male patients (26.0% vs. 11.9%) and a higher mean age (16 vs. 14 years), which corresponded to the difference in the Risser grade (4 vs. 3). Furthermore, this group demonstrated lower baseline lumbar curve mobility, as well as lower base-

line values for thoracic kyphosis and lumbar lordosis. At the same time, no differences were found in the baseline size of the primary thoracic curve.

These differences generally align with the primary prognostic criteria for undercorrection of the lumbar countercurve described above. Using univariate and multivariate logistic regression models, we aimed to identify the primary significant predictors of undercorrection risks for the lumbar countercurve. The strongest association was found with male sex, age over 15.8 years, baseline lumbar countercurve greater than 37.5°, and its mobility of less than 31.4%. Risk factors, such as the magnitude and mobility of the lumbar scoliotic curve, are consistent with existing literature data [15, 16].

To predict the risk of an insufficient degree of correction of the lumbar countercurve, a multifactorial model formula was developed, which, in addition to the aforementioned factors, accounted for identified predictors that reduce the risk: shoulder blade tilt of less than 12.0° and a plumb line-to-umbilicus distance of less than 5 mm. The use of the risk prediction formula allowed for predicting the risk of undercorrection of the lumbar countercurve with an accuracy of 73.8%, and its absence with an accuracy of 85.7%.

When planning surgical treatment for severe thoracic scoliosis with a lumbar compensatory curve, it is essential to consider the existing risk factors for undercorrection, the primary of which are the magnitude of the lumbar scoliotic curve, its mobility, and the patient's gender. If present, a classical approach to the instrumentation of the lumbar countercurve must be followed [5].

Conclusion

A combination of factors, including a lumbar countercurve exceeding 37.7° with a mobility of less than 31.4%, male sex, a shoulder blade tilt of less than 12.0°, and a plumb line distance of less than 5 mm anterior to the umbilicus, predicts the risk of undercorrection (less than 50%) of the lumbar countercurve in patients with severe idiopathic scoliosis, with a diagnostic accuracy of 81.0% (95% CI: 72.1–88.0%). Of note, exceeding these threshold values of the lumbar countercurve increases the odds of undercorrection by 8.50 times, a reduction in its mobility increases it by 3.25 times, and male sex is associated with a 3.36-fold risk increase.

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Received 01.02.2026

Review completed 30.03.2026

Passed for printing 09.06.2026

Additional information

Author contributions. A.S. Vasyura: conceptualization and study design; data collection and analysis; drafting the entire manuscript; data interpretation, discussion of results, and formulation of conclusions; A.V. Buzunov: discussion and analysis of results, stage-by-stage editing of the manuscript text, analysis and formation of the reference list; A.Yu. Sergunin: collection and processing of clinical and radiological data, data analysis. V.L. Lukinov: validated and performed advanced statistical analysis of the results using state-of-the-art methods, including the construction and evaluation of regression models, and the calculation of confidence intervals and odds ratios; developed an original multivariate logistic regression formula to quantify the individual risk of undercorrection of lumbar compensatory curve (less than 50%); V.V. Novikov: surgical treatment of patients, discussion of results, approval of the final version of the manuscript. All authors have approved the final manuscript and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethical review. The study was approved by the Biomedical Ethics Committee of the Ya.L. Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics (extract No. 025/25 from the minutes of the meeting No. 007/25 dated 28.10.2025).

Informed consent for publication. All participants provided written informed consent prior to enrollment in the study.

Sources of funding. None.

Disclosure of interest. The authors declare that they have no competing interests.

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