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ORIGINAL STUDY

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How can postoperative shoulder imbalance be prevented in adolescent idiopathic scoliosis type 2?

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Postoperative shoulder imbalance (PSI) is a common complication following adolescent idiopathic scoliosis (AIS) surgery. There is little data available in literature on prediction of PSI. Prospectively collected data of AIS with thoracic curve (Lenke 2), operated in 2014-2018 at a single scoliosis-center, were analyzed retrospectively using X-rays of whole spine and traction films (TA): age, Cobb-angle of proximal (PC), major thoracic (MC) and lumbar curve (LC), shoulder height [mm], clavicle angle [°], T1-tilt [°], plumb line [mm]. Results as mean ± standard deviation. Change over time (postOP-FU) compared using t-test (≥=0.05). Correlation of preOP parameters and curve correction with PSI (|≥|15mm) was analyzed by correlation (Pearson)- and regression-classification-analysis. 32 AIS, average age of 14±1.3 yrs. FU 16 months (84%). Curve correction was 52.5% (PC), 70.1% (MC), 69.9% (LC), significant change in FU for PC (-2.4°, p>0.05), not for MC, LC (p=0.2, p=0.6). Shoulder height was negative if right-side up: 2.9±15.1mm (preOP), 5.5±15.0 mm (TA), 17.9±14.9mm (postOP), 17.4±8.4mm (FU). 28% had preOP shoulder imbalance, 69% postOP and 44% FU had PSI. Shoulder height on TA correlated to change preOP to FU (r=0.62) and preOP shoulder height (r=-0.85), clavicle angle had strong correlation (r=-0.81). Regression-classification-analysis: correction of MC>62.4%, 81.5% of cases had PSI; with correction of MC>64.9% and LC>93.2%, 51.9% of cases had PSI. PSI is a common in Lenke2 AIS. In preOP planning TA, shoulder position and clavicle angle should be considered to prevent PSI. Correction of MC should be moderate, overcorrection of the LC avoided.

Keywords : Shoulder elevation; spinal deformity; posterior spinal fusion; level shoulder; frontal alignment.

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INTRODUCTION

Postoperative shoulder imbalance (PSI) in idiopathic scoliosis with structural proximal thoracic curve is a challenging postoperative complication after anterior and posterior spinal fusion *(1)*. The cosmetic result of the surgical procedure has a high value for the satisfaction of the patients and in some cases, it can lead to a surgical revision. PSI occurs in 25% to 36% of cases of adolescent idiopathic scoliosis (AIS) type 1 and 2 of the Lenke classification *(1,2)*, with the correction of the major and proximal minor curve (T1-T5) playing an important role *(3,4)*. In this context, the structural proximal thoracic minor curve (PC), with a residual curve >25° in bending and traction films, provides a challenge for preoperative planning. Various approaches have been described in the literature that provide a guideline for the strategy of surgical correction of both large and small curve angles of structural or non-structural entities *(5-11)*. Yang et al. (2017) and Chang et al. (2014) could prove that an overcorrection of the major curve (MC) represents an increased risk for a PSI *(6,11)*. Although surgical strategies with the appropriate selection of the UIV to avoid PSI are discussed and recommended in the literature. Up to now, little is known about reliable predictive parameters and the ideal extent of correction *(3,5,6,9,10)*.

The definition of PSI in the literature is not entirely unambiguous. In some studies, it is specified with ≥ 10 mm to ≥ 30 mm. A positive value is defined as left-sided, a negative value as right-sided shoulder elevation *(1,2,10)*. It has been proven that a postoperative shoulder height difference of ≥ 20 mm is associated with an increased risk for surgical revision *(10)*.

For the estimation of specific criteria numerous predictable parameters have been described and related to a PSI. In a retrospective analysis, the best correlation for postoperative shoulder balance (PSB) was a measured clavicle angle and secondary, the height of coracoid process. The length of trapezius muscle, first rib-index, preoperative bending films, curve angles and translation of the vertebral bodies did either not correlate with the PSB *(1)*.

Although, preoperative bending films are widely used, the experience of the senior author has shown, they are limited for AIS with PC and often do not allow an estimation of the expected postoperative shoulder position. They are highly dependent on the cooperation of the patient, and often has little effect on the less flexible proximal thoracic spine. In the author's experience, it is pivotal in preventing PSI to carefully considerate the behavior of shoulder position under preoperative traction films (TA), as well as the flexibility of the PC and a moderate of correction of both MC and PC.

The authors are not aware of any study in literature that analyzes TA and X-rays in the context of curve correction with the change in shoulder position. Hypothesis of the study was that change in shoulder position can be assessed by means of TA and the extent of curve correction.

MATERIAL AND METHODS

The data of 32 AIS patients with type 2 according to Lenke classification, operated between 2014 and 2018 at a specialized scoliosis center, were collected prospectively and analyzed retrospectively. Included were patients with a right convex MC and a left convex PC. All patients agreed to be included in the register database with data collection for research purposes. For the assessment of radiological parameters, preoperative X-rays of the whole spine in two planes, TA (posterior-anterior-radiation path = p.a.) as well as postoperative X-rays of the whole spine in two planes were evaluated during the inpatient hospital stay, five to ten days after the operation. Long-term results (follow-up = FU) were obtained using the most recent follow-up X-rays. The surgery was performed in a standardized procedure in all patients by posterior spinal fusion with pedicle screws and double-rod-system, freehanded under fluoroscopic control *(12)*. Depending on rigidity, either only partial facet resections (Schwab 1 osteotomies) or Ponte osteotomies (Schwab 2 osteotomies) were performed in the instrumentation area *(13)*. Data were collected on the age of the patients at the time of surgery and on the UIV and the lower instrumented vertebra (LIV).

The following parameters were evaluated using radiological imaging: Cobb angle of PC, MC and the lumbar minor curve (LC) [°]. The shoulder position was measured as the distance between the two horizontal lines through the cranial and distal end of the clavicle (cf. figure 1). A positive value corresponded to a left shoulder elevation, a negative value to a right shoulder elevation. The tilt angle of the first thoracic vertebral body (T1-tilt) was measured as the angle [°] between the end plate of T1 and the horizontal (positive: left side of end plate T1 is above the right side, negative: right side of end plate T1 is above the left side). The clavicle angle (CA) was measured as the angle [°] between the connecting line of the distal clavicle ends and the horizontal (positive: left end above, negative: right end above). In addition, the frontal plumb line deviation was measured by the distance of the vertical line to the central sacrum and the perpendicular to the vertebral body C7. A positive value corresponded to a plumb line deviation from the sacral midline to the left, a negative value to the right.

The statistical analysis was performed with the XLSTAT® 2020 program. All values were given as mean value ± standard deviation and corresponding 95% confidence interval, except age was given as median. Change in parameters over time (postoperative-FU) was compared with the paired students t-test. The significance level was defined as ≥ = 0.05. Based on the hypothesis, that the amount of curve correction has an influence on postoperative shoulder level, the corresponding shoulder height was compared according to percentage curve correction by means of students t-test.

To analyze possible other, influencing factors, preoperative parameters as well as the curve correction were correlated according to Pearson. A strong effect was determined with a correlation coefficient of $|r| \geq 0.5$. To analyze the influence of different parameters on a variable, an existing or non-existing PSI, a regression classification analysis was performed using preselected parameters. Therefore, a PSI was defined as |≥| 15 mm. According to the experience of the senior author, regression classification analysis included the shoulder height in TA, preoperative shoulder height, the UIV and relative correction of the individual curves.

Table I. – The extent of corrections to the respective curve

		preoperative (n=32)	traction film (n=32)	postoperative (n=32)	correction (pre-post-operative) [%] (n=32)	FU (n=27)	correction (postoperative-FU) [°] (n=27)	p-value (postoperative vs. FU) (n=27)
main curve [°Cobb angle]	**mean**	**72.2**	**48.7**	**21.6**	**70.1**	**23.3**	**-1.5 (-17.6%)**	0.2
	SD	9.8	11.4	8.9	10.7	7.8	6.0 (46.6%)	
	CI	75.6; 68.8	52.6; 44.7	24.7; 18.5	73.8; 66.4	26.2; 20.4	0.7; -3.8	
proximal curve [°Cobb angle]	**mean**	**49.8**	**38.8**	**23.4**	**52.5**	**25.4**	**-2.4 (-14.0%)**	**<0.05**
	SD	10.9	7.8	7.2	12.5	7.5	5.0 (22.9%)	
	CI	53.5; 46.0	41.56; 36.0	25.9; 20.9	56.9; 48.2	28.2; 22.6	-0.6; -4.3	
lumbar curve [°Cobb angle]	**mean**	**37.3**	**22.0**	**11.7**	**69.9**	**11.6**	**0.5 (38.6%)**	0.6
	SD	8.5	6.5	8.6	24.0	8.8	5.8 (92.0%)	
	CI	40.2; 34.3	24.2; 19.7	14.7; 8.7	78.2; 61.6	15.0; 8.3	2.7; -1.7	

SD = standard deviation, CI = confidence interval, FU = follow-up. P-value with significance level $\alpha = 0.05$.

RESULTS

32 patients were evaluated (21 females (65%); 11 males (35%)). The average age (median) of patients at time of surgery was 14.0 ± 1.3 years (min.: 12 yrs., max.: 17 yrs.). X-rays as part of the follow-up admission were performed after mean of 16 ±8.4 months, 27 patients (84.4%) could have been included.

The UIV was equivalent to T2 in 78%, T3 in 6% and T5 in 16%. The LIV was T12 in 12.5%, L1 in 50%, L2 in 22%, L3 in 12.5% and L4 in 3%.

Cobb angle - Preoperative MC averaged 72.2 ±9.8°, PC 49.8 ±10.9° and LC 37.3 ±8.5°. The mean value of the curves in the TA showed a regression to 48.7 ±11.4° (MC), 38.8 ±7.8° (PC) and 22.0 ±6.5° (LC) and postoperative to 21.6 ±8.9° (MC), 23.4 ±7.2° (PC) and 11.7 ±8.6° (LC). Change in curve correction over time (FU) was -1.5° (MC), -2.4° (PC), and 0.5° (LC) with statistically significant change in FU for PC ($p<0.05$). For the long-term result of correction for MC and LC there was no statistically significant change in FU ($p=0.2$, $p=0.6$). (cf. Table I)

Shoulder height - Preoperative shoulder height averaged 2.9 ±15.1 mm and in TA 5.5 ± 15.0 mm. Nine patients (28.1%) had preoperative shoulder imbalance (|≥|15 mm). Three and six of them with right-sided and left-sided shoulder elevation, respectively. Postoperative imaging showed an average shoulder elevation of 17.9 ±14.9 mm. 22 patients had a PSI (68.8%), only left-sided elevation. Mean shoulder height in FU was 17.4 ±8.4 mm, the rate of patients with PSI was 43.8%, only a left-sided elevation. Changing shoulder level from pre- to postoperative was statistically significant ($p<0.01$), change from preoperative to TA and from postoperative to FU was not statistically significant ($p=0.4$ and $p=0.9$, respectively) (cf. figure 2).

Clavicle angle - Preoperatively, a clavicle angle averaging 0.7 ±3.2° and 1.5 ±4.0° in the TA was measured. Postoperatively, average clavicle angle was 3.8 ±3.3°, in FU 4.1 ±2.3°.

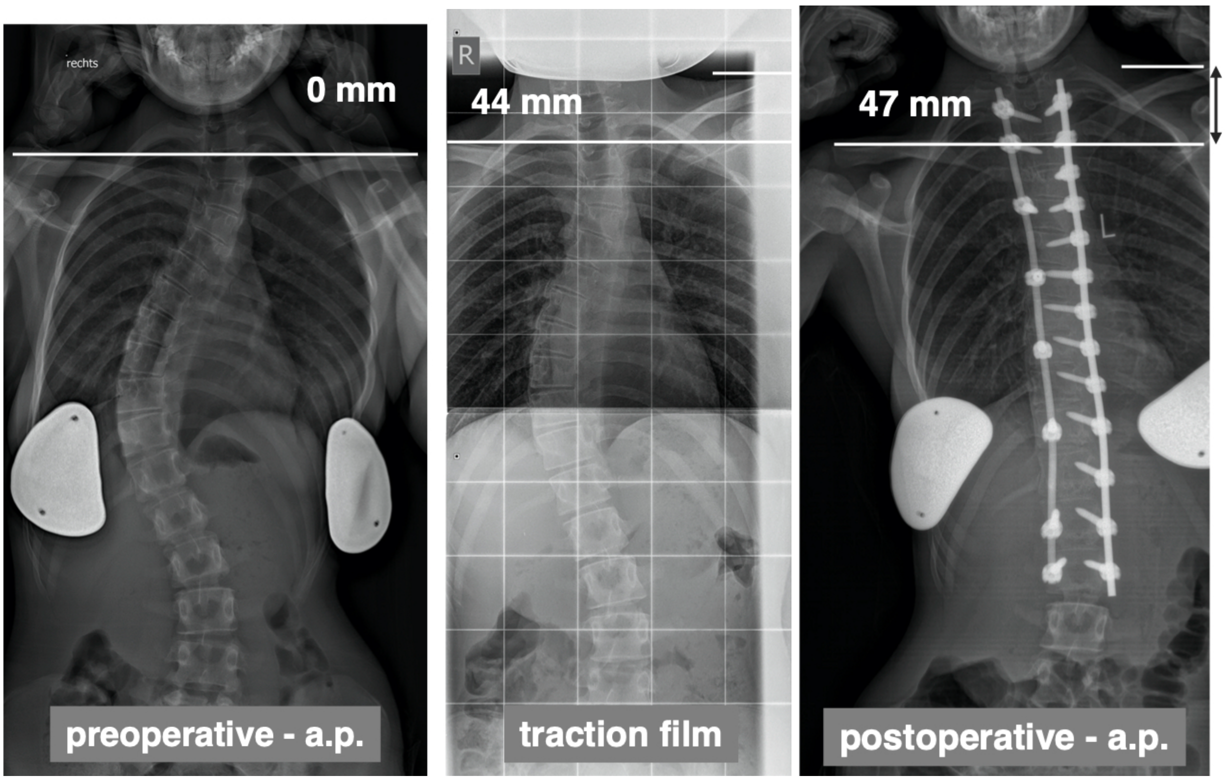


Fig. 1. – Exemplary demonstration of the measurement of the shoulder position based on the X-rays (a: preoperative, b: traction film, c: postoperative).

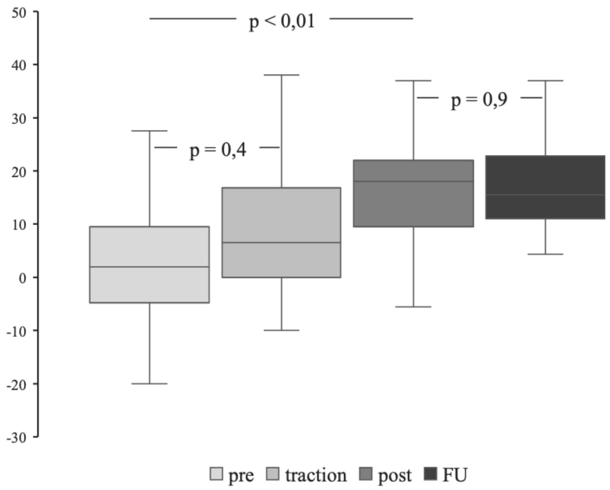


Fig. 2. – Box-Plot-diagram: shoulder position [mm]. P-value with significance level α = 0.05.

T1-tilt - Preoperative T1 angle averaged 10.1 ±6.6°. Postoperative imaging showed an average T1 angle of 10.5 ±4.0°. In FU 11.1 ±3.2°.

C7-plumb line deviation - The frontal deviation from the C7-plumb line was -7.1 ± 13.8 mm preoperatively. Preoperative TA showed an average deviation to the left of 1.4 ± 13.8 mm and postoperative of -1.1 ± 17.0 mm. The perpendicular deviation in the FU averaged -4.2 ± 9.0 mm. Values are summarized in Table II.

In the following, a statistical evaluation was performed in relation to PSI with the results of FU collective. Although the change in postoperative shoulder position over time was not qualitatively statistically significant (p=0.9), 19 patients initially had PSI postoperatively. In the follow-up controls, 5 of them showed PSB, which makes a qualitative difference and improves the power of the subsequent statistical analysis.

Based on the hypothesis, the amount of curve correction has an influence on postoperative shoulder level, the percentage corrections were grouped by increasing number. The corresponding shoulder height, postoperatively and in FU, were compared with each other by means of students t-test (cf. Table III). Shoulder height increased immediately postoperative with increasing extent of MC correction, moderate correction of PC and low correction of LC. Leveling shoulder was found in FU: moderate correction of the MC (60-75%) resulted in the lowest average shoulder position. As the results were not statistically significant, other influencing factors were examined in the following.

Table II. – Measured parameters from X-rays

		preoperative (n=32)	traction film (n=32)	postoperative (n=32)	FU (n=27)
shoulder height [mm]	**mean**	**2.9**	**5.5**	**17.9**	**17.4**
	SD	15.1	15.0	14.9	8.4
	CI	8.2; -2.3	10.7; 0.3	23.0; 12.7	20.6; 14.2
clavicle angle [°]	**mean**	**0.7**	**1.5**	**3.8**	**4.1**
	SD	3.2	4.0	3.3	2.3
	CI	1.8; -0.4	2.9; 0.2	4.9; 2.7	5.0; 3.2
T1-tilt [°]	**mean**	**10.1**	**-**	**10.5**	**11.1**
	SD	6.6	-	4.0	3.2
	CI	12.4; 7.8	-	11.9; 9.2	12.3; 9.9
C7-plumb line deviation [mm]	**mean**	**-7.1**	**1.4**	**-1.1**	**-4.2**
	SD	13.8	13.8	17.0	9.0
	CI	-2.3; -11.9	6.2; -3.3	4.8; -6.9	-0.9; -7.6

SD = standard deviation, CI = confidence interval, FU = follow-up.

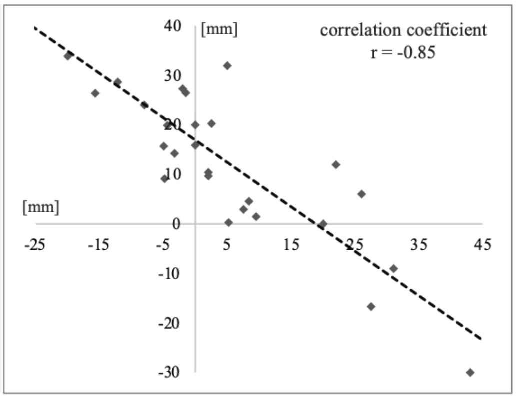
Table III. – Differences in postoperative shoulder level (postoperative and follow-up (FU)) according to the range of correction

	correction [%]	postoperative shoulder height [mm]	p-value	FU shoulder height [mm]	p-value
correction of MC	<60%	**14.7**	0.8	**18.0**	0.6
	60-75%	**16.3**	0.5	**15.2**	0.2
	>75%	**22.0**	0.4	**20.5**	0.7
correction of PC	<50%	**15.4**	0.3	**17.6**	0.8
	50-75%	**21.6**	0.6	**16.8**	0.8
	>75%	**15.9**	1.0	**17.9**	1.0
correction of LC	<60%	**20.9**	0.8	**17.8**	0.9
	60-80%	**19.5**	0.3	**17.0**	0.9
	>80%	**11.6**	0.2	**17.6**	1.0

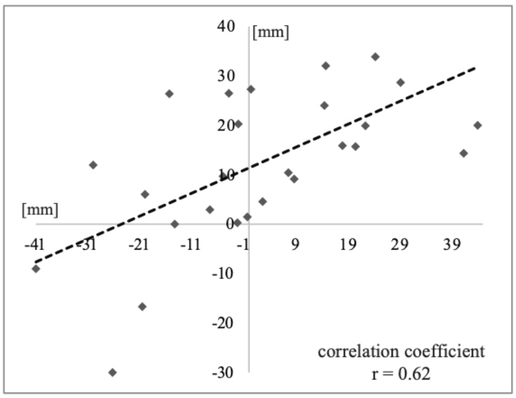
MC = major thoracic curve, PC = proximal thoracic curve, LC = lumbar curve. By means of a t-test, the shoulder levels were compared according to the correction shape. P-value with significance level α = 0.05.

Pearson's correlation analysis examines the statistical correlation of preoperative parameters and relative correction of curve [%] with shoulder position in FU and change in shoulder position (FU-preoperative), respectively. The descriptive results are summarized in Table IV. With a statistically strong effect, correlations were found for change in shoulder position (FU-preoperative) with each of preoperative shoulder position (r=-0.85), change in shoulder position (TA-preoperative) (r=0.62), and preoperative clavicle angle (r=-0.81). The following can be extrapolated from the above correlations: The smaller the shoulder height preoperatively (negative sign = right-sided shoulder elevation), the greater the difference of postoperative shoulder height (FU) and preoperative shoulder height. Nevertheless, the greater the preoperative shoulder position (positive sign = left-sided shoulder elevation), the smaller the change in shoulder level (cf. figure 3a). Change in shoulder level in TA (TA-preoperative) and in FU (FU-preoperative) showed a positive statistically strong correlation (r=0.62). Accordingly, if shoulder level is large (TA-preoperative), a large shoulder level (FU-preoperative) can also be expected in FU (cf. figure 3b). The preoperative clavicle angle is like preoperative shoulder position with a slightly smaller effect (r=-0.81). A preoperatively large clavicle angle is associated with a small change in shoulder position (FU-preoperatively) (cf. figure 3c). No significant correlation could be directly established for the T1-tilt. However, a statistically strong correlation between the postoperative shoulder position and the preoperative plumb line deviation or the plumb line deviation (FU-preoperative) could not be confirmed. A separate examination of the plumb line deviation showed that there is a positive correlation of the change in plumb line deviation from TA-preoperative and FU-preoperative with a strong effect (r=0.67). Thus, the greater the difference in the C7-plumb line deviation in the TA, the greater the change in the FU.

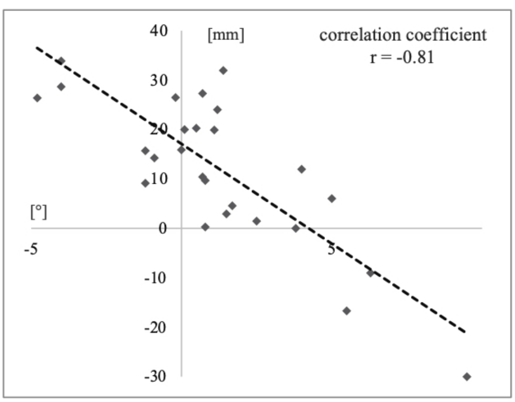
A correlation with the absolute postoperative shoulder position could not be proven for any of the parameters. Therefore, a regression classification analysis was used and resulted predictions for the surgical procedure were drawn. In total, 14 of the 27 patients had PSI (yes) and 13 patients did not have PSI (no). The correction of MC had the greatest influence. With a correction of more than 62.4%, a PSI (PSI = yes) was to be assumed in 81.5% of the cases. If the correction was ≤ 62.4%, the probability of PSB was only 18.2%. There was a side effect of the change in shoulder position in



Correlation-analysis
shoulder height preOP vs. shoulder difference FU-preOP



Correlation-analysis
shoulder height difference TA-preOp vs. FU-preOP



Correlation-analysis
preOP clavicle angle vs. shoulder height difference FU-preOP

Fig. 3. – Correlation-diagram: a - preoperative (preOP) shoulder height (x-coordinate) vs. shoulder height difference FU-preOP (y-coordinate). b - shoulder height difference TA-preOP (x-coordinate) vs. FU-preOP (y-coordinate). c - preOP clavicle angle (x-coordinate) vs. shoulder height difference FU-preOP (y-coordinate). preOP = preoperative, FU = follow-up, TA = traction film.

the TA: if the MC correction was ≤ 62.4% and the change in shoulder position was more than -17.7 mm (meaning a right-sided shoulder elevation in the TA), PSB was more likely. If the correction of the MC was more than 64.9%, the correction of the LC was determining: if the overcorrection of the LC was more than 93.2%, the presence of a PSI was probable, whereas if the correction of the LC was ≤ 93.2%, with a probability of almost 50%, a PSB could be achieved. Whereby a correction of the PC of less than 55% should then also be considered. The preoperative shoulder position as well as the UIV had no influence on the regression. The prediction rules derived from the analysis are listed in Table V and the analysis is shown graphically as a regression classification tree in figure 4.

DISCUSSION

In this study, the descriptive results show that AIS Lenke type 2 relatively often show a shoulder imbalance already preoperatively (28%) and resulted primarily in left shoulder elevation immediately after surgery, with almost 70% showing PSI. Long-term results demonstrated shoulder leveling with nearly 56% PSB. These results were slightly above the 25-36% complication rate of PSI described in the literature *(2,3)*.

Preoperative shoulder position, preoperative clavicle angle, and change in shoulder position in TA were found to be prognostic parameters. A right sided shoulder elevation and negative clavicle angle were expected to result in a larger change in shoulder position (FU-preoperatively), whereas left-sided shoulder elevation or clavicle angle tended to result in a small change in shoulder position. The greater the change in preoperative shoulder position in the TA, for example, from right-sided to left-sided, the greater the change in FU can be expected. Accordingly, these correlations can be included in the preoperative planning and obligatory TA should be performed. The conclusions of the above correlations can only be used as an approximation and underlines the importance of the preoperative TA. The clavicle

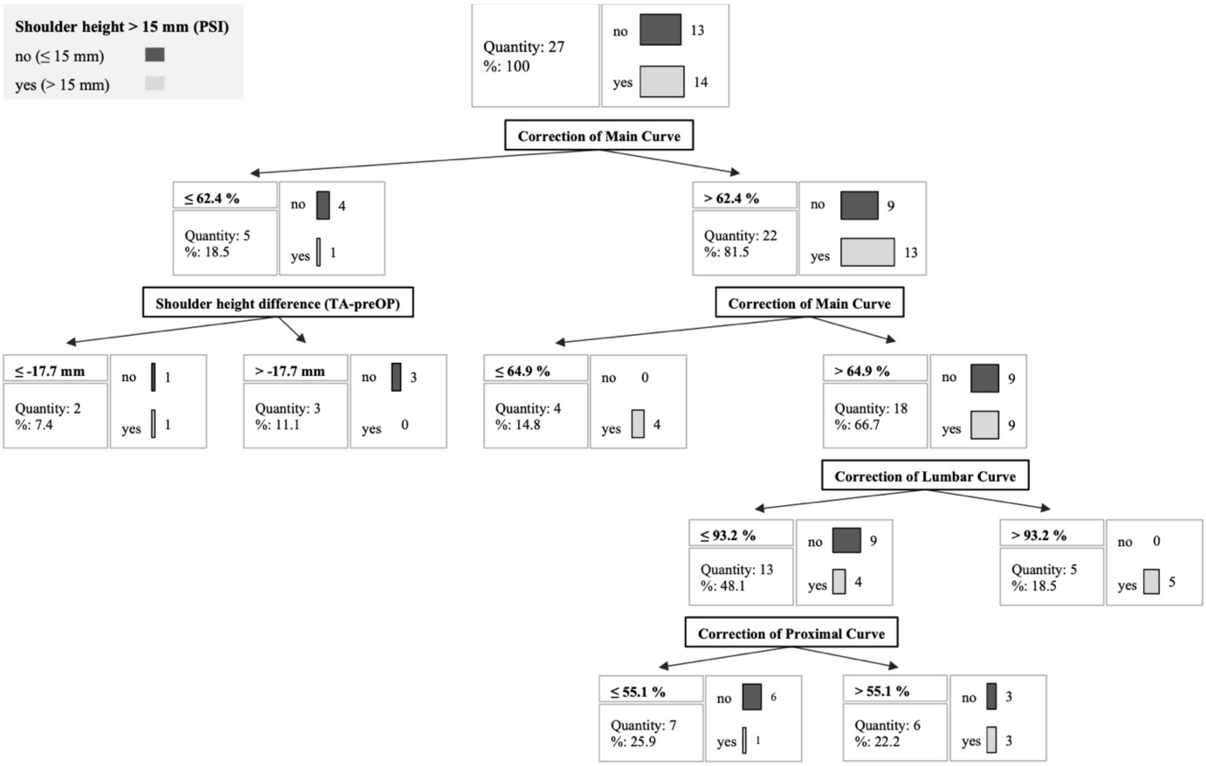


Fig. 4. – Regression-classification-tree (n=27).

angle has already been confirmed as a very good predictive factor by Kuklo et al. (2002) *(1)*.

The regression classification analysis showed in summary the relevance of MC correction with a moderate correction of MC (≤62.4%) for reaching PSB. With correction greater than 65%, a moderate correction of LC (<93%) and low correction of PC (<55%) is decisive for PSB. PSI is highly probable, when MC was corrected between 62.4 and 64.9% and the LC was overcorrected by more than 93%. Instrumentation of UIV and preoperative shoulder position had in this study no relevant influence on PSI. Compared with the results by Sielatycki et al. (2019), moderate correction of the PC (<52%) was also determining for PSB in this study. Likewise, Sielatycki et al. had analyzed that if the MC was already corrected >54%, the probability of PSB was reduced by more than half *(3)*. However, it is only approximately comparable because of a heterogenous collective (AIS Lenke type 1 and 2 *(3)*). The different anatomical and functional conditions in Lenke type 1 and type 2 underlines the relevance of this work with consideration of only one classification group. Like this study, Yang et al. und Sielatycki et al. showed that instrumentation of the UIV had no effect on PSI *(3,11)*. Consistent with the results of the work of Jian et al. the correction of the LC also has an influence on the PSB, but it is of secondary importance *(14)*.

Finally, to complete the analysis of coronary balance, the deviation of frontal plumb with postoperative average deviation of <0.5 cm to the right was seen as good. The descriptive results of the correlation analysis show a strong positive correlation of the change in shoulder position with the plumb line deviation. However, a predictive relevance on a postoperative shoulder balance could not be proven. Whereas the postoperative change in plumb line deviation can be estimated by the change in TA rather good.

Limitations of the study result from relatively short FU time of 16 months on average, but a change in shoulder position (postoperative FU) could be documented even at this time point. An FU rate of 84% can be regarded as good, but higher rates would be desirable and would improve the predictability of

Table IV. – Forecast rules fort the regression-classification-analysis (n=27)

Correlation analysis according to Pearson (correlation coefficient r)		
	shoulder height (FU) [mm]	shoulder height difference (FU-preOP) [mm]
shoulder height (preOP) [mm]	0.18	**-0.85**
shoulder height (TA) [mm]	-0.01	0.03
shoulder height difference (TA-preOP) [mm]	-0.14	**0.62**
clavicle angle (pre) [°]	0.18	**-0.81**
clavicle angle (TA) [°]	0.02	0.08
T1-tilt (preOP) [°]	-0.17	-0.43
correction MC (FU) [%]	0.19	-0.27
correction PC (FU) [%]	0.08	0.16
correction LC (FU) [%]	-0.14	-0.39
C7-plumb line deviation (preOP) [mm]	0.26	0.29
C7-plumb line deviation difference (FU-preOP) [mm]	-0.29	-0.14

preOP = preoperative, TA = traction film, MC = major thoracic curve, PC = proximal thoracic curve, LC = lumbar curve. Bold marks correlations with a strong effect, correlation coefficient |r| ≥ 0,5.

Table V. – Forecast rules fort the regression-classification-analysis (n=27)

Regression-classification-analysis		
	PSI no <15 mm yes ≥15 mm	Forecast rules for PSI
	no	If correction of MC ≤ 62.4 %, with 18.5 % PSI = no.
	yes	If correction of MC > 62.4 %, **with 81.5 % PSI = yes.**
	no	If correction of MC ≤ 62.4 % and shoulder height difference (TA-preOP) ≤ -17.7 mm, with 7.4 % PSI = no.
	no	If correction of MC ≤ 62.4 % and shoulder height difference (TA-preOP) > -17.7 mm, with 11.1 % PSI = no.
	yes	If correction of MC > 62.4 % and ≤ 64.9 %, with 14.8 % PSI = yes.
	no	If correction of MC > 64.9 %, **with 66.7 % PSI = no.**
	no	If correction of MC > 64.9 % and LC ≤ 93.2 %, **with 48.1 % PSI = no.**
	yes	If correction of MC > 64.9 % and LC > 93.2 %, with 18.5 % PSI = yes.
	no	If correction of MC > 64.9 %, LC ≤ 93.2 % and PC ≤ 55.1 %, with 25.9 % PSI = no.
	no	If correction of MC > 64.9 %, LC ≤ 93.2 % and PC > 55.1 %, with 22.2 % PSI = no.
		The preoperative shoulder height and the UIV did not have any influence on the postoperative shoulder balance or imbalance

preOP = preoperative, TA = traction film, PSI = postoperative shoulder imbalance, MC = major thoracic curve, PC = proximal thoracic curve, LC = lumbar curve, UIV = upper instrumented vertebra.

the data. Although a larger cohort size would have been desirable, an initial cohort size of 32 patients is acceptable because Lenke type 2 AIS has a lower frequency in the Lenke classification distribution.

In the present study, the subjective perception of the patients regarding a shoulder deformity was not considered. So far, there are no validated questionnaires that could ensure an acceptable comparability *(1)*. An assessment of physical appearance was judged differently by patients and parents with statistical significance, also the clinical evaluation differed from the radiological parameters *(15)*. Particularly in AIS with Lenke type 1 and 2, the assessment of shoulder position should be included in validated perioperative patient questionnaires.

In conclusion, considering and assessing the shoulder position and the postoperative outcome in AIS with Lenke type 2 should be a high priority in preoperative planning. Thereby, according to the authors, obligatory TA should be performed in every patient and the preoperative shoulder position as well as the clavicle angle should be considered in the planning. The extent of correction should be chosen with special attention to a moderate correction of MC and avoiding an overcorrection of LC to prevent PSI.

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